Image Processing
18KP3CSELCS3:A

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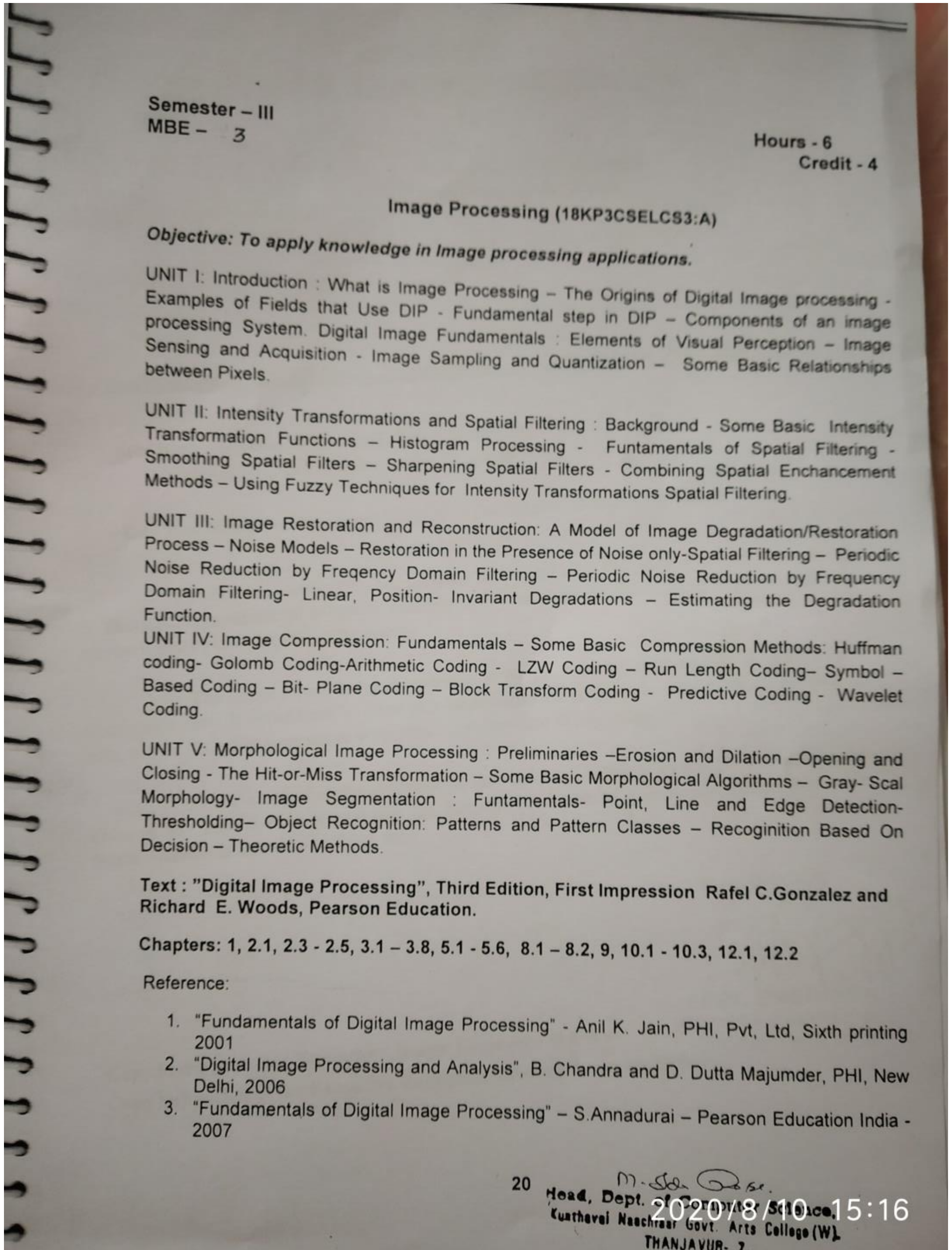
Syllabus



Semester – III
MBE – 3

Hours - 6
Credit - 4

Image Processing (18KP3CSELCS3:A)

Objective: To apply knowledge in Image processing applications.

UNIT I: Introduction : What is Image Processing – The Origins of Digital Image processing - Examples of Fields that Use DIP - Fundamental step in DIP – Components of an image processing System. Digital Image Fundamentals : Elements of Visual Perception – Image Sensing and Acquisition - Image Sampling and Quantization – Some Basic Relationships between Pixels.

UNIT II: Intensity Transformations and Spatial Filtering : Background - Some Basic Intensity Transformation Functions – Histogram Processing - Funtamentals of Spatial Filtering - Smoothing Spatial Filters – Sharpening Spatial Filters - Combining Spatial Enchancement Methods – Using Fuzzy Techniques for Intensity Transformations Spatial Filtering.

UNIT III: Image Restoration and Reconstruction: A Model of Image Degradation/Restoration Process – Noise Models – Restoration in the Presence of Noise only-Spatial Filtering – Periodic Noise Reduction by Freqency Domain Filtering – Periodic Noise Reduction by Frequency Domain Filtering- Linear, Position- Invariant Degradations – Estimating the Degradation Function.

UNIT IV: Image Compression: Fundamentals – Some Basic Compression Methods: Huffman coding- Golomb Coding-Arithmetic Coding - LZW Coding – Run Length Coding– Symbol – Based Coding – Bit- Plane Coding – Block Transform Coding - Predictive Coding - Wavelet Coding.

UNIT V: Morphological Image Processing : Preliminaries –Erosion and Dilation –Opening and Closing - The Hit-or-Miss Transformation – Some Basic Morphological Algorithms – Gray- Scal Morphology- Image Segmentation : Funtamentals- Point, Line and Edge Detection- Thresholding– Object Recognition: Patterns and Pattern Classes – Recoginition Based On Decision – Theoretic Methods.

Text : "Digital Image Processing", Third Edition, First Impression Rafel C.Gonzalez and Richard E. Woods, Pearson Education.

Chapters: 1, 2.1, 2.3 - 2.5, 3.1 – 3.8, 5.1 - 5.6, 8.1 – 8.2, 9, 10.1 - 10.3, 12.1, 12.2

Reference:

1. "Fundamentals of Digital Image Processing" - Anil K. Jain, PHI, Pvt, Ltd, Sixth printing 2001
2. "Digital Image Processing and Analysis", B. Chandra and D. Dutta Majumder, PHI, New Delhi, 2006
3. "Fundamentals of Digital Image Processing" – S.Annadurai – Pearson Education India - 2007

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- Unit I – Chapters: 1, 2

- Unit II – Chapter:3

Chapter 1

Introduction

Definition of Image

- An image may be defined as a two – dimensional functions, f (x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at the point.
- When x, y and the intensity values of f are all finite, discrete quantities, we call the image a digital image.

Definition of Image

- The field of digital image processing refers to processing digital image by means of a digital computer.
- These elements are called picture elements, image elements, pels, and pixels.

Types of Computerized Processes

- Low – level processes involve primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening.
- Mid – level processing on image involves tasks such as segmentation (partitioning an image into region or objects), description of those object to reduce them to a form suitable for computer processing, and classification (recognition) of individual object.

Scope of DIP

- The processes of acquiring an image of the area containing the text, preprocessing characters in a form suitable for computer processing, and recognizing those individual characters are in the scope of digital image processing.

Origins

- 1920:
  - Picture were first sent by submarine cable between London and New York.
  - The picture was transmitted in this way and reproduce on a telegraph printer fitted with typeface simulating a halftone pattern.
  - Initial problems in improving the visual quality.

Origins

- 1921:
  - Photograph reproduction made from tapes perforated at the telegraph receiving terminal.
  - Improvement over, both in tonal quality and in resolution.
- 1929:
  - Bartlane system where capable of coding images in five distinct levels of gray.
  - This capability was increased to 15 levels.

Origins

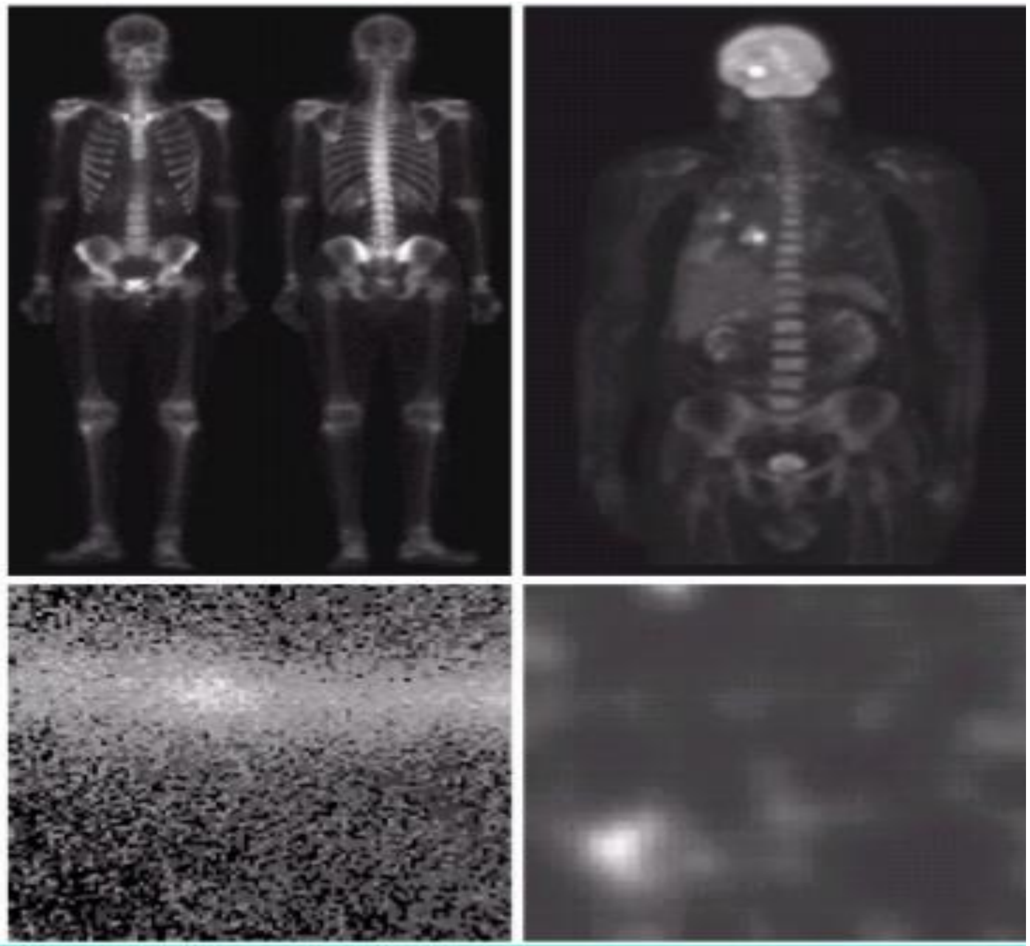
- 1940:
  1. A memory to hold a stored program and data.
  2. Conditional branching. These two ideas are the foundation of a central processing unit (CPU)
- 1950-60:

1. The invention of the transistor at Bell Laboratories in 1948
2. The development in the 1950s and 1960s of the high-level programming languages COBOL (Common Business-Oriented Languages)and FORTRAN (Formula Translator)
3. The invention of the integrated circuit (IC) at Texas Instruments in 1958
4. The development of operating systmes in the early 1960s
5. The development of the microprocessor (a single chip consisting of the central processing unit, memory and input and output controls) by Intel in the early 1970s
6. Introduction by IBM of the personal computer in 1981
7. Progressive miniaturization of components, starting with large scale integration (LI) in the late 1970s, then very large scale integration (VLSI) in the 1980s, to the present use of ultra large scale integration (ULSI)

Examples of Fields that use DIP

1. Gamma Ray Imaging
2. X-Ray Imaging
3. Imaging in the UltraViolet Band
4. Imaging in the Visible and Infrared Bands
5. Imaging in the Microwave Band
6. Imaging in the Radio band
7. Examples in which other imaging Modalities are used

