SCHEME of EVALUATION

IV/IV B.Tech (Regular) DEGREE EXAMINATION

Subject Name: Digital Image Processing

Subject code: 14EC704

Department: ECE

Month & Year: Nov, 2019

Semester: Seventh

Maximum: 60 Marks

Prepared by:

M.SUNEEL
Asst .Professor
Department of ECE

Verified & Forwarded by:

Dr N.Venkateswara Rao

Proessor & Head

Department of ECE

Hall Ticket Number:

14EC704

IV/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November,2019 — **Electronics and Communication Engineering**

Seventh Semester — **Digital Image Processing**

Time: Three Hours — **Maximum: 60 Marks**

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   - a) Define a digital image.
   - b) Define quantization.
   - c) Write the different distance measures.
   - d) What is bit plane slicing?
   - e) Define contrast stretching.
   - f) Define histogram equalization.
   - g) Define radiance and luminance.
   - h) What are the characteristics used to distinguish different colors.
   - i) Write the mathematical expression for Gaussian noise.
   - j) Compare enhancement and restoration.
   - k) What is the basic concept of run length coding.
   - l) Define the term "dilation".

UNIT I

2. a) Explain about the fundamental steps in digital image processing. 6M
   b) Describe the various elements of visual perception. 6M

(OR)

3. a) Define digital image processing and discuss various applications. 6M
   b) Consider the following image segment and find the d4, d8, dm distance between p & q for v={1,2}. 6M

	3	1	2	1	(q)
	2	2	0	2	
	1	2	1	1	
(p)	1	0	1	2	

UNIT II

4. a) Describe histogram equalization. Obtain histogram equalization for the following 8 bit Image segment of size 5×5. Write the inference on image segment before and after Equalization. 6M

200	200	200	180	240
180	180	180	180	190
190	190	190	190	180
190	200	220	220	240
230	180	190	210	230

   b) Explain the basic concept of frequency domain filtering. 6M

(OR)

5. a) Discuss histogram specification technique with mathematical equations. 6M
   b) Discuss various image smoothing techniques using frequency domain filters. 6M

UNIT III

6. a) What is meant by image restoration? Explain the image degradation model. 6M
   b) Discuss HSI color model in detail. 6M

(OR)

7. a) Discuss about constrained least squares filtering. 6M
   b) Describe the basics of color image enhancement. 6M

UNIT IV

8. a) Discuss about different types of redundancies. 6M
   b) Explain opening and closing operations with suitable examples. 6M

(OR)

9. a) Discuss about LZW coding. 6M
   b) Discuss the following: 6M
      i) Convex Hull.
      ii) Skeletons.

1. Each question carry's one mark

   a. Define a Digital Image.

      Ans: An image may be defined as a two-dimensional function f(x , y) ,where x and y are spatial coordinates and the amplitude of f at any pair of coordinates (x ,y) is called the intensity or gray level of image at that point. when x, y and f values are finite and discrete then it is a Digital image.

   b. Define Quantization.

      Ans: The process of converting continuous intensity values into discrete values is called Quantization.

   c. Write the different distance measures.

      Ans: The different distance measures are Euclidean distance, City-block distance, chessboard distance.

   d. What is Bit plane slicing?

      Ans: The process of decomposing an image into bit planes for analyzing the importance of each bit in image is called Bit plane slicing.

   e. Define Contrast Stretching.

      Ans: The process that expands the range of intensity levels in an image is called Contrast Stretching.

   f. Define Histogram equalization.

      Ans: The processed image obtained by mapping each pixel with level r_k in the input image into a corresponding pixel with level s_k in the output image. The transformation is called histogram equalization.

$$
\begin{aligned}
s_k = T(r_k) &= \sum_{j=0}^{k} p_r(r_j) \\
&= \sum_{j=0}^{k} \frac{n_j}{n} \qquad k = 0, 1, 2, \dots, L - 1.
\end{aligned}
$$

   g. Define Radiance and Luminance.

      Ans: Radiance: The total amount of energy that flow from the light source, measured in watts (W)

      Luminance: The amount of energy an observer perceives from a light source, measured in lumens

   h. What are the characteristics used to distinguish different colors?

      Ans: Hue, Saturation, Brightness are used to distinguish different colors.

i. Write the mathematical expression for Gaussian Noise?

Ans:

$$p_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$

j. Compare Enhancement and Restoration.

