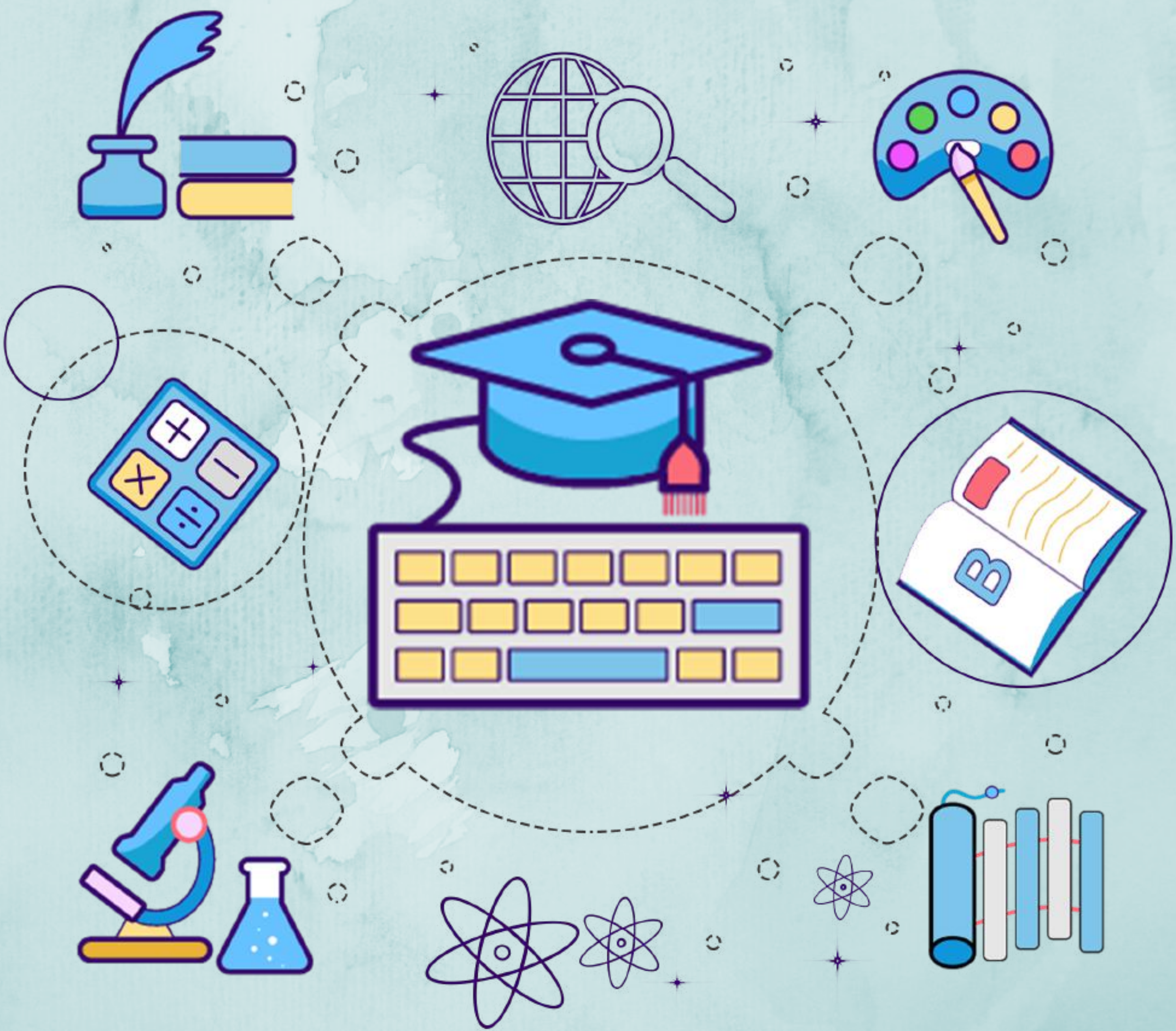
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

KeralaNotes



SYLLABUS | STUDY MATERIALS | TEXTBOOK

PDF | SOLVED QUESTION PAPERS

www.keralanotes.com

KeralaNotes

KTU STUDY MATERIALS

COMPUTER GRAPHICS AND IMAGE PROCESSING

CST 304

Module 4

Related Link :

