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Q1)(a) Discuss the various applications and problems associated with the digital image processing. How many images of size 800×600 with 8 bit gray value can be stored in a 512 MB storage space?

Soln → Digital image processing has a broad spectrum of applications, such as remote sensing via satellites and other spacecrafts, image transmission and storage for business applications, medical processing, radar, sonar, and acoustic image processing, robotics and automated inspection of industrial parts. Some applications are:

(i) Image enhancement and restoration

One of the most common uses of DIP techniques is to improve quality, remove noise etc. An image may be of poor quality because its contrast is low, or it is noisy or it is blurred. Many algorithms have been devised to remove these degradations. The difficult problem is how to remove degradations without hurting the signal.

(ii) Image recognition

Typically, a recognition system needs to classify an unknown input pattern into one of a set of prespecified classes. The task is fairly easy if the number of classes is small and if all members in the same class are almost exactly the same. However the problem can become very difficult if the number of classes is very large or if members in the same class can look very different. Thus challenging problem is how to recognize generic objects. For example how can one construct a system to recognize "chairs"?.

(iii) Compression

A modern trend in image storage and transmission is to use digital techniques. Digitizing a television signal results in ~100 megabits per second. But channel bandwidth is expensive. So, how can one compress the bit rate from 100 megabits per second to 1 kilobit per second without severe loss of image quality is the main problem.

(iv) Visualization

Commonly, visualization is considered as a part of computer graphics. The main task is to generate image or image sequences, based on three dimensional object and scene models. A challenging problem is how to model dynamic scenes containing nonrigid objects (such as clothing, hair, waves etc). The models have to be realistic and yet the computation cost has to be reasonable.

Now,

Total amount of pixel $= 800 \times 600$

$= (480000)$ pixels

Given that the gray level value is represented by 8 bits, so every pixel occupies 1 byte in the computer graphic memory.

$$\text{Total memory usage} = \left(\frac{480000}{1024 \times 1024}\right) \text{MB}$$

$\therefore$ single image size $= 0.46$ MB

Therefore,

No. of images that can be stored in a 512MB storage space $= \dfrac{512}{0.46}$

$= 1118.48$

$\simeq 1118$ Nos.

$\therefore$ 1118 nos. of images can be stored.

Q 1 b) What is Fast Fourier transform ? Explain FFT algorithm for one dimensional transform.

Soln → The Discrete Fourier Transform (DFT) is a specific form of Fourier analysis to convert one function (often in the time or spatial domain) into another (frequency domain). The Fast Fourier Transform (FFT) is an efficient implementation of DFT. Fast Fourier transform is applied to convert an image from the image (spatial) domain to the frequency domain. Applying filters to images in frequency domain is computationally faster than to do the same in the image domain.

The FFT not only reduces the computation time, it also substantially reduces the round-off errors associated with the computations. Both computation time and round-off error essentially are reduced by a factor of $(\log_2 N)/N$ where N is the number of data samples in the time series.

The FFT algorithm for one dimensional transform:

The FT of a discrete function of one variable $f(x)$ is given by,

$$F(u) = \frac{1}{M} \sum_{x=0}^{M-1} f(x) e^{-j2\pi ux/M}$$

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let $W_m = e^{-j2\pi/M}$ [M is assumed to be of the form $M = 2^n$, $n \geq$ +ve integer]

Thus,

$$F(u) = \frac{1}{M} \sum_{x=0}^{M-1} f(x) W_m^{ux}$$

let $M = 2K$, K being +ve integer.

$$F(u) = \frac{1}{2K} \sum_{x=0}^{2K-1} f(x) W_{2K}^{ux}$$

$$= \frac{1}{2K} \left[\sum_{x=0}^{K-1} f(2x) W_{2K}^{u(2x)} + \sum_{x=0}^{K-1} f(2x+1) W_{2K}^{u(2x+1)} \right]$$

we have,

$$W_{2K}^{2ux} = \left[e^{-j2\pi/2K} \right]^{2ux} = e^{-j2\pi ux/K} = W_K^{ux}$$

$$\therefore F(u) = \frac{1}{2K} \left[\sum_{x=0}^{K-1} f(2x) W_K^{ux} + \sum_{x=0}^{K-1} f(2x+1) W_K^{ux} \cdot W_{2K}^{u} \right]$$

$$= \frac{1}{2} \left[\frac{1}{K} \sum_{x=0}^{K-1} f(2x) W_K^{ux} + \frac{1}{K} \sum_{x=0}^{K-1} f(2x+1) W_K^{ux} \cdot W_{2K}^{u} \right]$$

$$\Rightarrow F(u) = \frac{1}{2} \left[F_{even}(u) + F_{odd}(u) \cdot W_{2K}^{u} \right] \quad \text{—— (A)}$$

where, $u = 0, 1, \ldots, K-1$

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Also,

$$F(u+K) = \frac{1}{2}\left[\frac{1}{K}\sum_{x=0}^{K-1} f(2x)\, W_K^{(u+K)x} + \frac{1}{K}\sum_{x=0}^{K-1} f(2x+1) . W_K^{(u+K)x} . W_{2K}^{(u+K)}\right]$$

we have,

$$W_K^{(u+K)} = e^{\left(-j\frac{2\pi}{K}\right)u+K}$$

$$= e^{-j2\frac{\pi u}{K}} . e^{-j\frac{2\pi . K}{K}}$$

$$= e^{-j2\pi u/K}$$

$$= W_K^{u}$$

$$W_{2K}^{u+K} = \left[e^{-j\frac{2\pi}{2K}}\right]^{u+K}$$

$$= e^{-j\frac{\pi u}{K}} . e^{-j\pi}$$

$$= e^{-j\pi\frac{u}{K}} . \left[\cos\pi - \sin\pi\right]$$

$$= -e^{-j\frac{\pi u}{K}}$$

$$= -e^{-j\frac{2\pi u}{2K}}$$

$$= -W_{2K}^{u}$$

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Now, substituting derived values,