Ans:

Image enhancement	**Image restoration**
Image enhancement is a subjective process.	Image restoration is objective and is based on sound mathematical principles.
It involves only cosmetic changes in the brightness and contrast. Often, this is a trial-and-error process. The enhancement procedure is heuristic.	It requires modelling of the degradations. The restoration algorithms are well defined.
The procedure is very simple.	The procedure is complex.

k. What is the basic concept of run length coding?

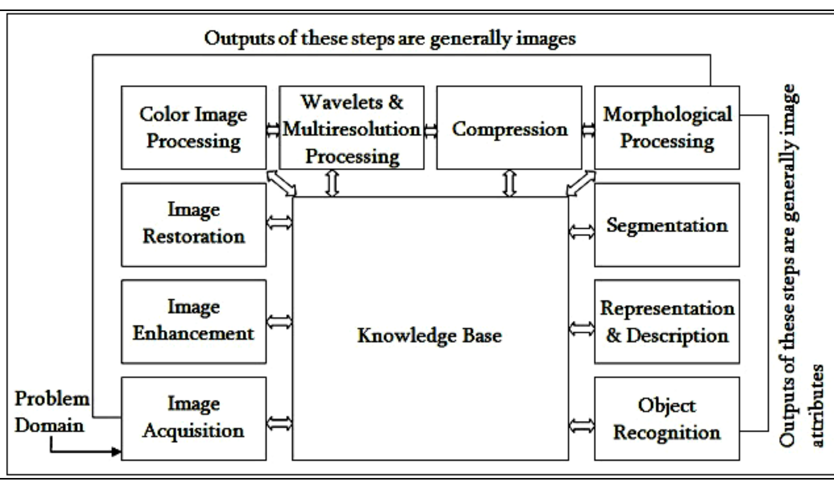
Ans: Run-length encoding (RLE) is a form of lossless data compression in which runs of data (sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run.

l. Define the term “Dilation”.

Ans: Dilation is used for expanding an element A by using structuring element B.

$$\boxed{A \oplus B = \left\{ z \mid (\widehat{B})_z \cap A \neq \phi \right\}}$$

UNIT-I

2(a)		6 M

(i) **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.

(ii) **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.

(iii) **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.

(iv) **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 modeling and processing in a digital domain etc.

(v) **Wavelets and Multiresolution Processing :** Wavelets are the foundation for representing images in various degrees of resolution. Images subdivision successively into smaller regions for data compression and for pyramidal representation.

(vi) **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.

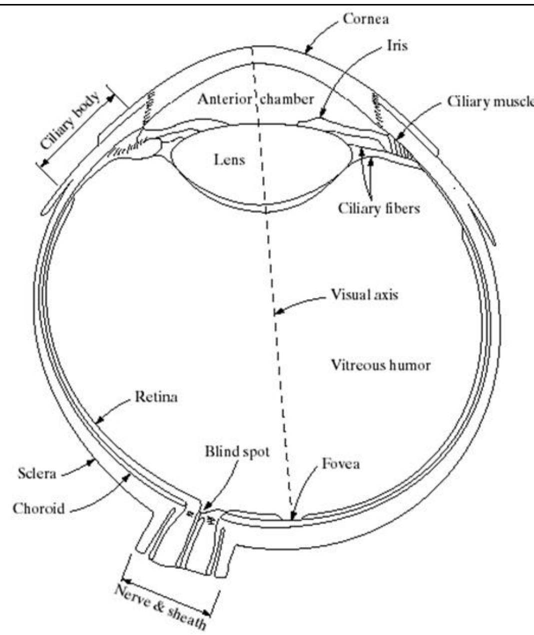
(vii) **Morphological Processing :** Morphological processing deals with tools for extracting image components that are useful in the representation and description of shape.

(viii) **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. A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually.

(ix) **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.

(x) **Object recognition :** Recognition is the process that assigns a label, such as, "vehicle" to an object based on its descriptors.

(xi) **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

<table>
<tr><td></td><td>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.</td><td></td></tr>
<tr><td>2(b)</td><td>


- Diameter: 20 mm
- 3 membranes enclose the eye
    - Cornea & sclera
    - Choroid
    - Retina

The choroid contains blood vessels for eye nutrition and is heavily pigmented to reduce extraneous light entrance and backscatter. It is divided into the ciliary body and the iris diaphragm, which controls the amount of light that enters the pupil (2 mm ~ 8 mm)
The lens is made up of fibrous cells and is suspended by fibers that attach it to the ciliary body. It is slightly yellow and absorbs approx. 8% of the visible light spectrum.
The retina lies in the entire posterior portion. Discrete light receptors are distributed over the surface of the retina:
cones (6-7 million per eye) and rods (75-150 million per eye)
Cones are located in the fovea and are sensitive to color. Each one is connected to its own nerve end. Cone vision is called photopic (or bright-light vision).
Rods are giving a general, overall picture of the field of view and are not involved in color vision. Several rods are connected to a single nerve and are sensitive to low levels of illumination (scotopic or dim-light vision).
The distribution of receptors is radially symmetric about the fovea. Cones are most dense in the center of the fovea while rods increase in density from the center out to approximately 20% off axis and then decrease.
</td><td>6M</td></tr>
</table>

(OR)

<table>
<tr><td>3(a)</td><td>Digital Image Processing is nothing but processing digital images through digital computer.