- KTU S6 CSE NOTES 2019 SCHEME
- KTU S6 SYLLABUS CSE COMPUTER SCIENCE
- KTU PREVIOUS QUESTION BANK S6 CSE SOLVED
- KTU CSE TEXTBOOKS S6 B.TECH PDF DOWNLOAD
- KTU S6 CSE NOTES | SYLLABUS | QBANK | TEXTBOOKS DOWNLOAD

www.keralanotes.com

Module 4

Introduction to Image processing and applications. Image as 2D data. Image representation in Gray scale, Binary and Colour images. Fundamental steps in image processing. Components of image processing system. Coordinate conventions. Sampling and quantization. Spatial and Gray Level Resolution. Basic relationship between pixels– neighbourhood, adjacency, connectivity. Fundamentals of spatial domain-convolution operation

Introduction to Image processing

- Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it.
- It is a type of signal processing in which input is an image and output may be image or characteristics/ features associated with that image.
- Nowadays, image processing is among rapidly growing core research area within computer science disciplines.
- Image processing basically includes the following three steps:
    - Importing the image via image acquisition tools;
    - Analysing and manipulating the image;
    - Output in which result can be altered image or report that is based on image analysis.

keralanotes.com

Purpose of image processing

- Visualization: Observe the objects that are not visible
- Image sharpening and restoration: To create a better image
- Image retrieval: Seek for the image of interest
- Measurement of pattern: Measures various objects in a image
- Image recognition: Distinguish the objects in a image.

There are two types of methods used for image processing namely, analogue and digital image processing.

- In Analogue image processing the images are manipulated by electrical means by varying the electrical signal. The common example include is the television image.
- Digital image processing techniques help in manipulation of the digital images by using computers

Analog image processing

- Analog image processing is done on analog signals. It includes processing on two dimensional analog signals. In this type of processing, the images are manipulated by electrical means by varying the electrical signal. The common example include is the television image.

Digital image processing

- The digital image processing deals with developing a digital system that performs operations on an digital image.

- Digital image processing has dominated over analog image processing with the passage of time due its wider range of applications.

Advantages of Digital image processing

1. It improves visual quality of an image and distribution of intensity
2. It can process an image in such a way that the result is more suitable than original image
3. Image can be easily modified with different techniques
4. Image compression technique reduces the amount of data required to represent digital image.
5. Mathematical and logical operations can be easily performed on the image

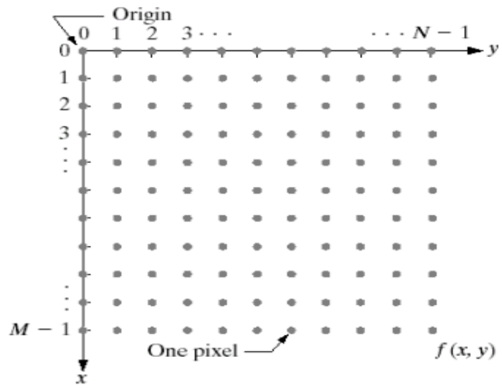
Disadvantages of Digital image processing

1. It requires so much processing power
2. Effect of environmental conditions may degrade the image quality
3. It involves various types of redundancy like data and pixel redundancy

For More Study Materials : www.keralanotes.com

What is a Digital Image?