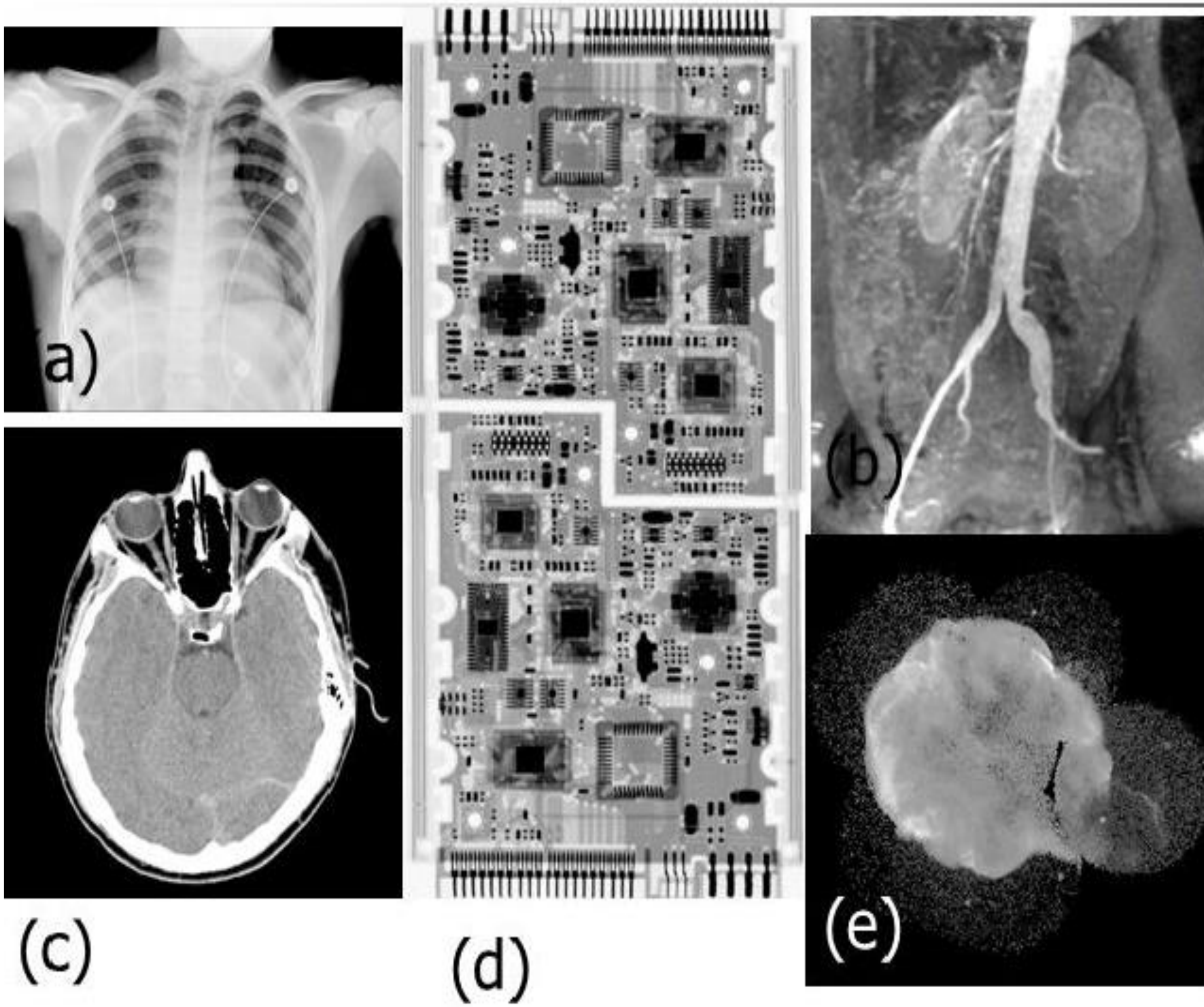
Gamma Ray Imaging



a b
c d

FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

Examples of X-ray imaging



- (a) Chest X-ray.
- (b) Aortic angiogram
- (c) Head CT.
- (d) Circuit boards.
- (e) Cygnus Loop.

UV Imaging

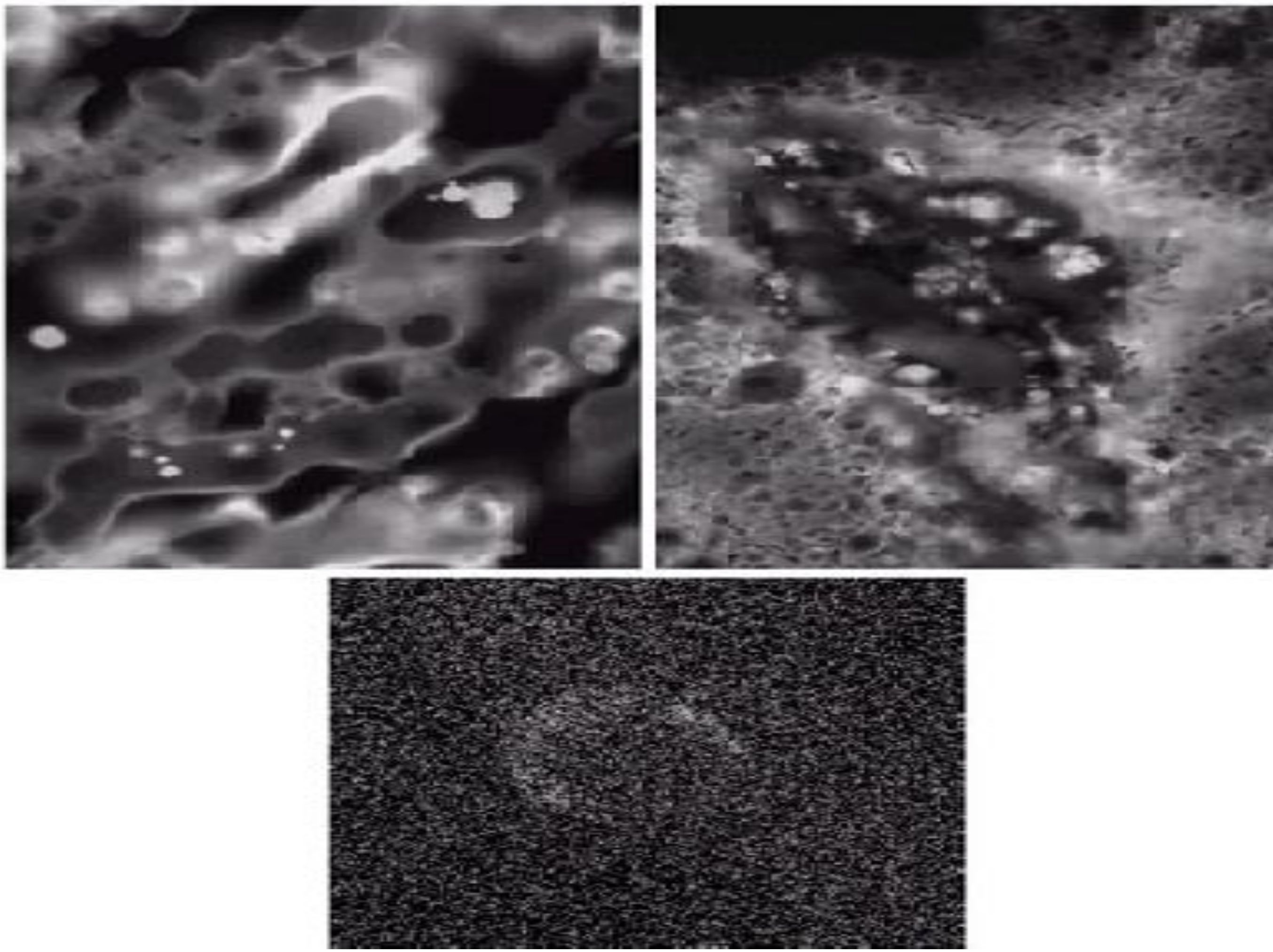


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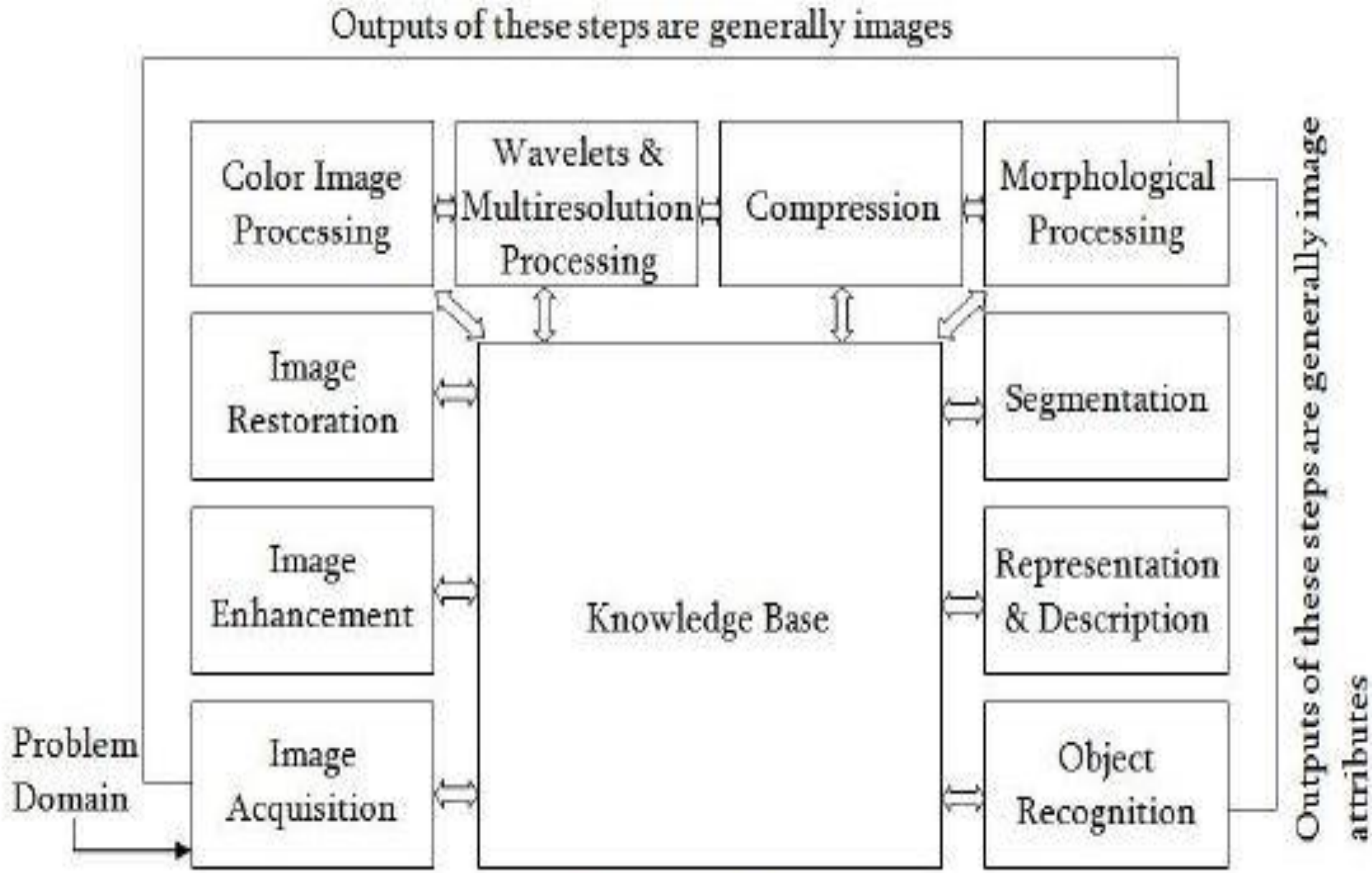
FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn. (b) Smut corn. (c) Cygnus Loop. (Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Fundamental Steps in DIP

- Image acquisition
- Image enhancement
- Image restoration
- Color image processing
- Wavelets
- Compression
- Morphological processing
- Segmentation
- Representation and description
- Recognition
-