The field of digital image processing has experienced continuous and significant expansion in recent years. The usefulness of this technology is apparent in many different disciplines covering medicine through remote sensing. The advances and wide availability of image processing hardware has further enhanced the usefulness of image processing.

• medical applications
• restorations and enhancements
• digital cinema
• image transmission and coding
• color processing
• remote sensing
• robot vision
• hybrid techniques
• facsimile
• pattern recognition
• registration techniques
• multidimensional image processing
• image processing architectures and workstations
• video processing
• programmable dsps for video coding
• high-resolution display
• high-quality color representation
• super-high-definition image processing
• impact of standardization on image processing.</td><td>6M</td></tr>
<tr><td>3(b)</td><td>$$\begin{array}{ccccc} & 3 & 1 & 2 & 1\ (q) \\ & 2 & 2 & 0 & 2 \\ & 1 & 2 & 1 & 1 \\ (p) & 1 & 0 & 1 & 2 \end{array}$$
V = {1, 2}
i. One possibility for 4-path:
p = (3; 0); (2; 0); (2; 1); (2; 2); (2; 3); (1; 3); (0; 3) = q
The length of this path is 6.
ii. One possibility for the shortest 8-path:
p = (3; 0); (2; 1); (1; 1); (0; 2); (0; 3) = q
The length of the shortest path is 4.
iii. One possibility for the shortest m-path:</td><td>6M</td></tr>
</table>

	p = (3; 0); (2; 0); (2; 1); (1; 1); (0; 1); (0; 2); (0; 3) = q The length of this path is 6.	

UNIT-II

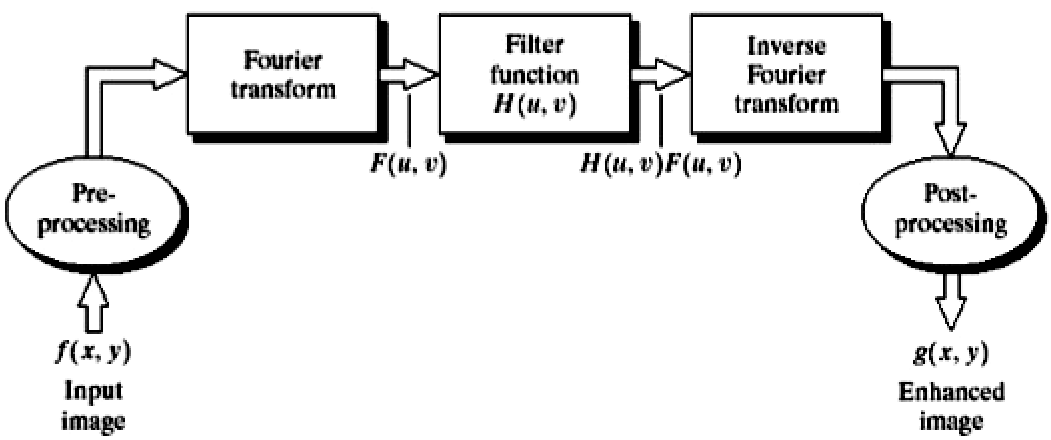
4(a)	$$\begin{bmatrix} 200 & 200 & 200 & 180 & 240 \\ 180 & 180 & 180 & 180 & 190 \\ 190 & 190 & 190 & 190 & 180 \\ 190 & 200 & 220 & 220 & 240 \\ 230 & 180 & 190 & 210 & 230 \end{bmatrix}$$ $$\text{Prob.} = \left[\begin{matrix} 180 & 190 & 200 & 210 & 220 \\ 7/25 & 7/25 & 4/25 & 1/25 & 2/25 \end{matrix}\right.$$ $$\left.\begin{matrix} 230 & 240 \\ 2/25 & 2/25 \end{matrix}\right]$$ $$\text{Cumulative Prob.} = \left[\begin{matrix} 7/25 & 14/25 & 18/25 & 19/25 & 21/25 \end{matrix}\right.$$ $$\left.\begin{matrix} 23/25 & 25/25 \end{matrix}\right]$$	6M

<table>
<tr><td></td><td>

$$\begin{bmatrix} 173 & 173 & 173 & 67 & 240 \\ 67 & 67 & 67 & 67 & 134 \\ 134 & 134 & 134 & 134 & 67 \\ 134 & 173 & 202 & 202 & 240 \\ 221 & 67 & 134 & 182 & 221 \end{bmatrix}$$

</td><td></td></tr>
<tr><td>4(b)</td><td>

Frequency domain filtering operation



Basic steps for filtering in the frequency domain.