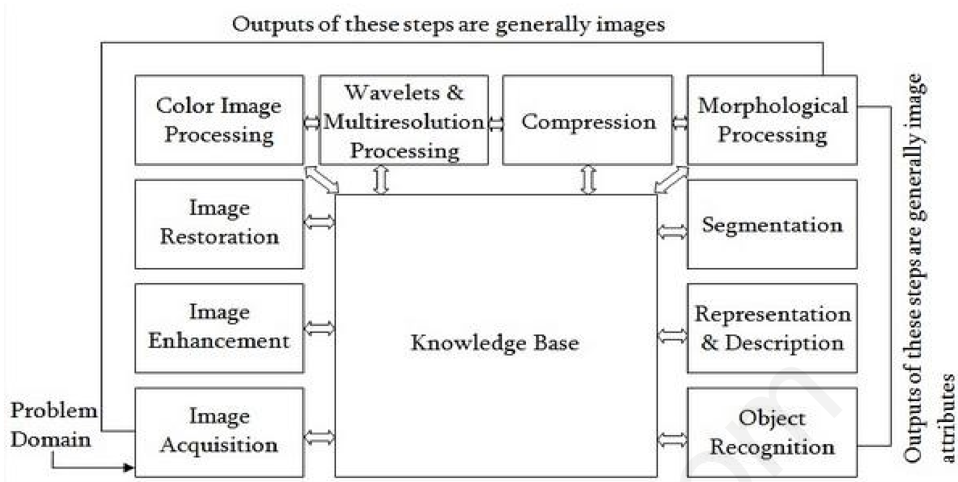
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels.
- It is defined by the mathematical function f(x,y) where x and y are the two co-ordinates horizontally and vertically.
- The value of f(x,y) at any point is gives the pixel value at that point of an image.
- The digital image contains a fixed number of rows and columns of pixels.
- Pixels are the smallest individual element in an image
- **Conventional Coordinate for Image Representation**



- Image is nothing but a two dimensional array of numbers ranging between 0 and 255.
- Each number represents the value of the function f(x,y) at any point.
- In this case the value 128 , 230 ,123 each represents an individual pixel value.

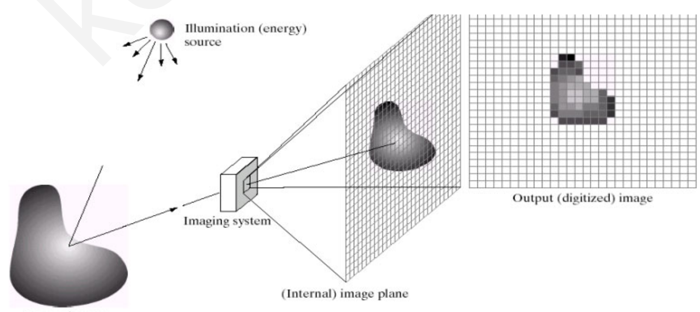
128	230	123
232	123	321
123	77	89
80	255	255

Fundamental Steps in image Processing



Step 1: Image Acquisition

- The image is captured by a sensor (eg. Camera), and digitized
- if the output of the camera or sensor is not already in digital form, use analogue-to-digital convertor



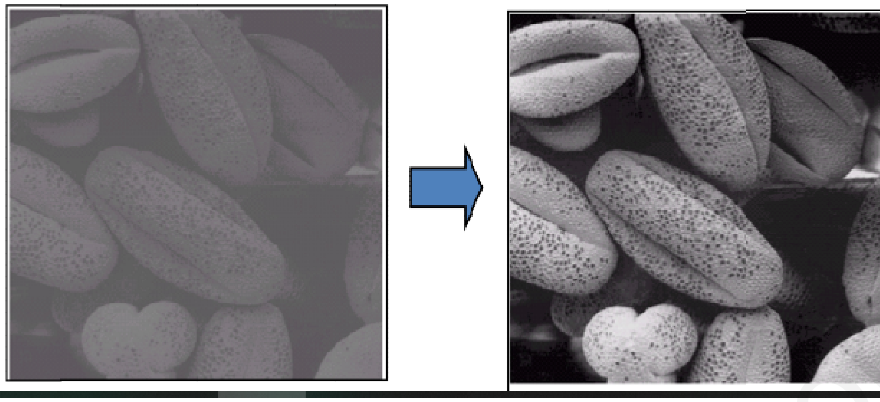
Sources of illumination

- Electromagnetic (EM) energy spectrum
  - Gamma-ray imaging: nuclear medicine and astronomical observations
  - X-rays: medical diagnostics, industry, and astronomy, etc.
  - Ultraviolet: industrial inspection, microscopy, lasers, biological imaging,and astronomical observations.
  - Visible and infrared bands: astronomy, remote sensing, industry,and law enforcement
- Acoustic waves
- Ultrasonic waves