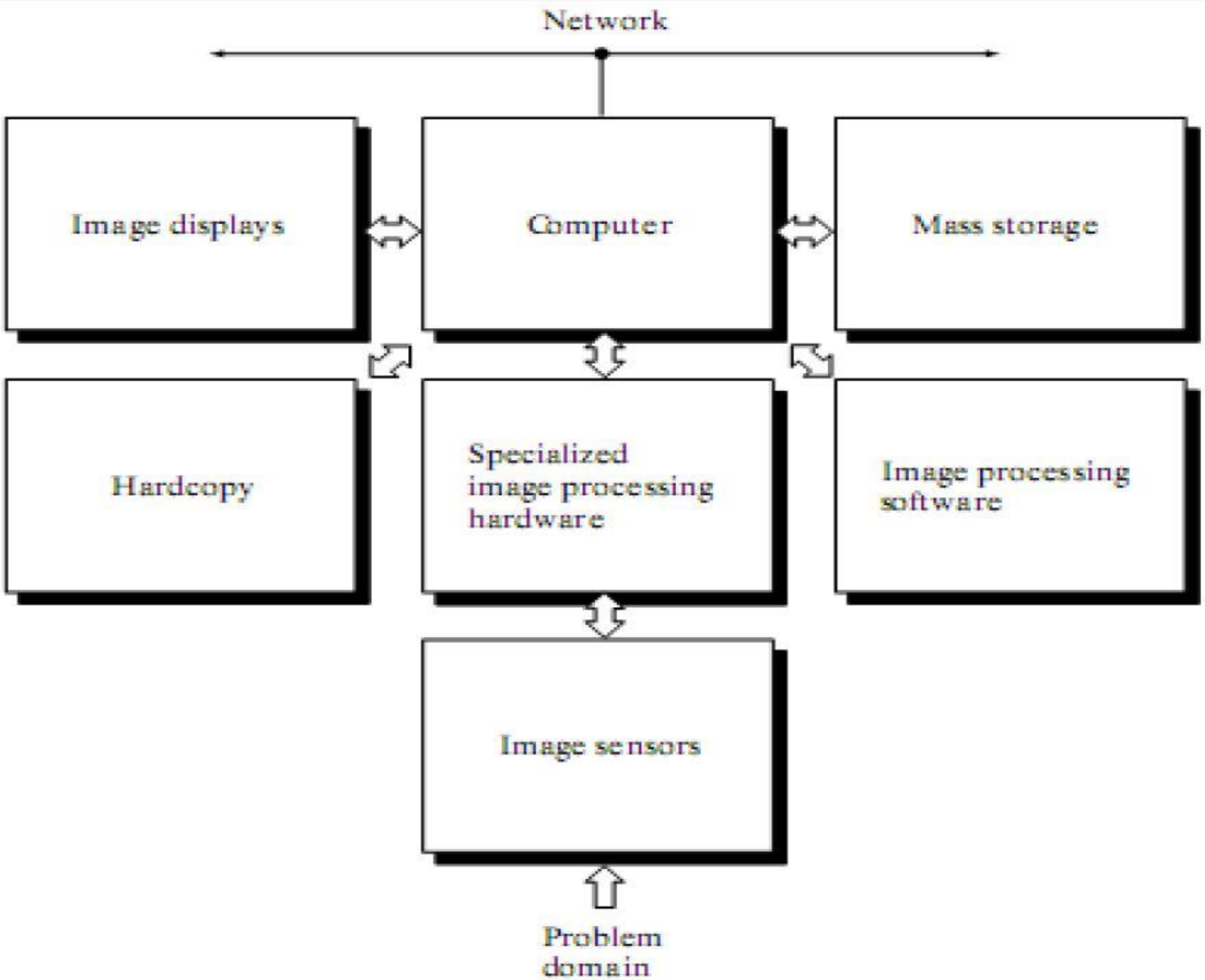


Outputs of these steps are generally images
Color Image Processing
Wavelets & Multiresolution Processing
Compression
Morphological Processing
Image Restoration
Segmentation
Image Enhancement
Knowledge Base
Representation & Description
Problem Domain
Image Acquisition
Object Recognition
Outputs of these steps are generally image attributes

Figure 1

Components of an IP System

- Specialized image processing hardware
- Computer
- Software
- Mass storage
- Image displays
- Hardcopy
- networking


Network
Image displays
Computer
Mass storage
Hardcopy
Specialized image processing hardware
Image processing software
Image sensors
Problem domain

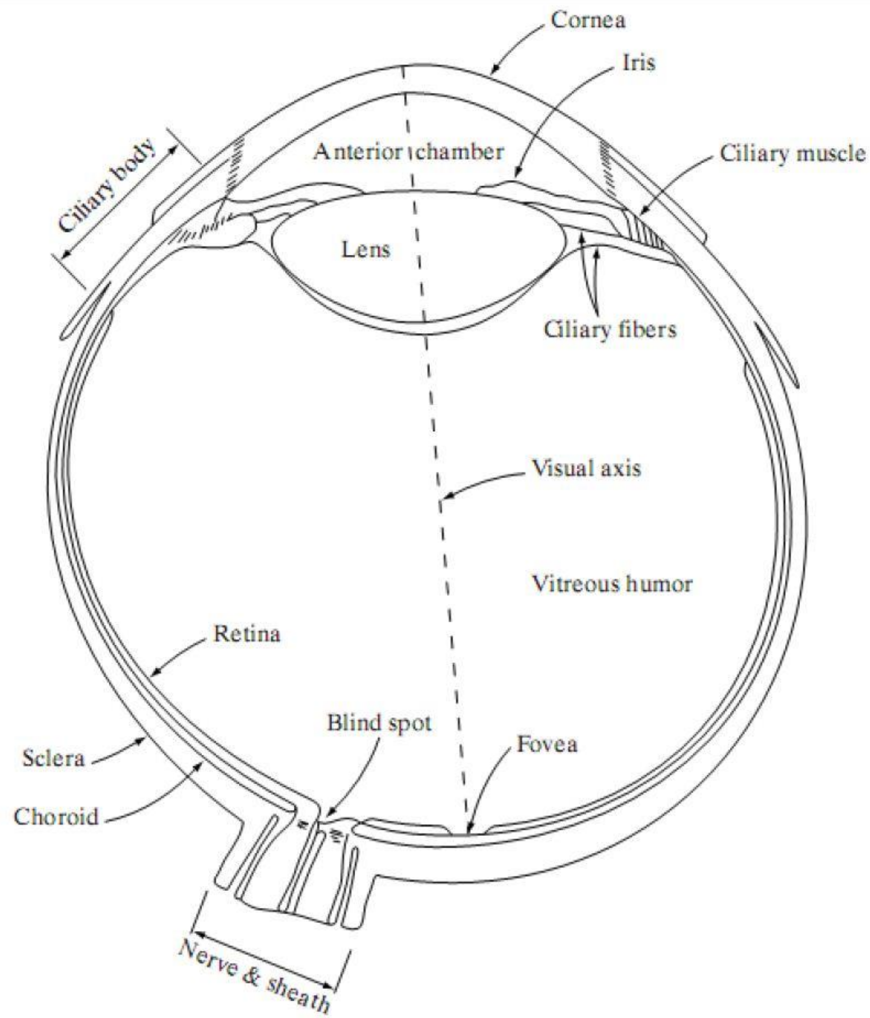
Chapter 2

Digital Image Fundamentals

Elements of Visual Perception

- Membrane of Eye: Cornea and Sclera
- Lens
- Ciliary body
- Cataracts
- Retina
- Receptors: Cones and Rods
- Scotopic
- Blind spot
- Fovea

Structure of Human Eye



Degree from Visual Axis (Centre of Fovea)

- Rods and cones in the retina

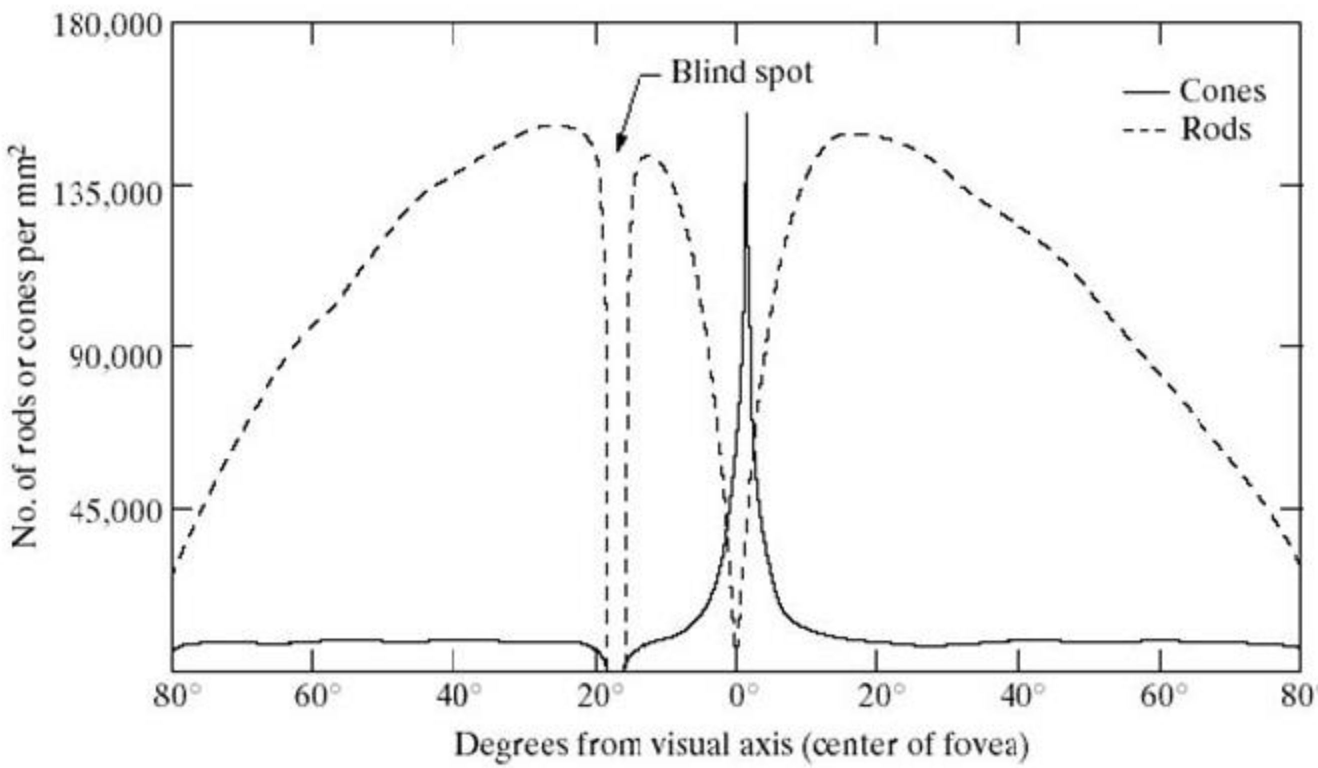


FIGURE 2.2 Distribution of rods and cones in the retina.

- Graphical representation of the eye looking at a palm tree

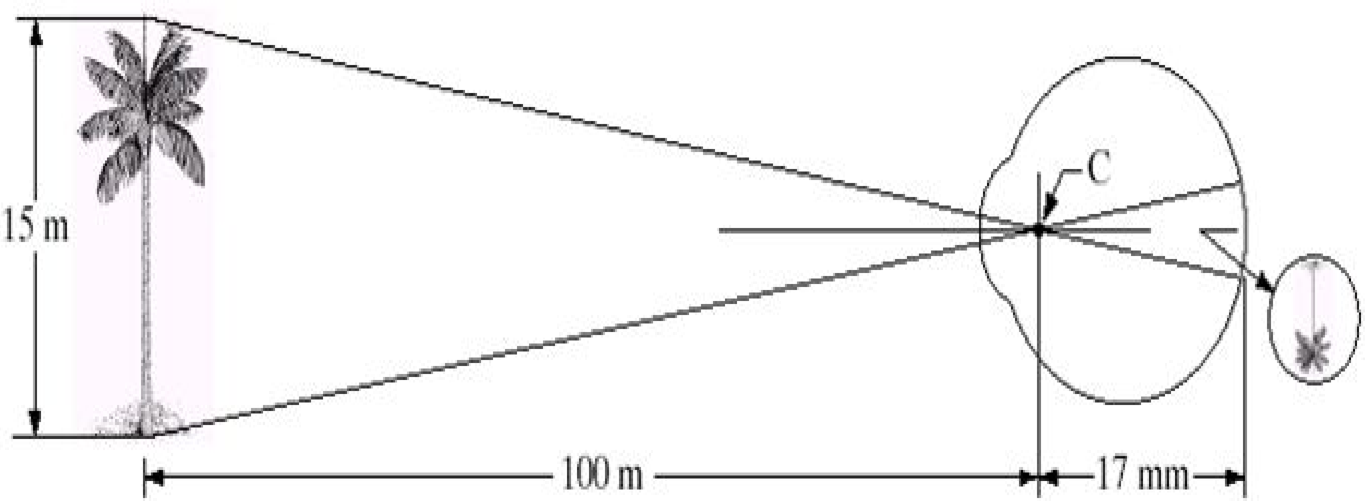
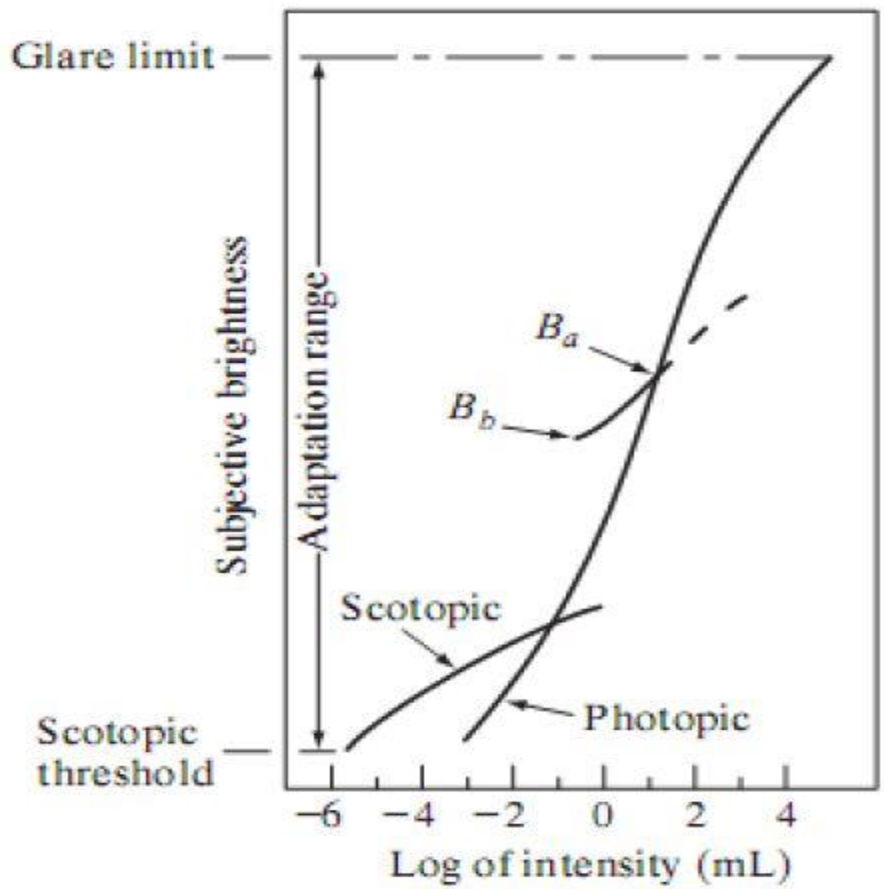