- We simply compute the Fourier transform of the image to be enhanced, multiply the result by a filter (rather than convolve in the spatial domain), and take the inverse transform to produce the enhanced image.
- Low pass filtering involves the elimination of the high frequency components in the image. It results in blurring of the image

</td><td>6M</td></tr>
</table>

<table>
<tr><td></td><td>

Figure : Transfer function for an ideal low pass filter.

</td><td></td></tr>
</table>

(OR)

<table>
<tr><td>5a</td><td>

Histogram specification:

Suppose we want to specify a particular histogram shape (not necessarily uniform) which is capable of highlighting certain grey levels in the image. Let us suppose that: p r)(r is the original probability density function p z)(z is the desired probability density function Suppose that histogram equalisation is first applied on the original image r.

$$s = T(r) = \int_0^r p_r(w)dw$$

Suppose that the desired image z is available and histogram equalisation is applied as well

$$v = G(z) = \int_0^z p_z(w)dw$$

$p_s(s)$ and $p_v(v)$ are both uniform densities and they can be considered as identical. Note that the final result of histogram equalisation is independent of the density inside the integral. So in equation $v = G(z) = \int_0^z p_z(w)dw$ we can use the symbol s instead of v.

The inverse process $z = G^{-1}(s)$ will have the desired probability density function. Therefore, the process of histogram specification can be summarised in the following steps.

(i) We take the original image and equalise its intensity using the relation $s = T(r) = \int_0^r p_r(w)dw$.

(ii) From the given probability density function $p_z(z)$ we specify the probability distribution function $G(z)$.

(iii) We apply the inverse transformation function $z = G^{-1}(s) = G^{-1}[T(r)]$

</td><td>6M</td></tr>
<tr><td>5b</td><td>

SMOOTHING FREQUENCY-DOMAIN FILTERS

Edges and other sharp transitions in the gray levels of an image contribute significantly to the high-frequency content of its Fourier transform. Hence smoothing (blurring) is

</td><td>6M</td></tr>
</table>

achieved in the frequency domain by attenuating a specified range of high-frequency components in the transform of a given image.

Our basic model for filtering in the frequency domain is given by

$$G(u,v)=H(u,v).F(u,v)$$

where F(u,v) is the fourier transform of the image to be smoothed. The objective is to select a filter transfer function H(u,v) that yields G(u,v) by attenuating the high-frequency components of F(u,v). we consider 3 types of lowpass filters:

1) Ideal Lowpass Filter (ILPF)

2) Butterworth Lowpass Filter (BLPF)

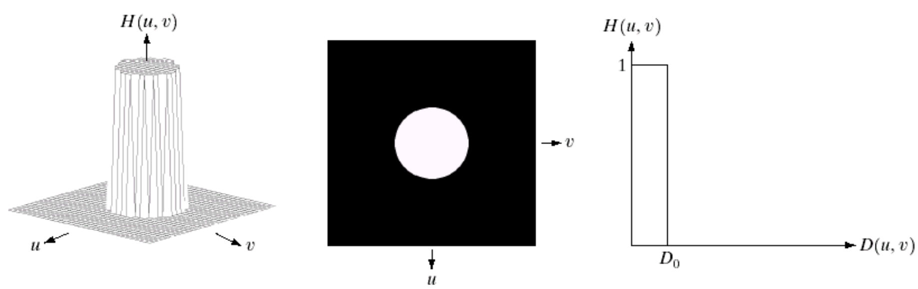
3) Gaussian Lowpass Filter (GLPF)

Ideal Lowpass Filter

The simplest lowpass filter we can visualize is a filter that cuts off all high frequency components of the Fourier transform that are at a distance higher greater than a specified distance D0 from the origin of the (centered) transform. Such a filter is called a two-dimensional ideal lowpass filter and has transfer function shown below

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \le D_0 \\ 0 & \text{if } D(u,v) > D_0 \end{cases}$$

where D0 is a specified non-negative quantity, and D(u,v) is the distance from point (u,v) to the origin of the frequency rectangle. If the image is of size MxN, we know that its transform also is of same size, so the center of the frequency rectangle is at (u,v) = (M/2,N/2).