For More Study Materials : www.keralanotes.com

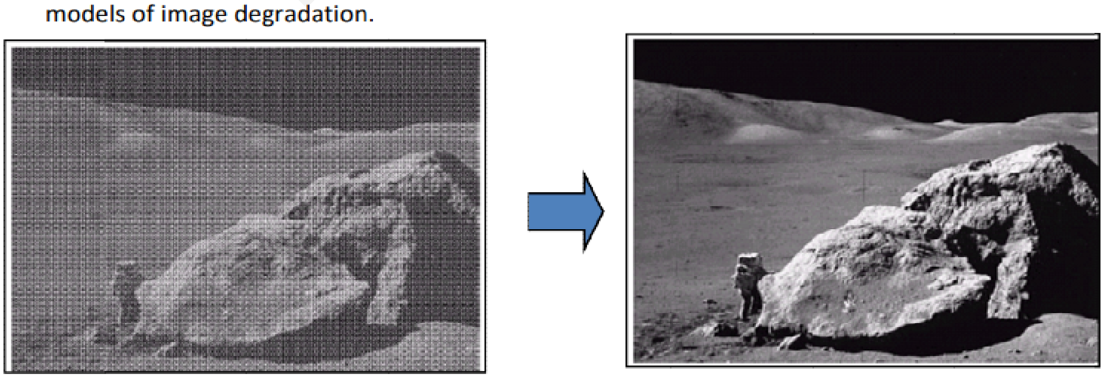
Step 2: Image Enhancement

- process of manipulating an image so that the result is more suitable than the original for specific applications.
- The idea behind enhancement techniques is to bring out details that are hidden, or simple to highlight certain features of interest in an image, Such as, changing brightness & contrast etc.



Step 3: Image Restoration

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



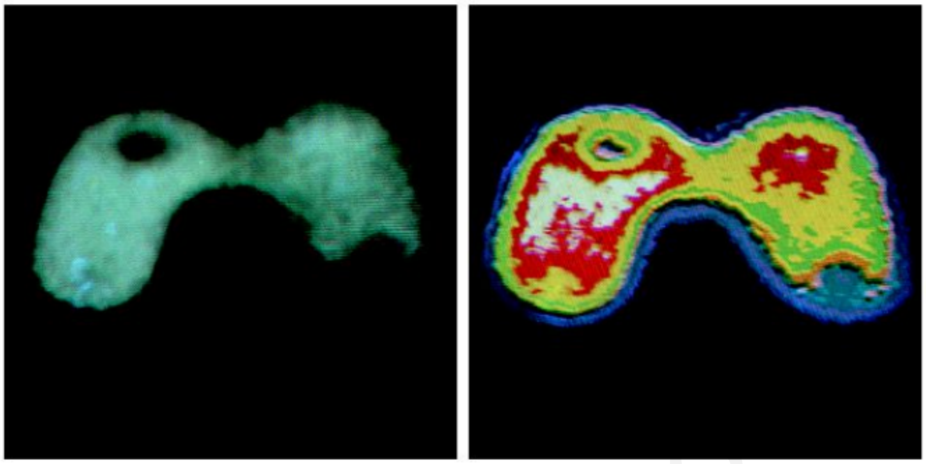
Step 4: Colour Image Processing

keralanotes.com

KeralaNotes

Step 4: Colour Image Processing

- Use the colour of the image to extract features of interest in an image.
- Colour modeling and processing in a digital domain.



Step 5: Wavelets

keralanotes.com

Step 5: Wavelets

- 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.
- It is used for image data compression where images are subdivided into smaller regions.

For More Study Materials : www.keralanotes.com

- Step 6 Compression
- Compression, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.
- Image compression is familiar (perhaps inadvertently) to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG (Joint Photographic Experts Group) image compression standard.

Step 7 Morphological Processing

- Tools for extracting image components that are useful in the representation and description of shape.
- In this step, there would be a transition from processes that output images, to processes that output image attributes

keralanotes.com

- Step 8 Segmentation
- It 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.
- On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. In general, the more accurate the segmentation, the more likely recognition is to succeed.