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Range of Subjective Brightness Sensations showing a Particular Adaptation Level



Brightness Adaptation and Contrast

Brightness : Amount of Light Stimulus
Contrast : Difference in the luminance of the objects

An example of *simultaneous contrast*

Image Sensing and Acquisition

- Image Acquisition using a Single Sensor
- Image Acquisition using Sensor Strips
- Image Acquisition using Sensor Arrays
- A Simple Image Formation Model

Image Sampling and Quantization

- Basic Concepts in Sampling and Quantization
- Representing Digital Images
- Spatial and Intensity Resolution
- Image Interpolation

Some Basic Relationships between Pixels

- Neighbours of a Pixel
  - N4, N8
- Adjacency, Connectivity, Regions, and Boundaries
  - 4-adjacency
  - 8-adjacency
  - M-adjacency
  - Digital path
  - Closed path
  - Connected
  - Border: inner border, outer border
  - Edge
- Distance Measures
  - Euclidean distance
  - City-block distance
  - Chessboard distance

Chapter 3

Intensity Transformations and Spatial Filtering

Introduction

Definition of intensity transformation

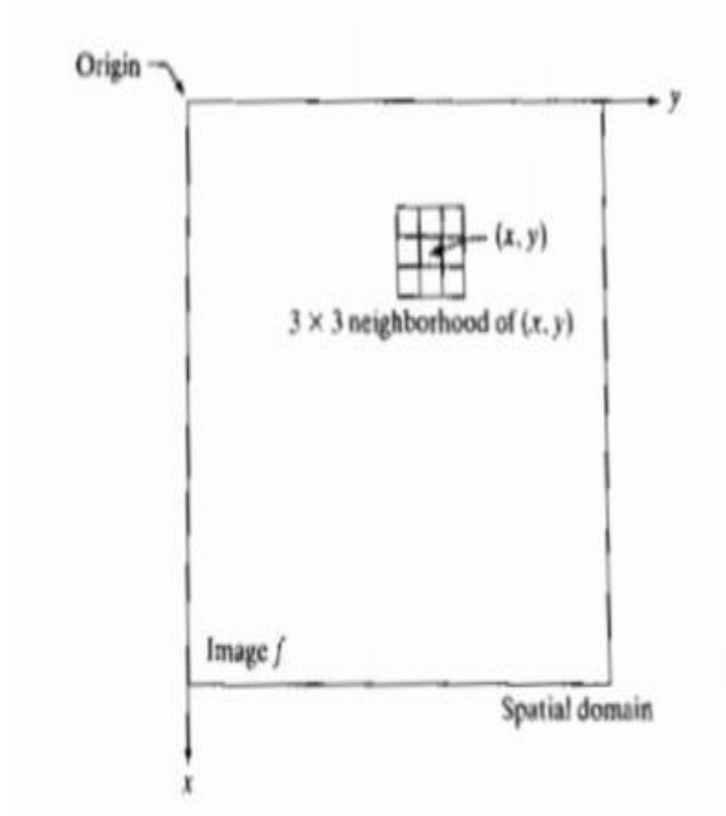
- Intensity transformation operate on single pixels of an image for the purpose of contrast manipulation and image thresholding spatial filtering deals with performing operation, such as image sharpening, by working in a neighborhood of every pixel in an image.
- Spatial filtering technique is used directly on pixels of an image.... This mask is moved on the image such that the center of the mask traverses all image pixels.

Intensity transformation and spatial filtering basics

- Operation take place in the spatial domain.
  - Operate directly on pixel values.
  - Often more computationally efficient and requires less resources.
- General form for operation is:
- **g(x, y) = T [f(x, y)]**
- **f(x, y)** –Input image.
- g**(x, y) –Output image.**
- **T– an operate on f defined over a neighborhood of point (x, y).**

Intensity transformation and spatial filtering basics (continued)

- The operator can apply to a single image or to a set of images.
- The point (x, y) shown is an arbitrary point in the image.
- The region containing the point is a neighborhood of (x, y).
- Typically the neighborhood is rectangular, centered on (x, y) and is much smaller Than the image.



- **Spatial filtering:**
  - **Generally involves operations over the image.**
  - **Operation take place involving pixels within a neighborhood of a point of interest (x y).**
  - **Also involves a Predefined Operation called a Spatial filtering.**
  - **The spatial filtering is also commonly referred to as:**
    - **Spatial mask.**
    - **Kernel.**
    - **Template**
    - **Window.**

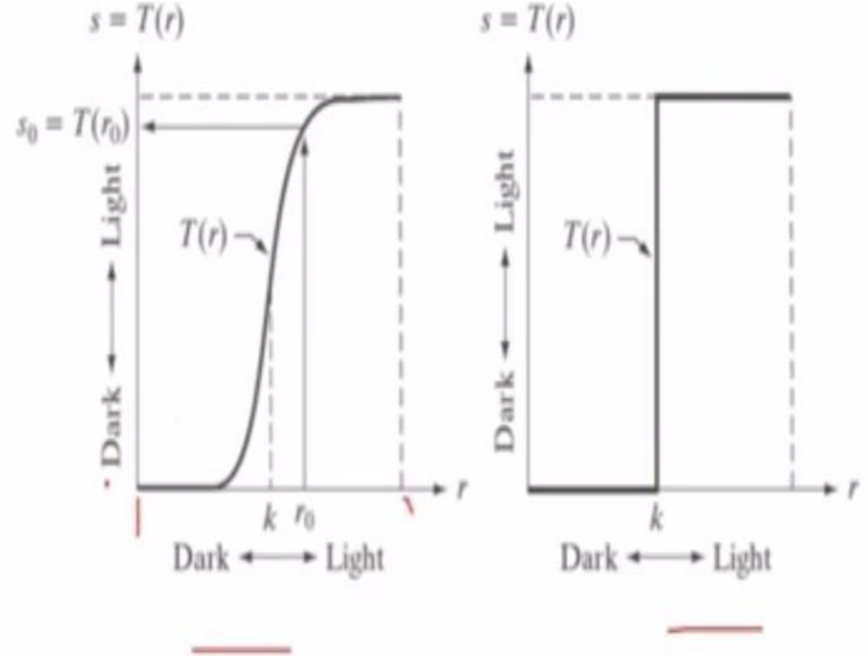
Point processing

- The smallest neighborhood of a pixel is 1*1 in size.
- Here, g depends only on the value of f at (x, y).
- T becomes an intensity transformation function of the form
  - $s=T(r)$
- S and r --represent the intensity of g and f at any point (x, y).
- Also called a **Gray-Level** or Mapping function.

Example of intensity transformation

1.Contrast stretching

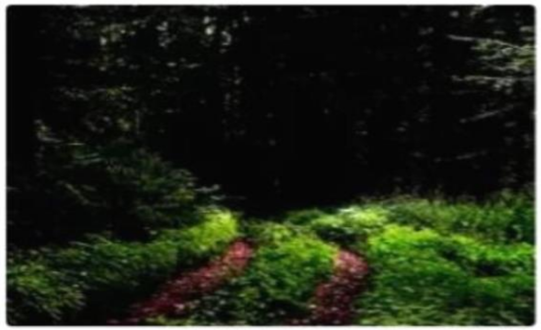
2.Thresholding function



a b

FIGURE 3.2 Intensity transformation functions. (a) Contrast-stretching function. (b) Thresholding function.

Example of contrast and thrsholding



Before Contrast Enhancement

After Contrast Enhancement

- For image thresholding or segmentation

Before Thresholding

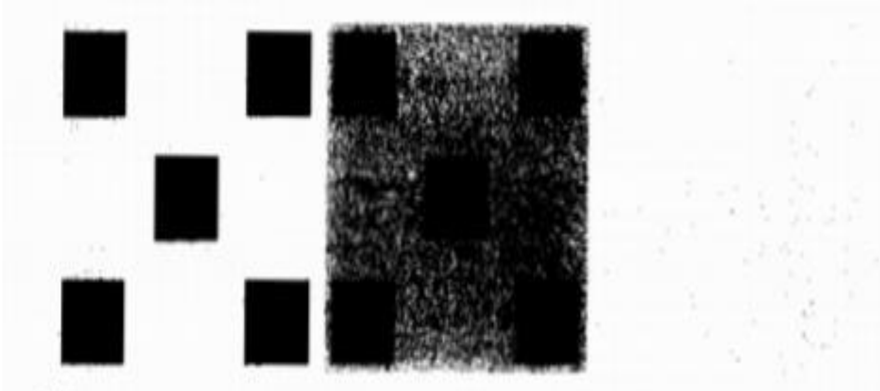
After Thresholding

Example of intensity transformation

Example of Spatial filtering

Using Histogram Statistics for Image Enhancement

- Statistics obtained directly from an image histogram can be used for image enhancement
- Let r – denote a discrete random variable
- Representing intensity values in the range [0,L-1]
- Let P(ri) denote the normalized histogram



a b c

FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3 × 3.