a b c

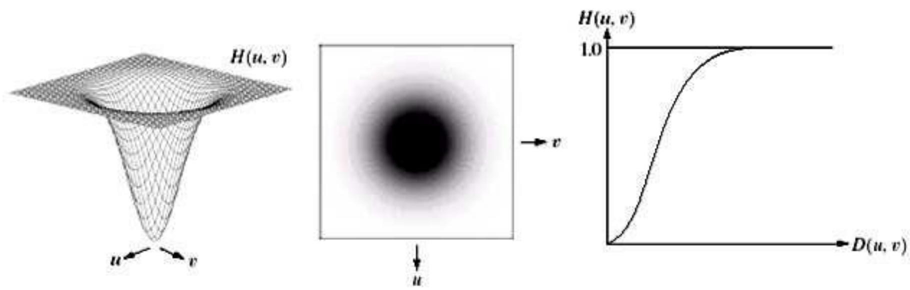
FIGURE 4.10 (a) Perspective plot of an ideal lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross section.

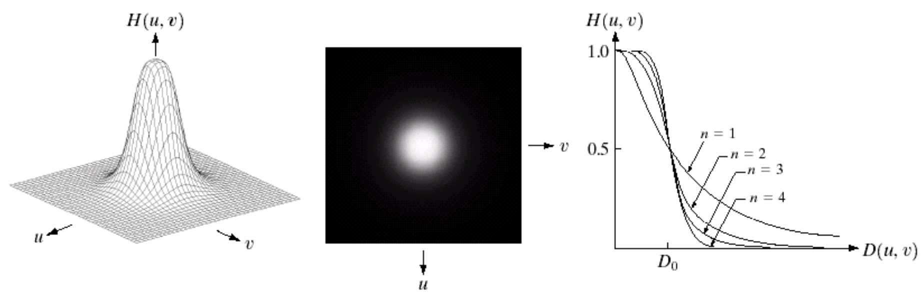
Butterworth Lowpass Filter:

The Butterworth filter has a parameter, called the filter order. For high values of this parameter the Butterworth filter approaches the form of the ideal filter. For lower-order values, the Butterworth filter has a smooth form similar to the Gaussian filter. The transfer function of the Butterworth lowpass filter of order n, and with cutoff frequency at a distance D0 from the origin, is defined as

$$H(u,v) = \frac{1}{1 + \left[D(u,v)/D_0\right]^{2n}}$$

where D(u,v) is the distance from point (u,v) to the origin of the frequency rectangle..





a b c

FIGURE 4.14 (a) Perspective plot of a Butterworth lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross sections of orders 1 through 4.

Gaussian Lowpass Filter:

The transfer function of a two dimensional Gaussian lowpass filter is given by

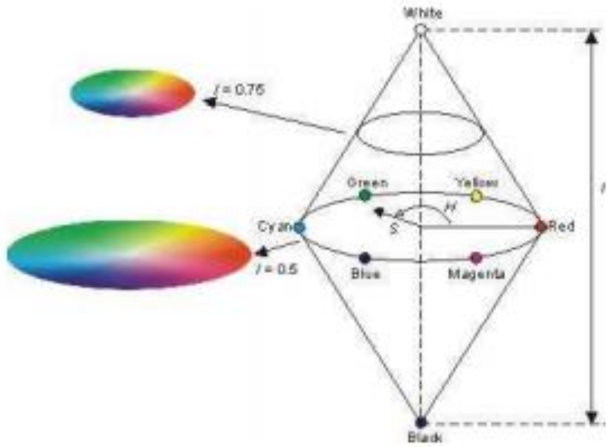
$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2}$$

where D(u,v) is the distance from point (u,v) to the origin of the frequency rectangle., σ is a measure of the spread of the Gaussian curve. By letting σ = D0, the transfer function changes to The inverse Fourier transform of the Gaussian lowpass filter also is Gaussian. A spatial Gaussian filter, obtained by computing the inverse Fourier transform of above equation will have no ringing.

The Gaussian lowpass filter did not achieve as smoothing as the BLPF of order 2 for the same value of cutoff frequency. This is because; the profile of the GLPF is not as tight as the profile of the BLPF of order 2.