$$F(u+K) = \frac{1}{2}\left[\frac{1}{K}\sum_{x=0}^{K-1} f(2x)\, W_K^{ux} + \frac{1}{K}\sum_{x=0}^{K-1} f(2x+1)\, W_K^{ux}\left(-W_{2K}^{u}\right)\right]$$

$$= \frac{1}{2}\left[F_{even}(u) - F_{odd}(u).\, W_{2K}^{u}\right] \quad - \text{(B)}$$

Q. 2 a) Define the term sequency in Hadamard Transform. How do you determine sequency in Hadamard transform from the natural order? Explain with example.

Sol^n→ Sequency in Hadamard Transform:

The basis vectors of the Hadamard transform can be generated by sampling a class of functions called the Walsh functions. These functions also take only the binary values ±1 and form a complete orthonormal basis for square integrable functions. The numbers of zero crossings of a Walsh function or the number of transitions in a basis vector of the Hadamard transform is called its "sequency".

In Walsh function, the initial state is always +1 and the functions satisfy certain other orthogonality relations. The 2^n walsh functions of order n are given by the rows of Hadamard matrix H_{2^n} when arranged in sequency order.

Recursively, we can define $|x|$, Hadamard Transform H_0 by the identity $H_0 = 1$ and then define H_m for $m > 0$ by,

$$H_m = \frac{1}{\sqrt{2}} \begin{bmatrix} H_{m-1} & H_{m-1} \\ H_{m-1} & -H_{m-1} \end{bmatrix}$$

where, $\frac{1}{\sqrt{2}}$ is a normalization factor which is sometimes ignored.

for $m > 1$, we can define H_m as,

$$H_m = H_1 \otimes H_{m-1}$$

where, $\otimes$ represents kronecker product.

For natural ordering we can follow after repeatedly applying the above definition:

$$\begin{array}{c c c}
 & & \text{Sequency} \\
\begin{array}{c} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{array} &
\begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{bmatrix} &
\begin{array}{c} 0 \\ 7 \\ 3 \\ 4 \\ 1 \\ 6 \\ 2 \\ 5 \end{array}
\end{array}$$

Now, sequential ordering:

This ordering is based on the no. of sign changes in a row which is analogous to sines and cosines in FT.

$$
\begin{array}{c c}
\text{row} & \text{sign changes} \\
\left[\begin{array}{cccc|cccc}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1
\end{array}\right] &
\begin{array}{c}
0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7
\end{array}
\end{array}
$$

Hence, Hadamard transform has good energy compaction for highly correlated images.

Q 2 b) What is Image enhancement in spatial domain? Bit plane slicing with suitable example.

Sol → The principle objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. The term spatial domain refers to the image plane itself and approaches in this category are based on direct manipulation of pixels in an image.

Most spatial domain enhancement operations can be reduced to the form:

$$g(x,y) = T[f(x,y)]$$

where,

$f(x,y)$ is the input image,
$g(x,y)$ is the processed image,
T is some operator defined over some neighborhood of (x,y).

<u>Bit-plane slicing:</u>

pixels are digital numbers composed of bits. Instead of highlighting intensity-level ranges, we could highlight the contribution made to total image appearance by specific bits.