- Component corresponding to value ri as indicated previously we may view p(ri) as an estimate of the probability intensity ri occurse in the image from which the histogram was obtained
- the n’th moment of r about is mean is defined as

$$\mu_n(r) = \sum_{i=0}^{L-1} (r_i - m)^n p(r_i)$$

- Where m is the mean (average intensity) value of r (the average intensity of the pixels in the image)

$$m = \sum_{i=0}^{L-1} r_i \, p(r_i)$$

- The second moment is particularly important

$$\mu_2(r) = \sum_{i=0}^{L-1} (r_i = m)^2 \, p(r_i)$$

- We recognize this expression as the intensity variance normally denote By Ø recall that the standard deviation is the square root of the variance) is a measure of contrast is an image
- Observe that all moments are computed easily using the preceding expression once the histogram has been obtained from a given image

- When working with only the mean and variance it is common practice to estimate them directly from the sample values without computing the histogram appropriately these estimate are called the sample mean and simple variance they are given by the following familiar expression from basic statistics

-

$$M = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)$$

$$\sigma^2 = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[f(x,y) - m\right]^2$$

- For X = 0,1,2....m-1 and y = 0,1,2....N-1

In other words as we known the mean intensity of an image can be obtained simply by summing the image

- A similar interpretation applies Eq (3.3.21) as we illustrate in the following example the result obtained using the two equations are identical to the result obtained using Eq(3.3-18) and (3.3-19)provided that the histogram used in these equations is computed from the same image used in (3.3-20) and (3.3-21)

- Before proceeding it will be usefull to work through a simple numerical example to fix ideas consider the following 2-bit image of size 5×5

0	0	1	1	2
1	2	3	0	1
3	3	2	2	0
2	3	1	0	0
1	1	3	2	2

- The pixels are represented by 2 bits therefore $L=4$ and the intensity levels are in the range (0,3) the total numbers of pixels is 25 so the histogram has the components
- $P(r0)=6/25= 0.24$,$P(r1)= 7/25=0.28$

$P(r2) =7/25=0.28$,$P(r3)= 5/25=0.20$

Where the numerator in $P(ri)$ is the number of pixels in the image with intensity level ri we can compute the average value of the intensity in the image.

$$m = \sum_{i=0}^{3} r_i p(r_i)$$

$$= (0)(0.24) + (1)(0.28) + (2)(0.28) + 3(0.25$$

$$= 1.44$$

Letting $f(x, y)$ denote the presenting 5×5 array and using Eq (3.3.20) we obtain

$$m = \frac{1}{25} \sum_{x=0}^{4} \sum_{y=0}^{4} f(x, y)$$

$$= 1.44.$$

- As expected the result agree similarly the result for the variance is the same (1.1264) using either Eq(3.3-19) and (3.3-21)
- We consider the two uses of the mean and variance for the enhancement purposes
- The global mean and variance are computed over an entire image and are useful for gross adjustment in overall intensity and contrast
- A more powerful use of these parameters is in local enhancement where the local mean and variance are used as the basic for making changes that depend on image

- Characteristics in a neighborhood about each pixels in an image

- let (x,y) denote the coordinates of any pixels in a given image and let Sxy denote a neighborhood(sub image) of specified size centred on (x,y) the mean value of the pixels in this neighborhood is given by the expression

$$m_{S_{xy}} = \sum_{i=0}^{L-1} r_i \, p_{S_{xy}}(r_i)$$

- Where Psxy is the histogram of the pixels in region Sxy
- This histogram has L-componentess corresponding to the L Possible intensity values in the input image
- However many of the components are 0 depending on the size of Sxy
- For example if the neighbourhood is of size 3×3 and L=256 only between 1 and 9 of the components of the histogram of the neighbourhood will be non zero

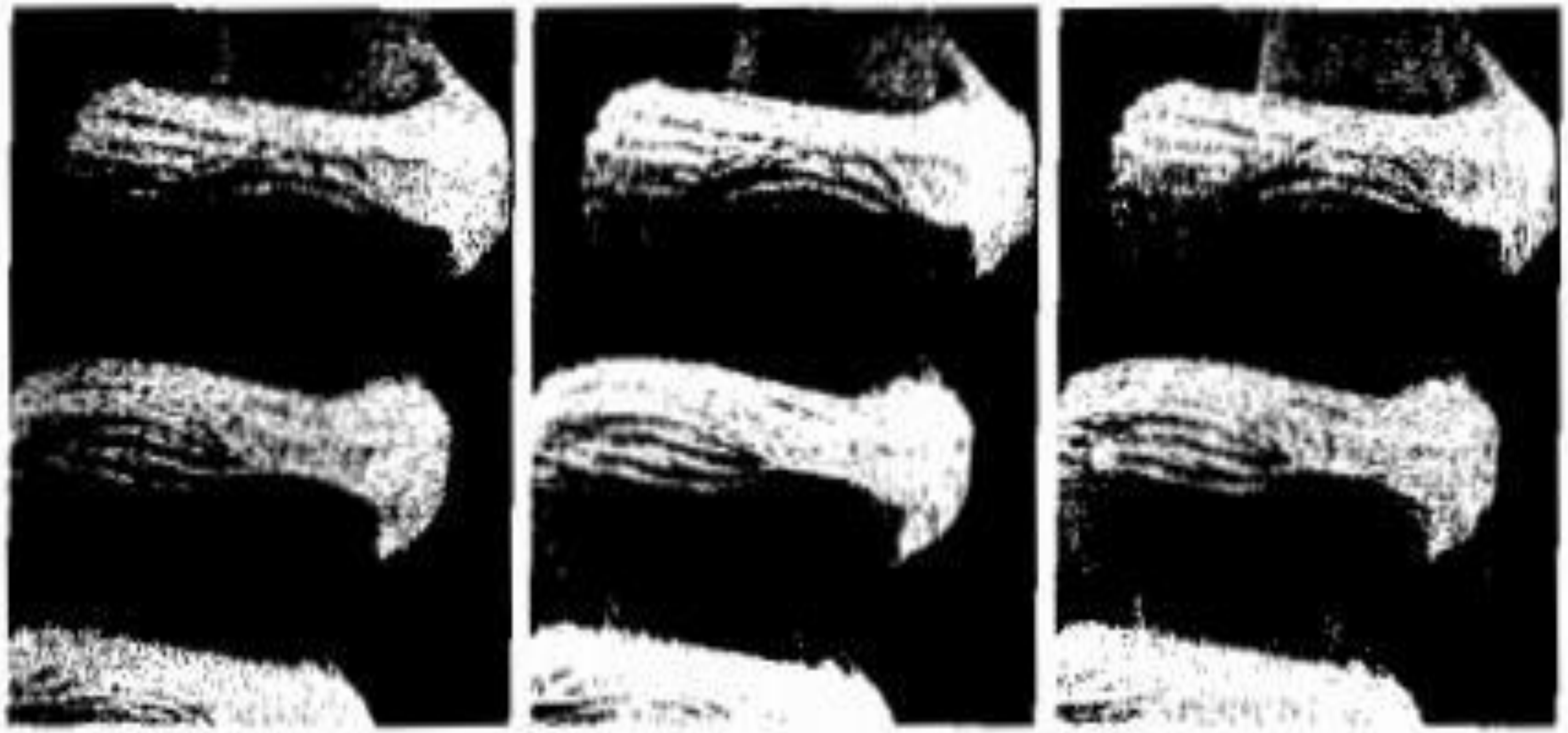
- These non zero values will correspond to the number of different intensities in Sxy
- The variance of the Pixels in the neighborhood similarly is given by

$$\sigma^2_{S_{xy}} = \sum_{i=0}^{L-1} (r_i - m_{S_{xy}})^2 \, p_{S_{xy}}(r_i)$$

- As before the local mean is a measure of average intensity in neighborhood Sxy and the local variance(or standard deviation) is a measure of intensity contrast in that neighborhood
- Expression analogous to (3.3-20) and (3.3-21) can be written for neighborhoods
- We simply use the pixcel value in the number of pixcels in the neighborhood in the denominator

- Show an SEM (scanning electron microscope) image of the tungsten filament wrapped around a support
- The filament in the center of the image and it’s support are quite clear and easy to study
- There is another filament structure on the right dark size of the image but is almost imperCrtiblr and it’s size And other characteristics certainly are not easy to discernable local enhancement by contrast manipulation is an ideal approach to problem such as this in which parts of an image may contain hidden features

FIGURE 3.24 SEM image of a tungsten filament and support, magnified approximately 130×. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene).



a b c

FIGURE 3.27 (a) SEM image of a tungsten filament magnified approximately 130×. (b) Result of global histogram equalization. (c) Image enhanced using local histogram statistics. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

- In this particular case of the problem is to enhance dark areas while leaving the light area as unchanged as possible because doesn’t require enhancement
- We can use the concepts presented in this section to formulate an enhancement method that can fell the difference between dark and light and at the same time is called of enhancing only the dark areas
- A measure of whether an area is relatively light or dark at point (x,y) Is to compare the avarege local intensity Msxy to the average image intensity called the global mean and denoted M’G

- This we hae the first element of our enhancement scheme we will consider the pixels at a point (x,y) as a candidate for processing if
- Msxy≤ Komg
- Ko is a possitive constant with values less the 1.0
- We consider at a pixel point (x,y) as a condidate enhancement if ØSxy≤k2ØG
- Where Ø is the global standard deviation
- K2 is a positive constant
- The value of this constant will be greater then 1.0 if we are interested in enhancing light ares anf less then 1.0 dark areas

- Finally we need to restrict the lowest value contrast we are willing to accept otherwise procedure would attempt to enhance constant areas whole standard derivation by requiring that K1ØG≤ØSxy
- $K1<K2$ a pixel at (x,y)that meets all the conditions for local enhancement is processed simply by the multiplying by a specific contant E to increse the value in intensity levek
- Pixcels that do not meet the enhancement cinditions are not changed

- Summarise the preceding apporoach as follows let f(x,y) represent the value of an image at any image coordinates (x,y) and g(x ,y) represent the corresponding enhanced value at those coordinates the

$$g(x,y) = \begin{cases} E \cdot f(x,y) & \text{if } m_{S_{xy}} \leq k_0 m_G \text{ AND } k_1 \sigma_G \leq \sigma_{S_{xy}} \\ f(x,y) & \text{otherwise} \end{cases}$$

- For X= 0,1,2......M-1 and y= 0,1,2...N-1
- E,k0,K1 and K2 are specified parameters
- MG is the global mean of the input image
- ØG is its standard deviation
- Parameters Msxy ang ØSxy are the local mean and standard deviation respectively
- As usual M and N are the row and column image dimentions

- The parameters is generally requires a bit of experimentation to gain familiarity with given image or class of image in this case the following values were selected E=4.0,K0=0.4,K1=0.02 and K2=0.4
- The reflectively low values of 0.4 for E was choosen that when it was multiplied by the levels in the areas being enhanced the result would Still tend forward the dark end of the sale and thus preserve the general Vishuval balance of the image

- A similar analysis led to the choice of value K1 and K2

Choosing these constants is not difficult ingeneral local area

- Sxy should be small as possible in under to preserve
- Region of size 3×3

Fundamentals of Spatial Filtering

Spatial Filters

- The spatial Filter is just moving the Filter mask From point to point in an image.
- The Filter mask is may be

    3*3 or 5*5 mask or to be 7*7 mask

  Examples:

    3*3 mask in a 5*5 of an image.

Basic of spatial Flitering

- The concept of filtering has its roots in the use of the Fourier
- transform for signal processing in the so-called frequency
- domain.
- Spatial filtering term is the filtering operations that are
- performed directly on the pixels of an image

Mechanism of Spatial Flitering

- The process consists simply of moving the filter mask from
- point to point in an image.
- At each point (x,y) the response of the filter at that point is
- calculated using a predefined relationship

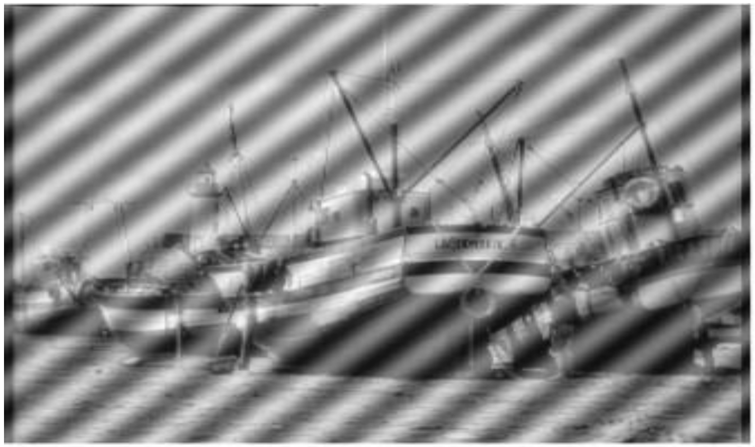
Linear Spatial Flitering

- The result is the sum products of the mask coefficients with corresponding pixels directly under the mask
- Pixels of image
- Mask coefficients

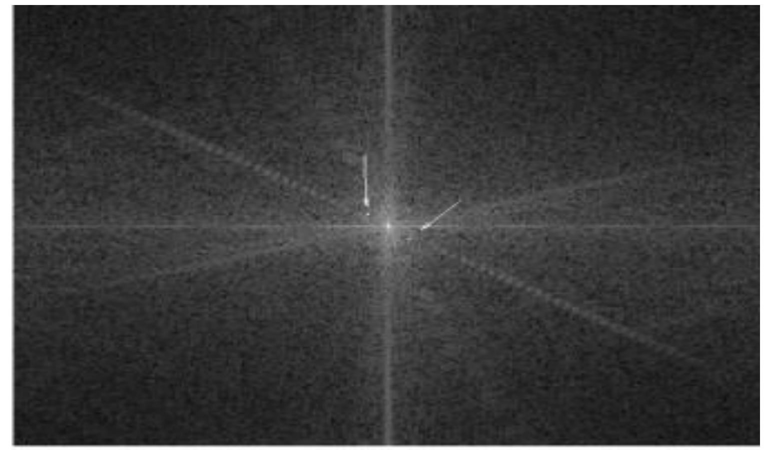
- The coefficient w(0,0) coincides with image value f(x,y),
- indicating that the mask is centered at (x,y) when the
- computation of sum of products takes place.
- For a mask of size mxn, we assume that m-2a+1 and
- n=2b+1, where a and b are nonnegative integer. Then m and m are odd