UNIT-III

6a	**A general model of a simplified digital image degradation process** A simplified version for the image restoration process model is $y(i,j) = H[f(i,j)] + n(i,j)$ Where $y(i,j)$ the degraded image $f(i,j)$ the original image H an operator that represents the degradation process $n(i,j)$ the external noise which is assumed to be image-independent **Possible classification of restoration methods** Restoration methods could be classified as follows: • **deterministic:** we work with sample by sample processing of the observed (degraded) image • **stochastic** : we work with the statistics of the images involved in the process • **non-blind** : the degradation process H is known • **blind** : the degradation process H is unknown • **semi-blind** : the degradation process H could be considered partly known From the viewpoint of implementation: • **direct** • **iterative** • **recursive**	6M
6b	The HSI color space is very important and attractive color model for image processing applications because it represents color s similarly how the human eye senses colors. The HSI color model represents every color with three components: hue (H), saturation (S), intensity (I). The below figure illustrates how the HIS color space represents colors.	



The Hue component describes the color itself in the form of an angle between [0,360] degrees. 0 degree mean red, 120 means green 240 means blue. 60 degrees is yellow, 300 degrees is magenta.

The Saturation component signals how much the color is polluted with white color. The range of the S component is [0,1].

The Intensity range is between [0,1] and 0 means black, 1 means white.

As the above figure shows, hue is more meaningful when saturation approaches 1 and less meaningful when saturation approaches 0 or when intensity approaches 0 or 1. Intensity also limits the saturation values.

To formula that converts from RGB to HSI or back is more complicated than with other color models, therefore we will not elaborate on the detailed specifics involved in this process.

(OR)

7a	**Constrained least squares (CLS) restoration** It refers to a very large number of restoration algorithms.The problem can be formulated as follows. minimize $$J(\mathbf{f}) = \|\mathbf{n}(\mathbf{f})\|^2 = \|\mathbf{y} - \mathbf{H}\mathbf{f}\|^2$$ subject to $$\|\mathbf{C}\mathbf{f}\|^2 < \varepsilon$$ where $\mathbf{Cf}$ is a high pass filtered version of the image. **The idea behind the above constraint is that the highpass version of the image contains a considerably large**	6M

<table>
<tr><td></td><td>

amount of noise! Algorithms of the above type can be handled using optimization techniques. Constrained least squares (CLS) restoration can be formulated by choosing an $\mathbf{f}$ to minimize the Lagrangian

$$\min\left(\|\mathbf{y}-\mathbf{Hf}\|^2+\alpha\|\mathbf{Cf}\|^2\right)$$

Typical choice for $\mathbf{C}$ is the 2-D Laplacian operator given by

$$\mathbf{C}=\begin{bmatrix}0.00 & -0.25 & 0.00\\ -0.25 & 1.00 & -0.25\\ 0.00 & -0.25 & 0.00\end{bmatrix}$$

α represents either a Lagrange multiplier or a fixed parameter known as **regularisation parameter** and it controls the relative contribution between the term $\|\mathbf{y}-\mathbf{Hf}\|^2$ and the term $\|\mathbf{Cf}\|^2$. The minimization of the above leads to the following estimate for the original image $\mathbf{f}=\left(\mathbf{H}^T\mathbf{H}+\alpha\mathbf{C}^T\mathbf{C}\right)^{-1}\mathbf{H}^T\mathbf{y}$

Computational issues concerning the CLS method

Choice of α

The problem of the choice of α has been attempted in a large number of studies and different techniques have been proposed. One possible choice is based on a **set theoretic approach**: a restored image is approximated by an image which lies in the intersection of the two ellipsoids defined by

$$Q_{\mathbf{f}|\mathbf{y}}=\{\mathbf{f}\mid\|\mathbf{y}-\mathbf{Hf}\|^2\le E^2\}\text{ and}$$

$$Q_{\mathbf{f}}=\{\mathbf{f}\mid\|\mathbf{Cf}\|^2\le\varepsilon^2\}$$

The center of one of the ellipsoids which bounds the intersection of $Q_{\mathbf{f}|\mathbf{y}}$ and $Q_{\mathbf{f}}$, is given by the equation

$$\mathbf{f}=\left(\mathbf{H}^T\mathbf{H}+\alpha\mathbf{C}^T\mathbf{C}\right)^{-1}\mathbf{H}^T\mathbf{y}$$

with $\alpha=(E/\varepsilon)^2$. Another problem is then the choice of E^2 and ε^2. One choice could be

$$\alpha=\frac{1}{\text{BSNR}}$$

</td><td></td></tr>
<tr><td>7b</td><td>

Smoothing and Sharpening

- The next step beyond transforming each pixel of a color image without regard to its neighbors (as in the previous section) is to modify its value based on the characteristics of the surrounding pixels.
- The basics of neighborhood processing are illustrated within the context of color image smoothing and sharpening.