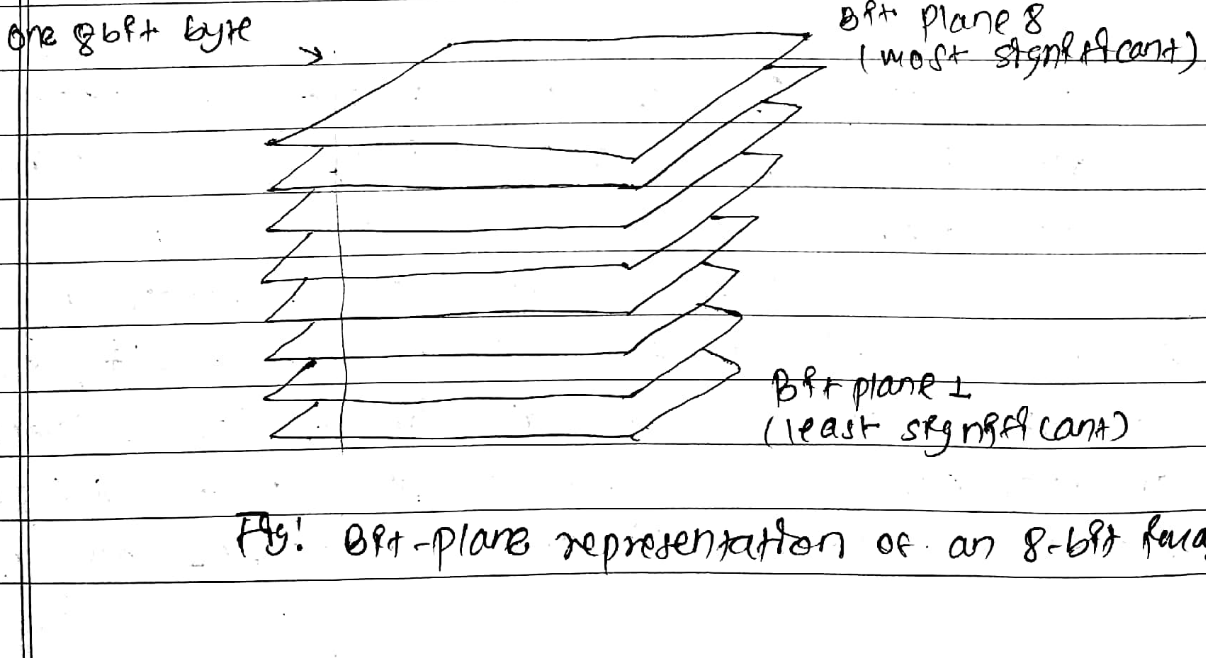

Fig: Bit-plane representation of an 8-bit image

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Above figure shows an 8-bit image, it may be considered as being composed of eight -1 bit planes, with plane 1 containing the lowest-order bit of all pixels in the image and plane 8 all the highest-order bits.

The higher order bits (especially the top four) contain the majority of the visually significant data.

The other bit planes contribute to more subtle details in the image.

Separating a digital image into it's bits planes is useful for analysing the relative importance played by each bit of the image. Also, this type of decomposition is useful for image compression.

Q3(a) Explain the following image enhancement technique in spatial domain method:

(i) Median filter

(ii) Histogram equalization

Sol? # Median filter:

Median filter is the best-known filter in order-statistic (Nonlinear) filters. As its name implies, replaces the value of a pixel by the median of the intensity values in the neighborhood of that pixel. Median filters are quite popular because, for certain types

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of random noise; they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Median filters are particularly effective in the presence of impulse noise, also called salt-and-pepper noise because of its appearance as white and black dots superimposed on an image.

For example, suppose that a 3X3 neighborhood has values (10,20,20,20,15, 20,20, 25,100). These values are sorted as (10,15, 20,20,20,20, 20, 25,100), which results in a median of 20.

Thus, the principal function of median filters is to force points with distinct intensity levels to be more like their neighbors.

Histogram equalization:

The histogram of an image represents the relative frequency of occurence of the various gray levels in the image. Histogram Equalization is the process for increasing the contrast in an image by spreading the histogram out to be approximately uniformly distributed.

The increase in dynamic range

produces an increase in contrast.

→ The gray levels of an image that has been subjecte to histogram equalization are spread out and always reach ~~white~~ white. For image with low contrast, histogram equalization has the adverse effect of increasing visual grainness.

→ The intensity transformation function we are constructing is of the form,

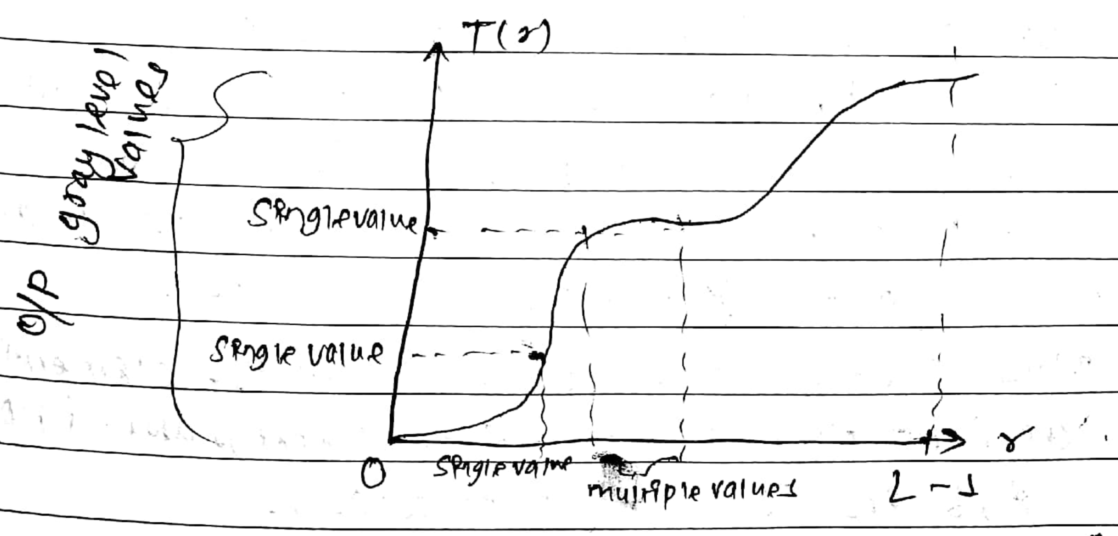
$$s = T(r) \qquad 0 \le r \le L-1$$

An output intensity level, s is produced for every pixel in the input-image having intensity, r. We assume T(r) is monotonically increasing in the interval $0 \le r \le L-1$

i.e. $0 \le T(r) \le L-1$ for $0 \le r \le L-1$

If we define inverse,

$$r = T^{-1}(s) \qquad 0 \le s \le L-1$$



Fig(a): Monotonically increasing funⁿ showing how multiple values map to single value.