- In general, linear filtering of an image f of size MxN with a
- filter mask of size mxn is given by the expression:
- The process of linear filtering similar to a frequency domain concept called “convolution”

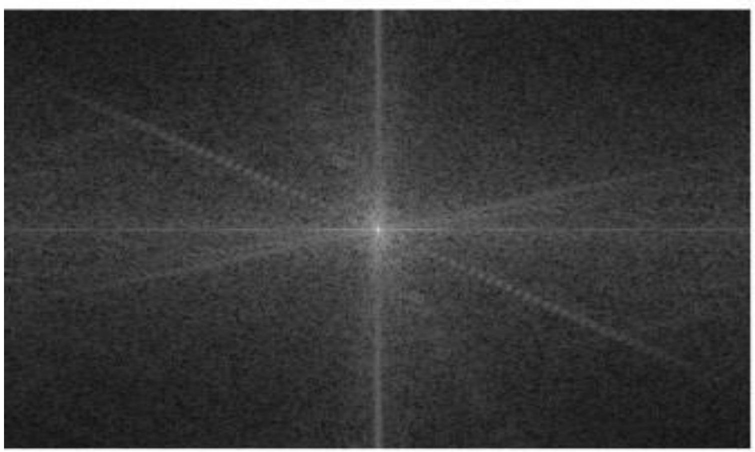
Examples



(A) Image Contaminated with Periodic Noise



(B) DFT of (A) with the Points Corresponding to the Noise Highlighted



(C) DFT (A) with the Periodic Noise Remove

(D) Recovered Image

Non linear Spatial Flitering

- Nonlinear spatial filters also operate on neighborhoods, and
- the mechanics of sliding a mask past an image are the same as
- was just outlined.
- The filtering operation is based conditionally on the values of
- the pixels in the neighborhood under consideration

Examples

(a)

(b)

(c) PSNR = 9.2898 dB

(d) PSNR = 12.4450 dB

Smoothing Spatial Fliters

- Smoothing filters are used for blurring and for noise
- reduction.
- Blurring is used in preprocessing steps, such as removal of
- Small details from an image prior to object extraction, and
- bridging of small gaps in lines or curves
- Noise reduction can be accomplished by blurring

Smoothing Spatial Filters

- One of the simplest spatial filtering operations we can perform is a smoothing operation
  - Simply average all of the pixels in a neighbourhood around a central value
  - Especially useful in removing noise from images
  - Also useful for highlighting gross detail

$^1/_9$	$^1/_9$	$^1/_9$
$^1/_9$	$^1/_9$	$^1/_9$
$^1/_9$	$^1/_9$	$^1/_9$

Simple averaging filter

Types of smoothing Flitering

- There are 2 way of smoothing spatial filters
- Smoothing Linear Filters
- Order-Statistics Filters

Smoothing linear Fliters

- Linear spatial filter is simply the average of the pixels
- contained in the neighborhood of the filter mask.
- Sometimes called “averaging filters”.
- The idea is replacing the value of every pixel in an image by
- The average of the gray levels in the neighborhood.

Examples

Two 3x3 Smoothing Linear Filters

$$\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Standard average

$$\frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Weighted average

- The general implementation for filtering an MxN image with
- A weighted averaging filter of size mxn is given by the Expression

Ordering linear Flitering

- Order-statistics filters are nonlinear spatial filters whose
- response is based on ordering (ranking) the pixels
- contained in the image area encompassed by the filter,
- and then replacing the value of the center pixel with the
- value determined by the ranking result.
- Best-known “median filter”

Sharpening spital Flitering

- The principal objective of sharpening is to highlight fine detail in an image or to enhance detail that has been blurred,
- Either in error or as an natural effect of a particular method

  Image acquisition.

Examples

Sharpening Filters - Example

- **Warning**: the results of sharpening might contain negative values (i.e., re-map them to [0, 255])

Input Image

Sharpened Image

(for better visualization, the original image is added to the sharpened image)

COMBINIING SPATIAL ENHANCEMENT METHODS

- We have to exception like combining blurring with thresholding.
- At the time we focused to attention in the individual approaches.
- While we require application of several complementary techniques in order to achieve an acceptable result.
- Next we have to discuss about how to combine several approaches developed in this chapter to address a difficult image enhancement task.

- Fig(a)When the image is nuclear whole body scan used to detect diseases like bone infection and tumours.
- Main objective of the image is sharpening and bringing out more of the skeletal detail.
- Dynamic range of the intensity levels and high noise content make to image difficult to enhance.
- The strategy we have to follow laplation to highlight fine detail and gradient to enhance prominent edge.

- A smoothed version of the gradient image will used to mask the laplacian image.
- Finally we attempt to increase the dynamic range of the intensity levels by using an intensity transformation.
- Fig (b)Laplacian of the original image obtain using the filter.
- Image was scaled using the same technique in fig(c).

- We can obtain have to apply sharpened image of the point by adding in fig (a) and fig(b).
- One way that comes to immediately to mind to reduce the noise to use a median filter.
- Median filtering is non-linear process capable of removing image features. But not acceptable in medical image processing.
- An alternate approach is used to mask formed from smoothed version of the gradient of the original image.

- Main motivation is straightforward and based its propertied of first and second order derivatives is explained.
- Laplacian is being in second order derivative operator have advantage is superior in enhancing fine detail. It have to produce noisier results than to gradient.
- The gradient has stronger average response in areas of significant intensity transition than does the laplacian.
- The response of the gradient to noise and fine details is lower than laplacian and can be lowered further by smoothing the gradient with an averaging filter.

- We will preserve details in the strong areas while reducing noise in the relatively flat areas.
- Process can be interpreted roughly as combining the best features of the laplacian and the gradient.
- The result is added to the original to obtain a final sharpened image.
- We obtained using the masks in edges are much more dominant in this image that in the laplacian image.

- The smoothed gradient image was obtained by using an averaging filter of the size 5X5.
- The two gradient images were scaled to display the same manner as the laplacian image.
- The smallest possible value of the gradient image is 0 the background is black in the scaled gradient image,rather than gray of the scaled in laplacian.
- Much bigger than again of the gradient image with significant edge content has value that are higher in general than in a laplacian image.

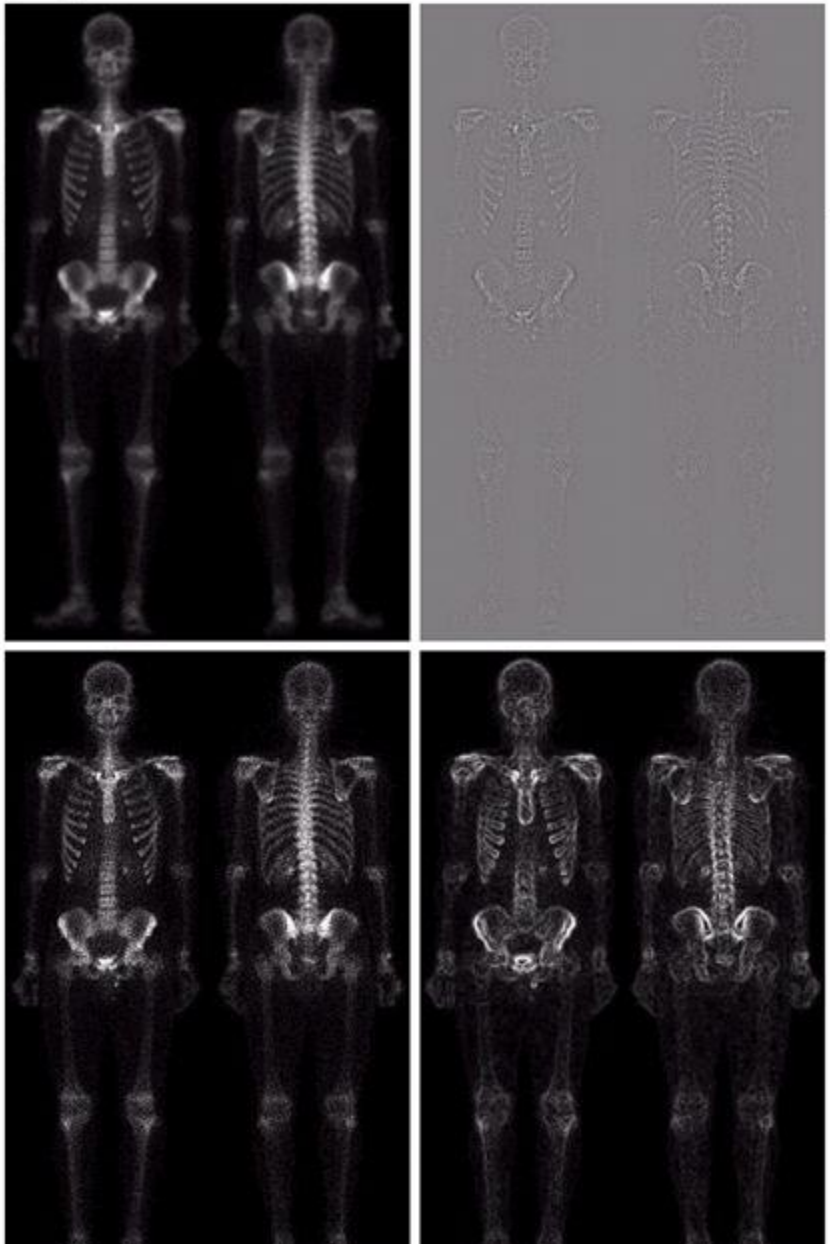
- The product of the laplacian and smoothed gradient image are shown.
- The dominance of the strong edges and the relative lack of visible noise and the key objective behind masking the laplacian with a smoothed gradient image.
- The product image have to adding in the orginal resulted in the sharpened image.
- To increase the sharpness of the detail in this image over the original is evident more part of the image.

- We have to include the ribs, spinal cord and skull.
- This is type of the improvement would not have been possible by using the laplacian or the gradient alone.
- The sharpening have to procedure just discussed does not affect in an appreciable way the dynamic range the intensity levels in an image.
- Final step in our enhancement task is to increase the dynamic range of the sharpening image.
- There are number of intensity transformation function that can accomplish the objective.

- The results that is histogram equalization is not likely to work well on image that have dark intensity distribution like our image.
- Histogram specification could be a solution.
- The dark characteristics of the image which we are dealing lend themselves much better to a power-law transformation.
- After few trials this equation we arrived at the result are obtained with y=0.5 and c=1.we see that significant new detail are visible.

- They are around the wrists, hands, ankles and feet are good examples.
- The skeletal bone structure also much more pronounced, including the arm and leg tissue.
- Note also the faint definition of the outline of the body and of body tissue.
- The nature by expanding the dynamic range of the intensity levels also enhanced noise, but represent in significant visual improvement over the original image.