</td><td>6M</td></tr>
</table>

<table>
<tr><td></td><td>

Color Image Smoothing

- The basics of neighborhood processing
  - As a spatial filtering operation in which the coefficients of the filtering mask are all 1's
  - The mask is slid across the image to be smoothed
  - Each pixel is replaced by the average of the pixels in the neighborhood defined by the mask

$$\bar{c}(x,y)=\begin{bmatrix}\frac{1}{K}\sum_{(x,y)\in S_{xy}} R(x,y)\\ \frac{1}{K}\sum_{(x,y)\in S_{xy}} G(x,y)\\ \frac{1}{K}\sum_{(x,y)\in S_{xy}} B(x,y)\end{bmatrix}$$

</td><td></td></tr>
</table>

UNIT-IV

<table>
<tr><td>8a</td><td>

There are **three** types of redundancy:

- Coding redundancy
- Interpixel redundancy
- Psychovisual redundancy

Coding redundancy:

A code is a symbol (letters, numbers, bits) used to represent a body of information (Gonzalez and Woods, 2016). Each information is assigned a sequence of code symbols, called a code word. The number of symbols in each code word is its length.

Symbols with higher appearing probabilities are assigned with codes of less amount of data.

Symbol: codes that human represent information

E.g., Chinese characters, English letters, …

Coding: transform symbols into more efficient codes

E.g., A: 00, B: 01, C: 10, …

Interpixel redundancy:

Also called spatial redundancy, geometric redundancy, inter-frame redundancy. Results from structural or geometric relationships between objects and the image. Adjacent pixels are usually

</td><td>6M</td></tr>
</table>

	highly correlated (pixel similar or very close to neighboring pixels), thus information is unnecessarily replicated in the representations. Neighboring pixels in a natural image are highly correlated. In natural images, local area usually contains pixels of same or similar gray level. Psychovisual redundancy: For human visual perception, certain information has less relative importance. E.g,: appropriate quantization of gray levels does not impact its visual quality, e.g.,: Tiffany	
8b	i. Opening and closing are two important morphological operations. ii. Opening generally smoothest the contour of an object, breaks narrow isthmuses, and eliminates thin protrusions. iii. Closing also tends to smooth sections of contours but, as opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour. $A\circ B=(A\Theta B)\oplus BA\circ B=(A\Theta B)\oplus B$ iv. The opening of set A by structuring element B, denoted A o B, is defined as A¥BA¥B Thus, the opening A by B is the erosion of A by B, followed by a dilation ofthe result by B. v. Similarly, the closing of set A by structuring element B, denoted by, isdefined as $A¥B=(A\oplus B)\Theta BA¥B=(A\oplus B)\Theta B$ which says that the closing of A by B is simply the dilation of A by B, followed by the erosion of the result by B. vi. The opening operation has a simple geometric interpretation (Fig.1). Suppose that we view the structuring element B as a (flat) “rolling ball.” The boundary of A • B is then established by the points in B that reach the farthest into the boundary of A as B is rolled around the inside of this boundary. This geometric fitting property of the opening operation leads to a settheoretic formulation, which states that the opening of A by B is obtained by taking the union of all translates of B that fit into A.	6M

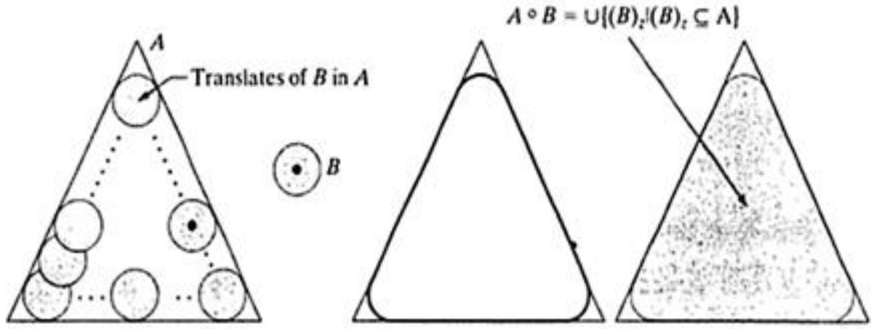


Figure 1 (a) Structuring element B “rolling” along the inner boundary of A (the dot indicates the origin of B), (b) Structuring element, the heavy line is the outer boundary of the opening. (c) Complete opening (shaded). We did not shade A in (a) for clarity.

vii. Closing has a similar geometric interpretation, except that now we roll B on the outside of the boundary (Fig. 2).