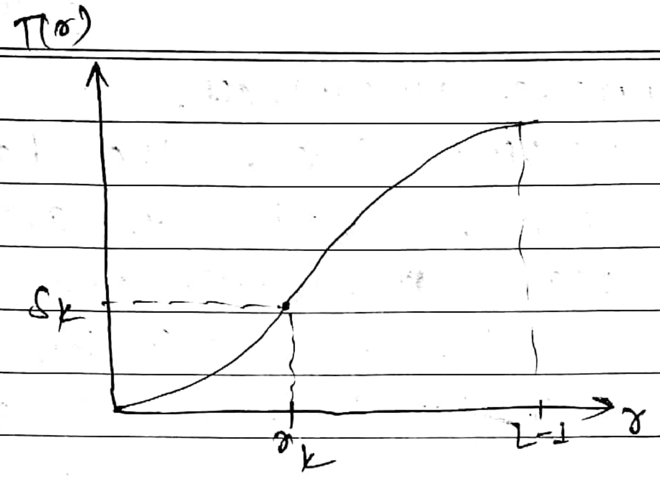


Fig (b): Strictly monotonically increasing
(one to one mapping)

→ Spreading out the frequencies in an image (or equalizing the image) is a simple way to improve dark or washed out images.

Now, the transformation function s_k is given as,

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{M \times N}$$

where, r_k is the k^{th} gray level
n_j is the no. of pixels with that gray level.
$M \times N$ is the no. of pixels in the image
and $k = 0, 1, \ldots L-1$.

This yields an s with as many elements as the original image's histogram (normally 256 for our test images).

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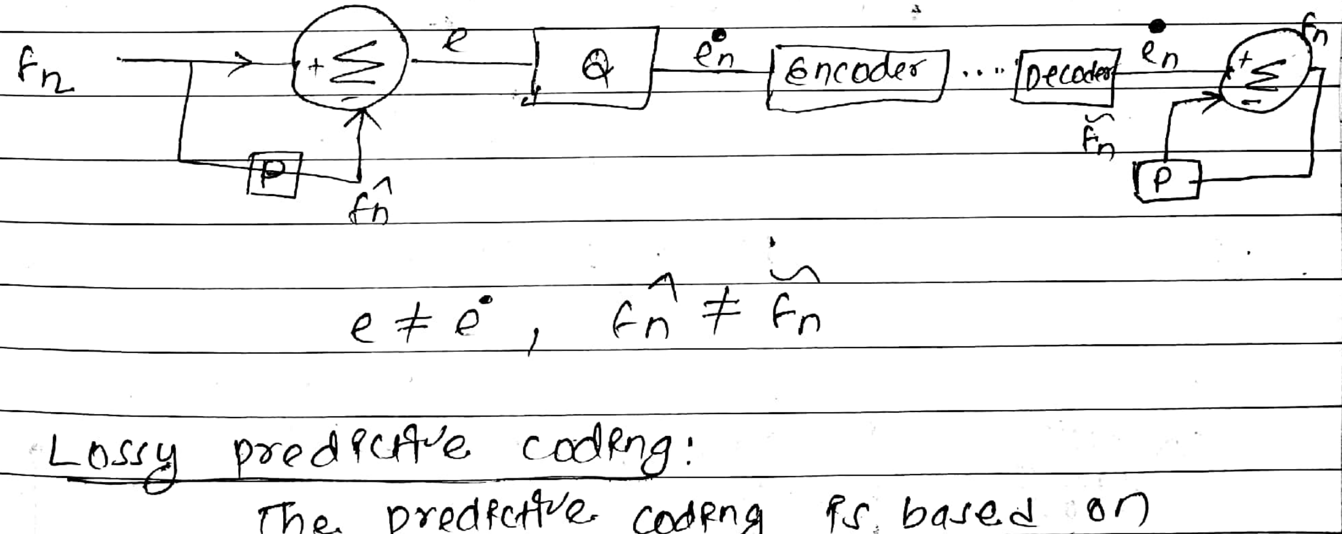
Q 3 b) What do you mean by lossy compression? explain lossy predictive coding in brief.

Soln → **Lossy compression:**

Lossy compression or irreversible compression is the class of data encoding methods that uses inexact approximations and partial data discarding to represent the content. 'Lossy' image file types are designed to show the image using an optimum amount of data. Lossy compression is a destructive file format since the image is degraded by successive edit/save cycles. Lossy compression uses a quantizer to compress further the number of bits required to encode the error.



$$e \neq \dot{e}, \quad \hat{f_n} \neq \tilde{f_n}$$

Lossy predictive coding:

The predictive coding is based on eliminating the redundancies of closely spaced pixels - in space and / or time - by extracting and coding only the new information in each pixel. The new information of a pixel is defined as the difference between the actual and predicted value of the pixel.

In lossy predictive coding, we add a quantizer to the lossless predictive coding model and examine the trade-off betⁿ reconstruction accuracy and compression performance within the context of spatial predictors.