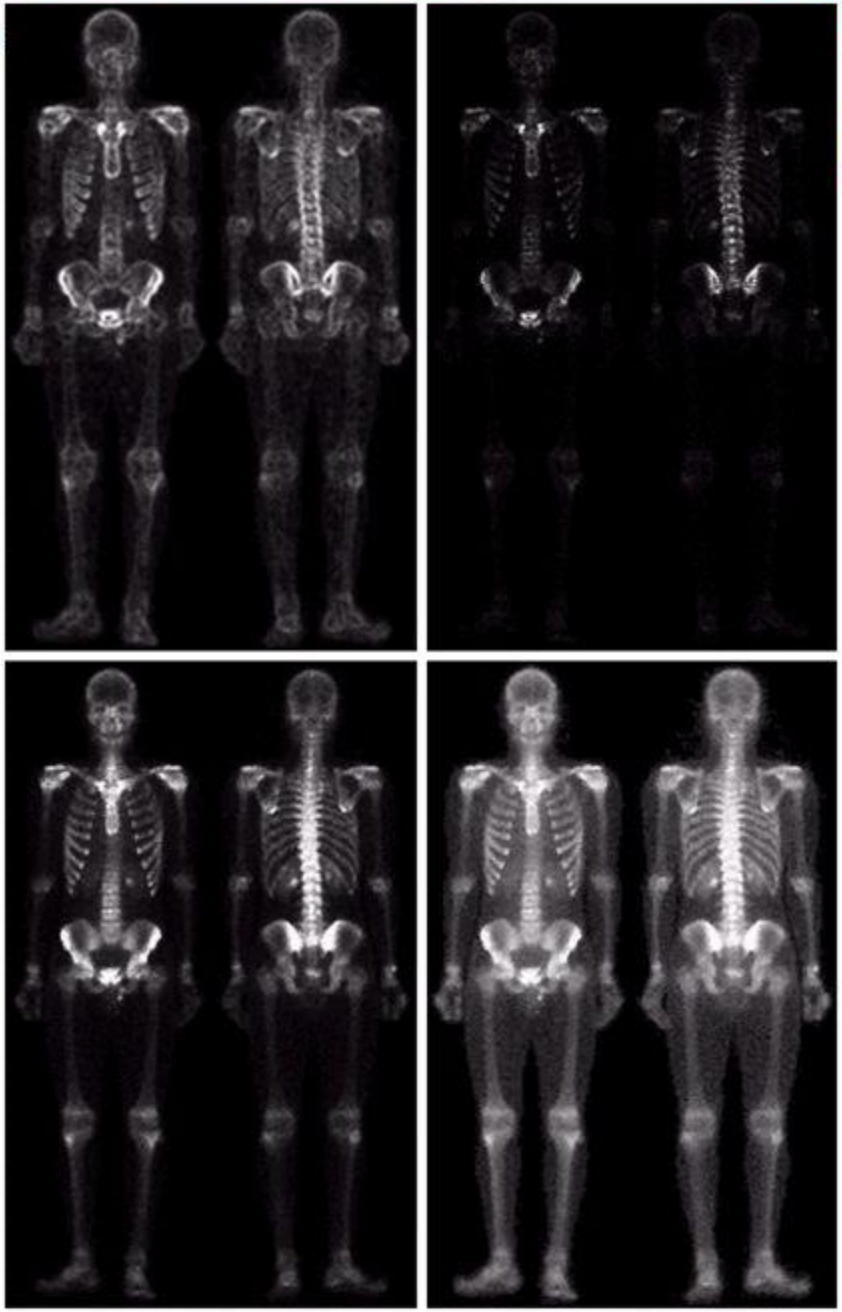
Combining Spatial Enhancement Methods



a	b
c	d

FIGURE 3.46 (a) Image of whole body bone scan. (b) Laplacian of (a). (c) Sharpened image obtained by adding (a) and (b). (d) Sobel of (a).

Combining Spatial Enhancement Methods



e	f
g	h

FIGURE 3.46 *(Continued)* (e) Sobel image smoothed with a 5 × 5 averaging filter. (f) Mask image formed by the product of (c) and (e). (g) Sharpened image obtained by the sum of (a) and (f). (h) Final result obtained by applying a power-law transformation to (g). Compare (g) and (h) with (a). (Original image courtesy of G.E. Medical Systems.)

Using Fuzzy Sets For Intensity Transformation

3.8.4 Using Fuzzy Sets for Intensity Transformations

Consider the general problem of contrast enhancement, one of the principal applications of intensity transformations. We can state the process of enhancing the contrast of a gray-scale image using the following rules:

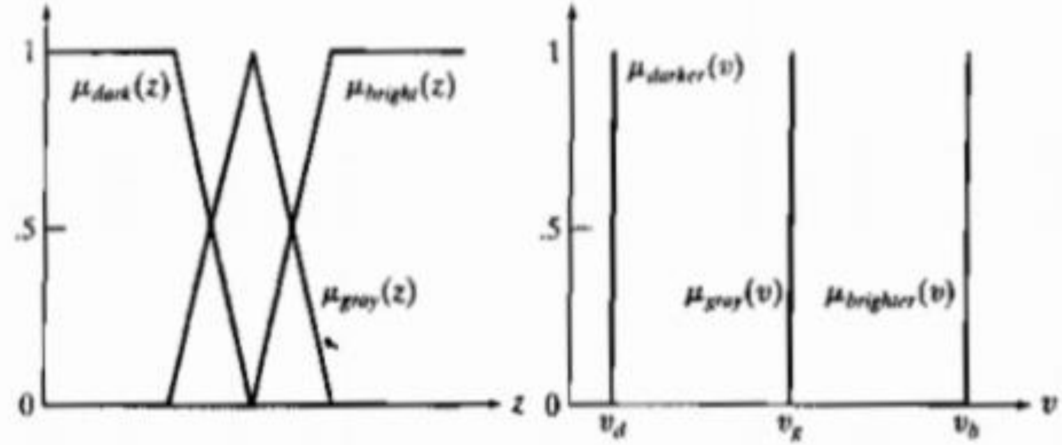
IF a pixel is dark, THEN make it *darker*.

IF a pixel is gray, THEN make it gray.

IF a pixel is bright, THEN make it brighter.

Keeping in mind that these are fuzzy terms, we can express the concepts of *dark*, *gray*, and *bright* by the membership functions in Fig. 3.53(a).

In terms of the output, we can consider *darker* as being degrees of a dark intensity value (100% black being the limiting shade of dark), *brighter*, as being degrees of a bright shade (100% white being the limiting value), and *gray* as being degrees of an intensity in the middle of the gray scale. What we mean by



a b

FIGURE 3.
(a) Input
(b) outpu
membersh
functions
fuzzy, rule
contrast
enhancem

"degrees" here is the amount of one specific intensity. For example, 80% black is a very dark gray. When interpreted as *constant* intensities whose strength is modified, the output membership functions are *singletons* (membership functions that are *constant*), as Fig. 3.53(b) shows. The various degrees of an intensity in the range [0, 1] occur when the singletons are clipped by the strength of the response from their corresponding rules, as in the fourth column of Fig. 3.52 (but keep in mind that we are working here with only one input, not two, as in the figure). Because we are dealing with constants in the output membership functions, it follows from Eq. (3.8-18) that the output, v_0, to any input, z_0, is given by

$$v_0 = \frac{\mu_{dark}(z_0) \times v_d + \mu_{gray}(z_0) \times v_g + \mu_{bright}(z_0) \times v_b}{\mu_{dark}(z_0) + \mu_{gray}(z_0) + \mu_{bright}(z_0)} \qquad (3.8\text{-}22)$$

a b c

FIGURE 3.54 (a) Low-contrast image. (b) Result of histogram equalization. (c) Result of using fuzzy, rule-based contrast enhancement.

Comparing Figs. 3.54(b) and 3.54(c), we see in the latter a considerable improvement in tonality. Note, for example, the level of detail in the forehead and hair, as compared to the same regions in Fig. 3.54(b). The reason for the improvement can be explained easily by studying the histogram of Fig. 3.54(c), shown in Fig. 3.55(d). Unlike the histogram of the equalized image, this histogram has kept the same basic characteristics of the histogram of the original image. However, it is quite evident that the dark levels (talk peaks in the low end of the histogram) were moved left, thus darkening the levels. The opposite was true for bright levels. The mid grays were spread slightly, but much less than in histogram equalization.

The price of this improvement in performance is considerably more processing complexity. A practical approach to follow when processing speed and image throughput are important considerations is to use fuzzy techniques to determine what the histograms of well-balanced images should look like. Then, faster techniques, such as histogram specification, can be used to achieve similar results by mapping the histograms of the input images to one or more of the "ideal" histograms determined using a fuzzy approach. ∎

3.8.5 Using Fuzzy Sets for Spatial Filtering

When applying fuzzy sets to spatial filtering, the basic approach is to defin neighborhood properties that "capture" the essence of what the filters are sup posed to detect. For example, consider the problem of detecting boundarie between regions in an image. This is important in numerous applications o image processing, such as sharpening, as discussed earlier in this section, and i image segmentation, as discussed in Chapter 10.

We can develop a boundary extraction algorithm based on a simple fuzz concept: *If a pixel belongs to a uniform region, then make it white; else make i black*, where, *black* and *white* are fuzzy sets. To express the concept of a "uni form region" in fuzzy terms, we can consider the intensity differences betweer the pixel at the center of a neighborhood and its neighbors. For the $3 \times$ neighborhood in Fig. 3.56(a), the differences between the center pixel (labelec z_5) and each of the neighbors forms the subimage of size 3×3 in Fig. 3.56(b) where d_i denotes the intensity difference between the ith neighbor and the center point (i.e., $d_i = z_i - z_5$, where the zs are intensity values). A simple se of four IF-THEN rules and one ELSE rule implements the essence of the fuzzy concept mentioned at the beginning of this paragraph:

Fuzzy concepts

IF d_2 is *zero* AND d_6 is *zero* THEN z_5 is *white*

IF d_6 is *zero* AND d_8 is *zero* THEN z_5 is *white*

IF d_8 is *zero* AND d_4 is *zero* THEN z_5 is *white*

IF d_4 is *zero* AND d_2 is *zero* THEN z_5 is *white*

ELSE z_5 is *black*

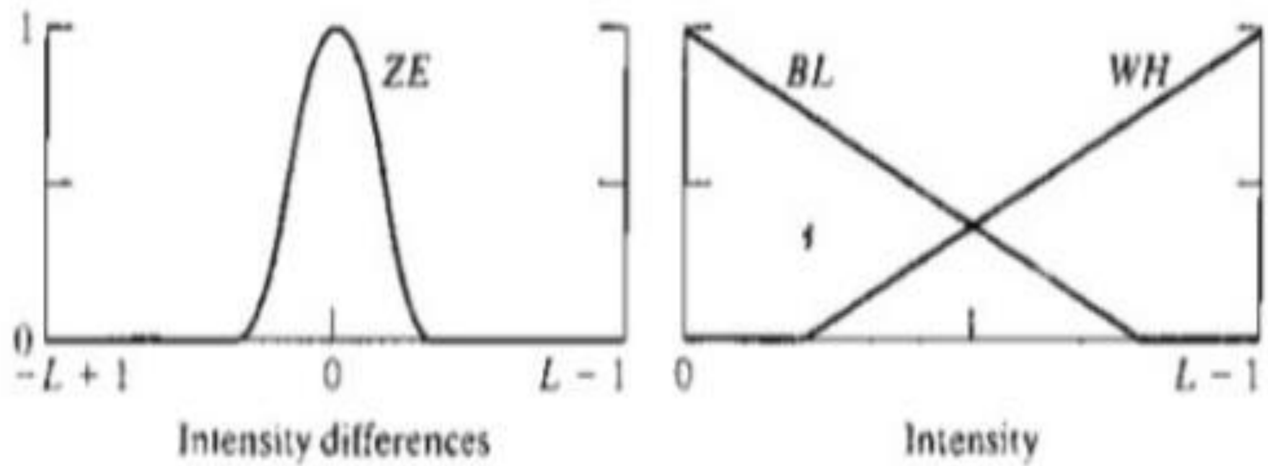
a b

FIGURE 3.56 (a) A 3×3 pixel neighborhood, and (b) corresponding intensity differences between the center pixels and its neighbors. Only d_2, d_4, d_6, and d_8 were used in the present application to simplify the discussion.

where *zero* is a fuzzy set also. The consequent of each rule defines the values to which the intensity of the center pixel (z_5) is mapped. That is, the statement "THEN z_5 is white" means that the intensity of the pixel located at the center of the mask is mapped to white. These rules simply state that the center pixel is considered to be part of a uniform region if the intensity differences just mentioned are zero (in a fuzzy sense); otherwise it is considered a boundary pixel.

Figure 3.57 shows possible membership functions for the fuzzy sets *zero*, *black*, and *white*, respectively, where we used ZE, BL, and WH to simplify notation. Note that the range of the independent variable of the fuzzy set ZE for an image with L possible intensity levels is $[-L + 1, L - 1]$ because intensity differences can range between $-(L - 1)$ and $(L - 1)$. On the other hand, the range of the output intensities is $[0, L - 1]$, as in the original image. Figure 3.58 shows graphically the rules stated above, where the box labeled z_5 indicates that the intensity of the center pixel is mapped to the output value WH or BL.