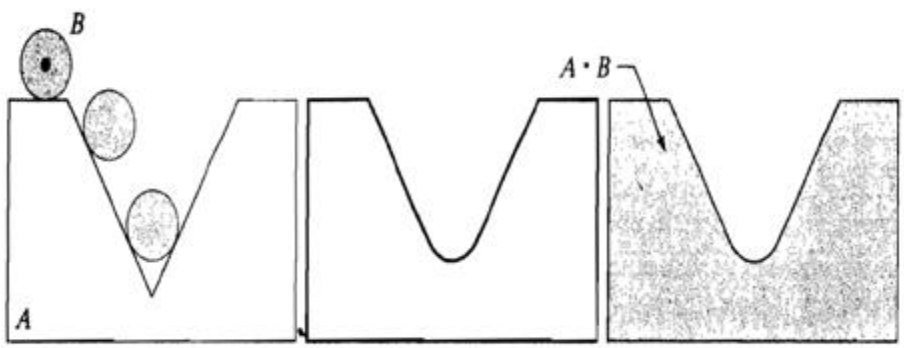


Figure 2 (a) Structuring element B “rolling” on the outer boundary of A (b) The heavy line is the outer boundary of the closing. (c) Complete closing(shaded). We did not shade A in (a) for clarity.

viii. This is all about the opening and closing of a digital image, we can say that opening and closing operations are duals of each other.

(OR)

9a

Lempel-Ziv-Welch (LZW) coding assigns fixed length code words to variable length sequences of source symbols.

- It also takes care of the interpixel redundancies.
- Popular coding scheme used in formats like GIF, TIFF, and PDF.

1-D coding

Let us first consider the 1-D input: an alphabet of input "symbols"

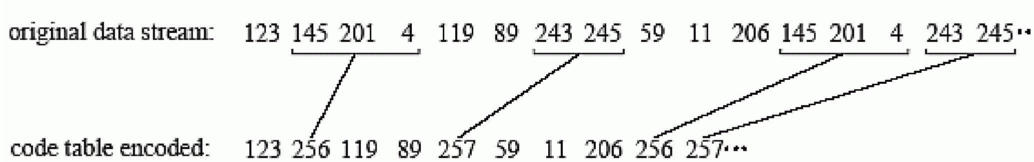
Method

- Construct a "dictionary" of input symbol sequences (155's) and output (replacement) symbols
- Initially, the dictionary contains only the individual input symbols
  - *"sequences of length 1 "*
- Scanning input from start to finish
  - *add each newly-encountered 155 to the dictionary*
  - *replace each 155 found in the dictionary with matching output symbol*
  - *then skip over the matched 155, and continue*

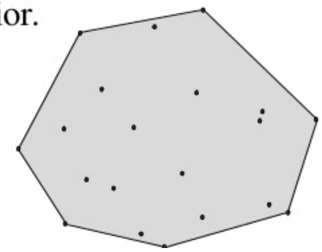
Example of code table compression. This is the basis of the popular LZW compression method. Encoding occurs by identifying sequences of bytes in the original file that exist in the code table. The 12 bit code representing the sequence is placed in the compressed file instead of the sequence. The first 256 entries in the table correspond to the single byte values, 0 to 255, while the remaining entries correspond to *sequences* of bytes. The LZW algorithm is an efficient way of generating the code table based on the particular data being compressed. (The code table in this figure is a simplified example, not one actually generated by the LZW algorithm).

Example Code Table

	code number	translation
identical code	0000	0
	0001	1
	⋮	⋮
	0254	254
	0255	255
unique code	0256	145 201 4
	0257	243 245
	⋮	⋮
	4095	xxx xxx xxx



6M

9b	**Convex hull** - Convex hull is defined as a set of given object - Convex hull of a set Q of points, denoted by CH(Q)is the smallest convex polygon P for which each points in Q is either on the boundary of P or in its interior.  **Skeleton** - The skeleton of A is defined by terms of **erosions** and **openings**: $$S(A) = \bigcup_{k=0}^{K} S_k(A)$$ - with $S_k(A) = (A \ominus kB) - (A \ominus kB) \circ B$ - Where B is the structuring element and $(A \ominus kB)$ indicates k successive erosions of A: $$(A \ominus kB) = (\ldots((A \ominus B) \ominus B) \ominus \ldots) \ominus B$$ - k times, and K is the last iterative step before A erodes to an empty set, in other words: $K = \max\{k \mid (A \ominus kB) \neq \emptyset\}$ - in conclusion S(A) can be obtained as the union of skeleton subsets Sk(A).	6M