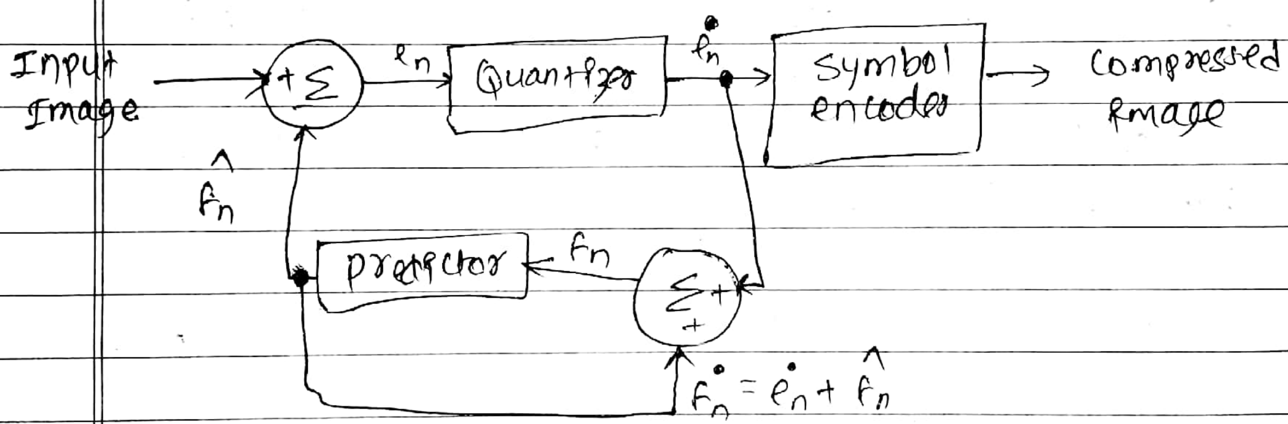


Fig (a): Encoder

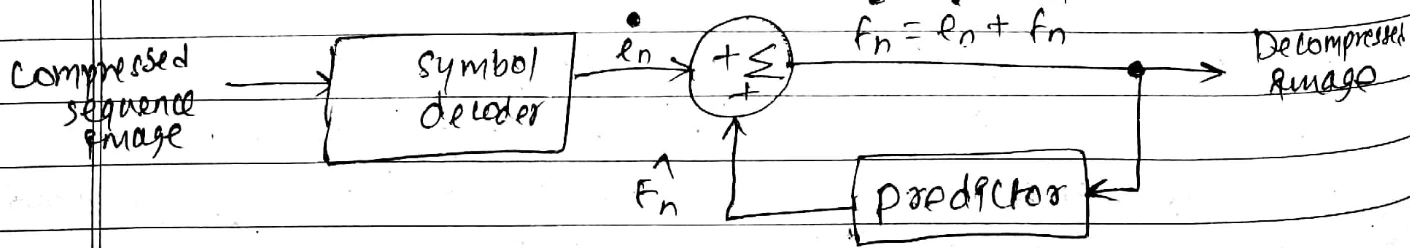


Fig (b): Decoder

Fig: Lossy prediction coding model.

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- The Quantizer maps the prediction error into a limited range of output denoted by $\dot{e}_n$.
- Here the lossy encoder's predictor is placed within a feedback loop where it's input denoted $\dot{f}_n$ is generated as a function of past predictions and the corresponding quantized errors.

i.e. $\dot{f}_n = \dot{e}_n + \hat{f}_n$

This closed loop configuration prevents error buildup at the decoder's output.

Q4 a) Explain the steps of pattern Recognition system with the suitable sequence of block diagram.

Sol^n → pattern recognition is the study of how machines can observe the environment, learn to distinguish patterns of interest, make sound and reasonable decisions about the categories of the patterns.

There are different steps in pattern recognition systems.

(i) Data acquisition and sensing:
- Measurements of physical variables.
- Important issues: bandwidth, resolution, sensitivity, distortion, SNR, latency etc.