■ Figure 3.59(a) shows a 512×512 CT scan of a human head, and Fig. 3.59(b) is the result of using the fuzzy spatial filtering approach just discussed. Note the effectiveness of the method in extracting the boundaries between regions, including the contour of the brain (inner gray region). The constant regions in the image appear as gray because when the intensity differences discussed earlier are near zero, the THEN rules have a strong response. These responses in turn clip function WH. The output (the center of gravity of the clipped triangular regions) is a constant between $(L-1)/2$ and $(L-1)$, thus producing the grayish tone seen in the image. The contrast of this image can be improved significantly by expanding the



2.6.6 Using Fuzzy Sets for Spatial Filtering

- Example 3.20

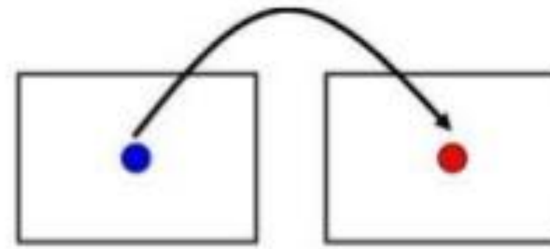
a b c

FIGURE 3.59 (a) CT scan of a human head. (b) Result of fuzzy spatial filtering using the membership functions in Fig. 3.57 and the rules in Fig. 3.58. (c) Result after intensity scaling. The thin black picture borders in (b) and (c) were added for clarity; they are not part of the data. (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

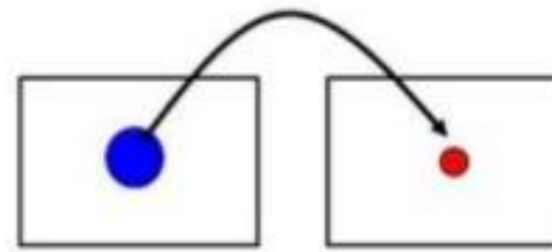
The contrast of this image can be improved significantly by expanding the gray scale.
Fig.3.59(c) was obtained by performing the intensity scaling defined in Eqs. (2.6-10) and (2.6-11), with $k = L - 1$. the net result is the intensity values in Fig.3.59(c) span the full gray scale from 0 to $(L - 1)$

Spatial Operations

- Point/Pixel operations
  - Output value at specific coordinates (x,y) is dependent only on the input value at (x,y)



- Local/neighborhood operations
  - The output value at (x,y) is dependent on the input values in the neighborhood of (x,y)



- Geometric spatial transformations
  - Affine transformation
  - Image Registration

Local/neighborhood operation

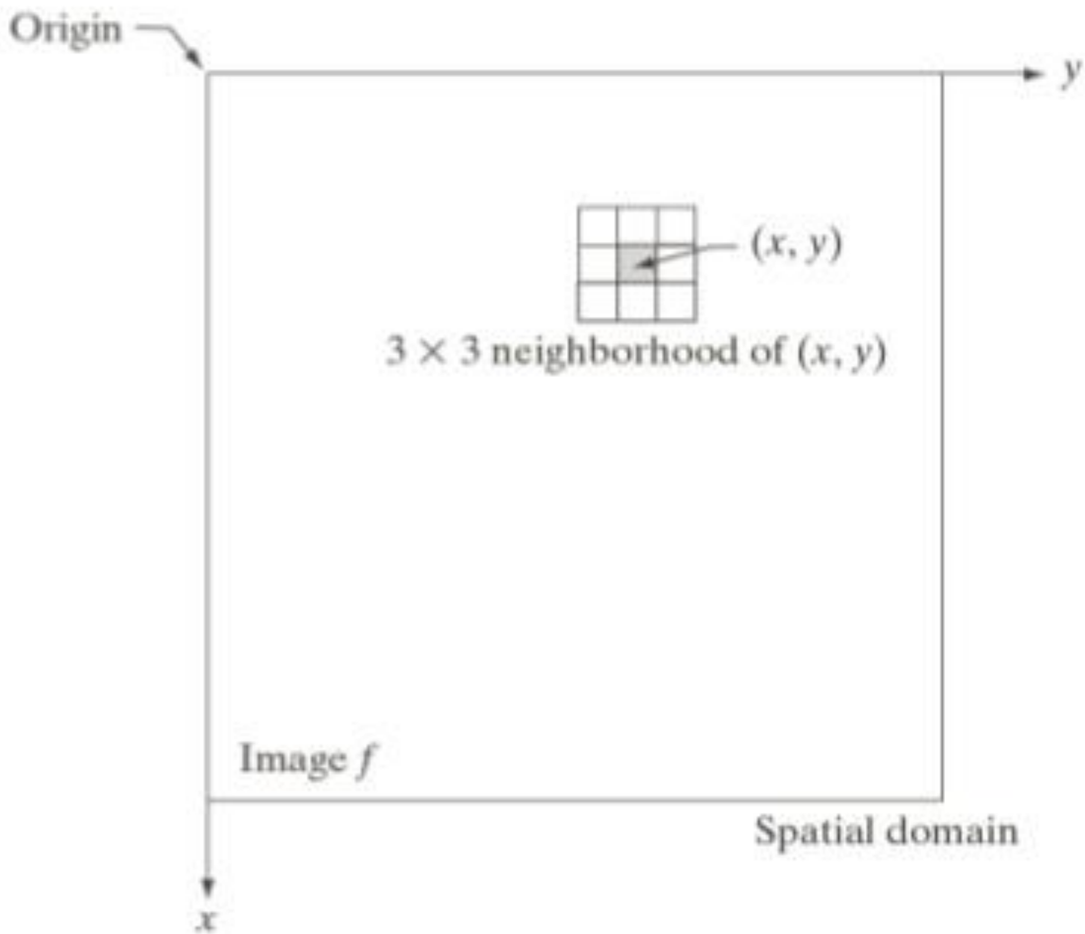
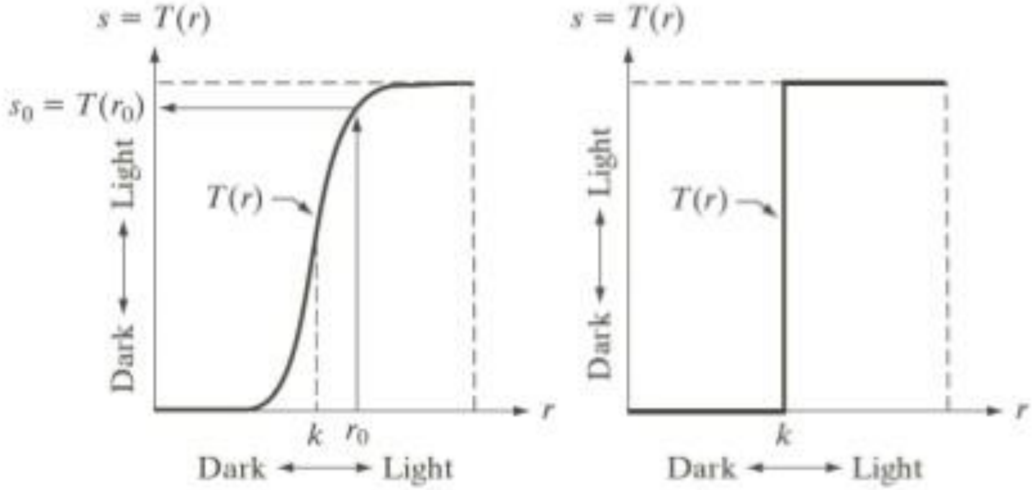


FIGURE 3.1 A 3×3 neighborhood about a point (x, y) in an image in the spatial domain. The neighborhood is moved from pixel to pixel in the image to generate an output image.

Point/Pixel operations

Intensity transformation function

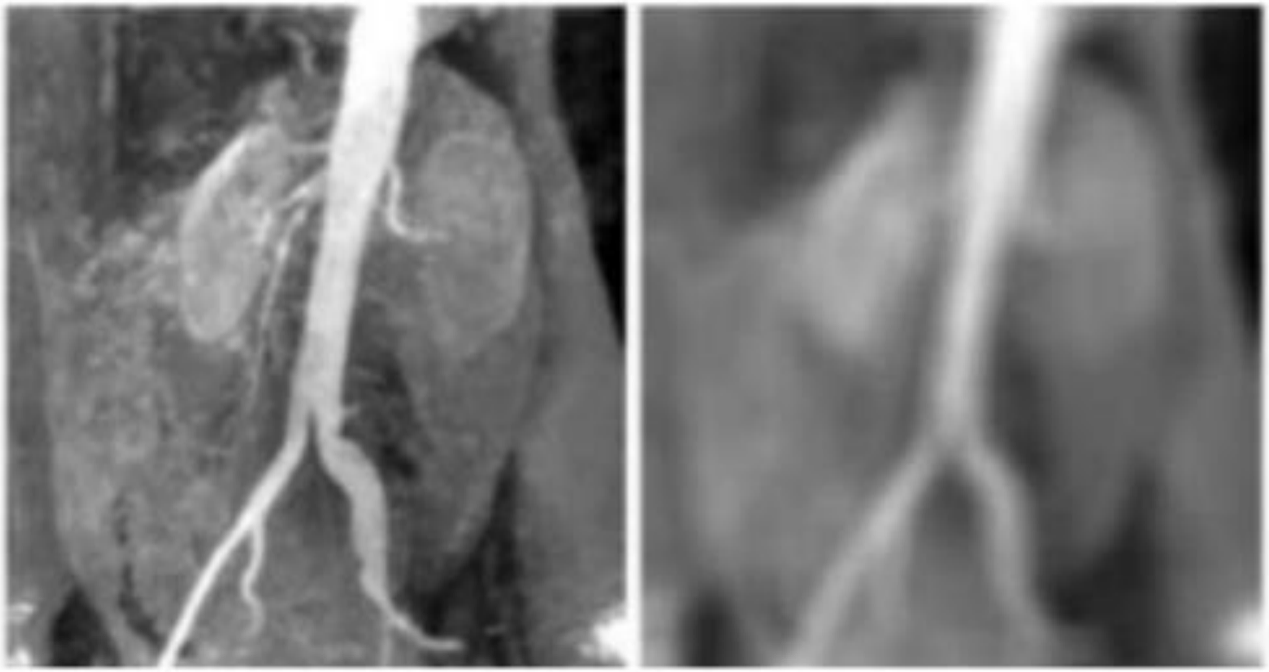
$$s = T(r)$$



a b

FIGURE 3.2 Intensity transformation functions. (a) Contrast-stretching function. (b) Thresholding function.

Local/neighborhood operation



Geometric/Spatial transformation

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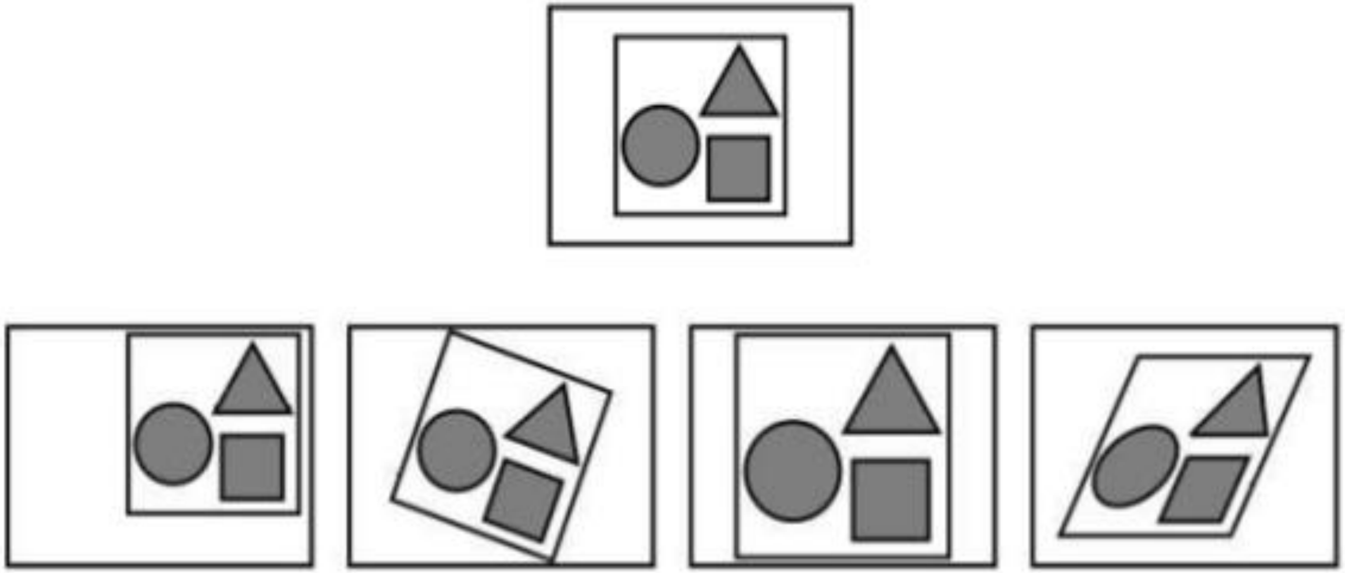

Image Registration

- One of the most important applications of geometric transformations is image registration
- Goal: Image registration seeks to align images taken in different times, or taken from different
- How: estimate a transformation that aligns the two or more images.
- Image registration has applications especially in
  - Medicine
  - Remote sensing
  - Entertainment

Image Registration

- Background—Example, Panorama Stitching

image 1

image 2

Two images, sharing some objects

Image Registration

Transform image 1 into the same coordinate system of image 2