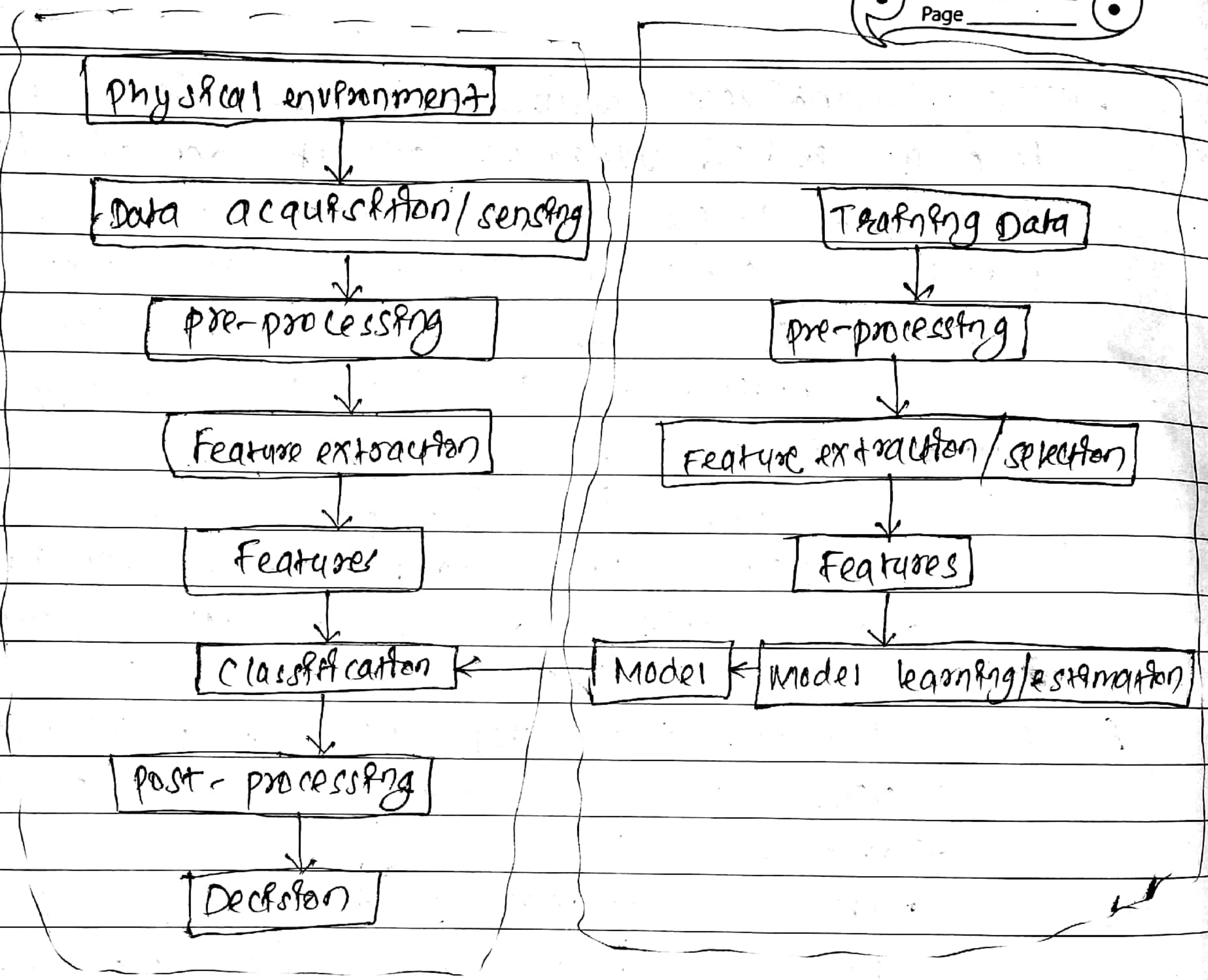

Figure: object/process diagram of a pattern recognition system

(ii) pre-processing:

- Removal of noise in data.
- Isolation of patterns of interest from the background.

(iii) Feature extraction:

- Finding a new representation in terms of features.

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(iv) Model learning and estimation:
- learning a mapping between features and pattern groups and categories.

(v) classification
- Using features and learned models to assign a pattern to a category.

(vi) post - processing
- Evaluation of confidence in decisions.
- Exploitation of context to improve performance.
- combination of experts.

Q 4(b) Explain minimum distance classifier for pattern classification.

Soln → Recognition techniques based on matching represent each class by a prototype pattern vector. An unknown pattern is assigned to the class to which it is closest in terms of a predefined Metric. The simplest approach is minimum distance classifier, which computes the (Euclidean) distance between the unknown and each of the prototype vectors. It chooses the smallest distance to make a decision.

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Suppose that we define the prototype of each pattern class to be the mean vector of pattern of that class:

$$m_j = \frac{1}{N} \sum_{x \in w_j} X_j \qquad j = 1, 2, \ldots N$$

where N_j is the number of pattern vectors from class w_j and the summation is taken over these vectors.

We assign X to class w_i if $D_i(x)$ is the smallest distance.

$$D_j(x) = \| x - m_j \|$$

- It is not difficult to show that selecting the smallest distance is equivalent to evaluating the ~~smallest~~ functions $d_j(x) = x^T m_j - \frac{1}{2} m_j^T m_j$

- assign x to class w_i if $d_i(x)$ is the largest numerical value. This formula agrees with the concept of a decision function.

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Q 5 a) Compare the edge detection by Roberts, prewitt and Sobel Operator with their equations and characteristics.

Soln → Edge detection extract edges of object from an image. Edge characterize object boundaries and therefore it is useful for segmentation, registration and identification of an object in the scenes.

(i) edge detection by Roberts Operators

let the 3X3 area shown in the figure below represents the gray level in a neighborhood of an image.

$$\begin{bmatrix} z_1 & z_2 & z_3 \\ z_4 & z_5 & z_6 \\ z_7 & z_8 & z_9 \end{bmatrix}$$

Fig: 3X3 image

The Roberts cross-gradient operators are one of the earliest attempts to use 2-D masks with a diagonal preference. The Roberts Operators are based on implementing the diagonal differences,

$$g_x = \frac{df}{dx} = (z_9 - z_5)$$

and

$$g_y = \frac{df}{dy} = (z_8 - z_6)$$

The derivative can be implemented for the entire image by using mask which is given as:

-1	0
0	1

d_1

0	-1
1	0

d_2

Roberts

Here, the mask of 2X2 are upward because they do not have clear center.

(ii) Prewitt Operators

It is defined as,

$d_1 = G_x = [(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)]$

$d_2 = G_y = (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)$

Then, the prewitt operator mask will be:

-1	-1	-1
0	0	0
1	1	1

d_1

-1	0	1
-1	0	1
-1	0	1

d_2

prewitt

Here, the difference betn the first and third row of an 3X3 image region approximates the derivative in the x-direction and the difference between the 3rd and 1st column approximates the derivatives in y-direction.

(iii) Slobel Operators:

In Slobel operator higher weights are assigned to the pixels, close to the candidate pixel.

So, it is defined as,

$$d_1 = G_x = \frac{df}{dx} = [(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)]$$

$$d_2 = G_y = \frac{df}{dy} = [(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)]$$

Then, the corresponding 3x3 mask for slobel operator will be,

d_1:

-1	-2	-1
0	0	0
1	2	1

d_2:

-1	0	1
-2	0	2
-1	0	1

sobel

The prewitt masks are simpler to implement than the sobel masks but, the slight computational difference between them typically is not issue. The fact that the sobel masks have better noise-suppression (smoothing).

Q5(b) What is Hough transform? How it is useful in line detection?

soln → Hough transform:

The Hough transform is a technique which can be used to isolate features of a particular shape within an image. Because it requires that the desired features be specified in some parametric form, the classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses etc. The main advantage of Hough transform technique is that it is tolerant of gaps in feature boundary descriptions and is relatively unaffected by image noise.

Now lets consider global relationships between pixels. Suppose that, for n points in an image, we want to find all subsets of these points that lie on straight lines. Consider a point (x_i, y_i) in the plane xy-plane and the equation for the straight line $y_i = ax_i + b$.

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- Infinitely many lines pass through the point (x_i, y_i) all satisfying the equation for varying values of a and b.
- However, writing this equation as $b = -x_i a + y_i$ and considering the ab-plane (also called parameter space) yields the equation of a single line for a fixed pair (x_i, y_i).
- A second point (x_j, y_j) also has a line in the parameter space associated with it.
- This line intersects the line associated with (x_i, y_i) and (a', b'). (a' is the slope and b' is the intercept of the line containing both (x_i, y_i) and (x_j, y_j) in the plane xy-plane.

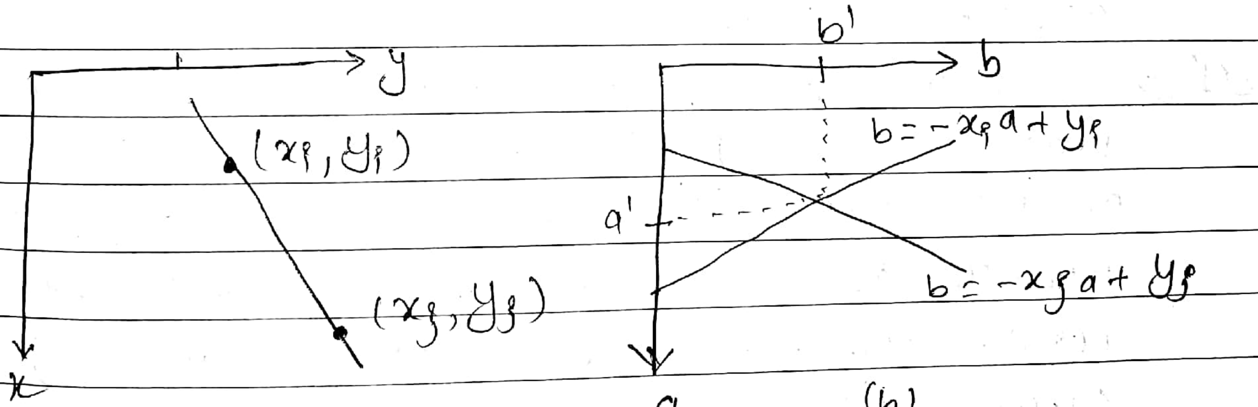

Figure (a): x-y plane
(b): parameter space.

→ The all points that lie on this line have corresponding lines in the parameter space that intersect at (a', b').

An approach based on the Hough transform is as follow for line detection:

(i) Obtain a binary edge image using any of the techniques (i.e. compute the gradient of an image)

(ii) Specify subdivisions in the $\rho\theta$-plane.

(iii) Examine the counts of the accumulator cells for high pixel concentrations.

(iv) Examine the relationship (principally for continuity) between pixels in a chosen cell.

Q. 6 (a) Explain the region growing technique for image segmentation. What are the problems associated with it.

Soln → Region growing is a procedure that groups pixels or subregions into larger regions based on predefined criteria for growth. The basic approach is to start with a set of "seed" points and from these grow regions by appending to each seed those neighboring pixels that have predefined properties similar to the seed (such as specific ranges of intensity or color).

Let us, pick up an arbitrary pixel (r, c), from the domain of an image to be segmented. This pixel is called seed pixel.

Now, examine the nearest neighbor (i.e. 4 or 8 neighbor) of (r,c) one by one and neighbourhood pixel accepted belongs to the same region as (r,c).

Once a new pixel is accepted due to the ~~prop~~ homogeneity property of a region as a member of the current region. then the nearest neighbour of this new pixel are examined.

Problems in region growing technique:

(i) The selection of the seeds.

(ii) Criteria of similarity.

(iii) Gray level's similarity / connectivity / texture / moments

(iv) Formulation of a stopping rule.

(v) Growing a region should stop when no more pixels satisfy the criteria for inclusion in that region.

Q 6 (b) What is Neural Network? Explain Hamming Nets in detail.

Soln → Neural network is the branch of the field known as Artificial Intelligence (AI). A neural network can be considered as black-box i.e. able to prediction of output pattern when it recognizes the given input pattern. Neural network in image processing:

- NN for image compression.
- NN for pattern recognition
- NN for perceptron (perception).

Hamming Net:

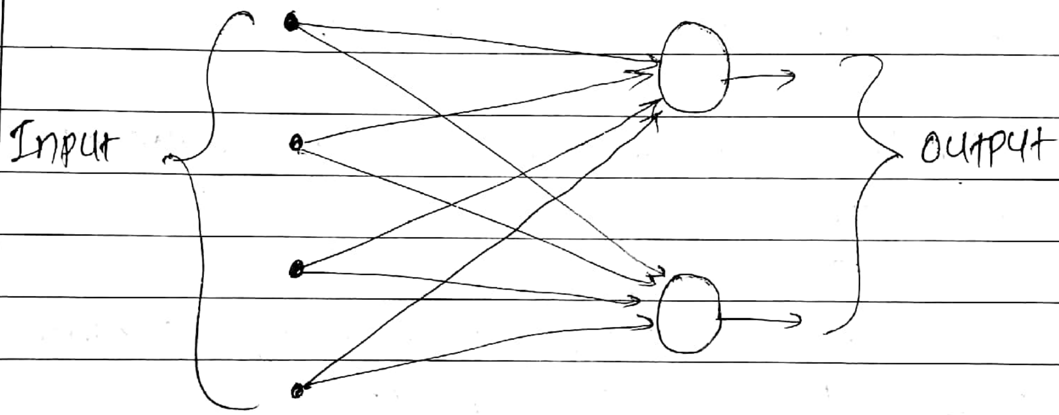

Figure: Hamming Neural Network

The Hamming neural network has the following properties:

- Feed forward network.
- Single layer network.
- A fixed weights network.
- cluster the input.

For a Hamming net, M exemplar bipolar vectors $e^{(1)}, e^{(2)} \ldots e^{(M)}$ are given. They are used to form the weight matrix of the network. The Hamming net is therefore a fixed-weight

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net.
For any given input vector x, the Hamming net finds the exemplar vector that is closet to x. Therefore if a collection of input vectors are given, the Hamming net can be used to cluster these vectors into M different groups.

Let two vectors a and b are close to each other. Hamming distance, $H(a,b)$ and the number of corresponding bits that agrees with each other by $A(a,b)$.

For bipolar vectors;

$$a.b = A(a,b) - H(a,b)$$

and,

$$N = A(a,b) + H(a,b)$$

we eliminate the Hamming between these two equations and solve for $A(a,b)$ to get

$$A(a,b) = \frac{a.b}{2} + \frac{N}{2}.$$

~~The two vectors are~~

The two vector a and b are close to each other if $A(a,b)$ is large.

We will use $A(a,b)$ to measure the closeness of two vectors in the Hamming net.

We want to identify 'a' with an input vector X (assumed to be a row vector of length N), and 'b' with one of the exemplar vectors.

- With M exemplar vectors, they can be scaled down by a half and stored column-wise to form the weight matrix for the Hamming net.

Thus the weight matrix is N×M, and its elements are,

$$w_{ij} = \frac{1}{2} e_i^{(j)} \quad i = 1, \ldots, N \quad \text{and} \quad j = 1, \ldots, N$$

The bias vector is a row vector of length M and has elements N/2.

$$b_j = \frac{1}{2} N, \quad j = 1, \ldots, M$$

For a given input vector x, the number of bits of agreement that it has with each of the exemplar vector form a vector

$$\boxed{y_{in} = xW + b}$$

of inputs to the neurons at the Y layer.

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7. Write short notes on (Any two)

(a) Gaussian High pass Frequency domain filter

Sol → Frequency domain is the space defined by FT and its frequency variable $S(u,v)$.

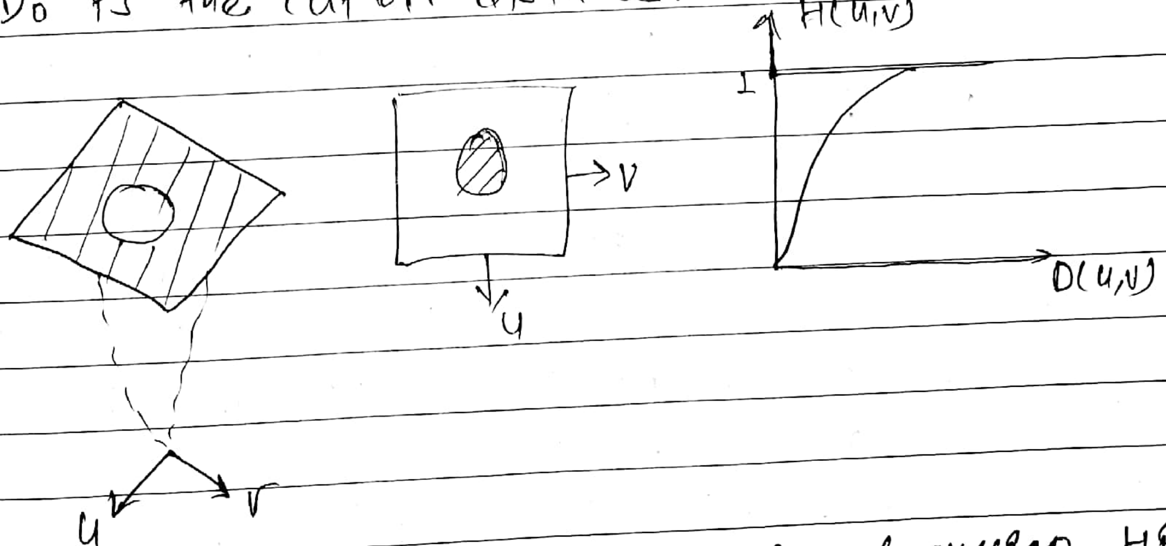
The transfer function of the Gaussian highpass filter (GHPF) with cutoff frequency locus at a distance D_0 from the center of the frequency rectangle is given by,

$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2}$$

Where $D(u,v)$ is given by,

$$D(u,v) = \left[(u - P/2)^2 + (v - Q/2)^2\right]^{1/2}$$

D_0 is the cut off distance.



The results obtained using Gaussian High pass frequency domain filter are smoother. Even the filtering of the smaller objects and thin bars is cleaner with Gaussian filter.

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Q 7.(b) **Histogram specification:**

Soln The method used to generate a processed image that has a specified histogram is called histogram matching or histogram specification.

Histogram specification is not interactive because it always gives one result, i.e. an approximation to an uniform histogram.

It is at time desirable to have an interactive methods in which certain gray levels are highlighted.

Histogram specification procedure:

Suppose that $P_r(r)$ is the original pdf (probability density function) and $P_z(z)$ is the desired pdf.

then, histogram equalization is first applied on the original image.

$$S = T(r) = \int_0^r P_r(r)\, dr.$$

Histogram equalization of desired image 'z' is that:

$$V = G(z) = \int_0^z P_z(r)\, dz$$

Now,

The inverse process $z = G^{-1}(s)$ which have the desired pdf that provide histogram specification. i.e.

$$\boxed{z = G^{-1}(s) = G^{-1}(T(r)) = G^{-1}\int_0^r P_r(r)\, dr}$$