Step 9: Representation and Description

- **Representation:** Make a decision whether the data should be represented as a boundary or as a complete region. It always follows the output of a segmentation stage.
  - **Boundary Representation:** Focus on external shape characteristics, such as corners and inflections.
  - **Regional Representation:** Focus on internal properties, such as texture or skeletal shape.
- Transforming raw data into a form suitable for subsequent computer processing.
- Description: also called as feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

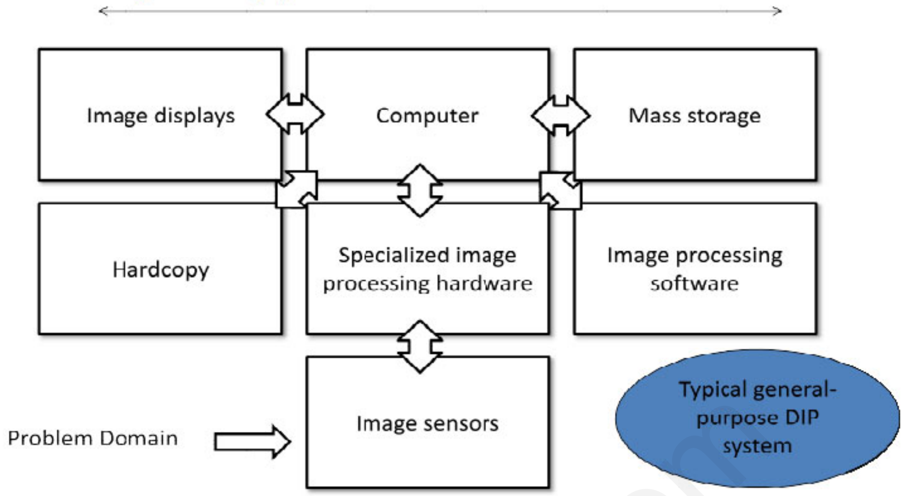
Step 10: Object Recognition

- **Recognition:** the process that assigns label to an object based on the information provided by its description (descriptors).
- Recognition is the process that assigns a label, such as, "vehicle" to an object based on its descriptors.

Knowledge Base:

- Knowledge may be as simple as detailing regions of an image where the information of interest is known to be located, thus limiting the search that has to be conducted in seeking that information.
- The Knowledge base also controls the interaction between modules.
- The knowledge about a problem is coded into an image processing system in the form of a Knowledge base.

Components of an Image Processing System



Specialized image processing hardware

- Specialized image processing hardware usually consists of the digitizer and a hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), that performs arithmetic and logical operations in parallel on entire images.
- One example of how an ALU is used is in averaging images as quickly as they are digitized, for the purpose of noise reduction.
- This type of hardware sometimes is called a front-end subsystem, and its most distinguishing characteristic is speed.
- In other words, this unit performs functions that require fast data throughputs (e.g., digitizing and averaging video images at 30 frames/s) that the typical main computer cannot handles

Computer

- The computer in an image processing system is a general-purpose computer and can range from a PC to a supercomputer.
- In dedicated applications, sometimes custom computers are used to achieve a required level of performance,
- . In these systems, almost any well-equipped PC-type machine is suitable for off-line image processing tasks.

keralanotes.com

software

- Software for image processing consists of specialized modules that perform specific tasks.
- A well-designed package also includes the capability for the user to write code that, as a minimum, utilizes the specialized modules.
- More sophisticated software packages allow the integration of those modules and general-purpose software commands from at least one computer language.

Mass Storage

- Mass storage capability is a must in image processing applications. An image of size pixels, in which the intensity of each pixel is an 8-bit quantity, requires one megabyte of storage space if the image is not compressed.

- When dealing with thousands, or even millions, of images, providing adequate storage in an image processing system can be a challenge.

Image displays

- Image displays in use today are mainly color (preferably flat screen) TV monitors.
- Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system.

keralanotes.com

Hard copy

- Hardcopy devices for recording images include laser printers, film cameras, heat-sensitive devices, inkjet units, and digital units, such as optical and CDROM disks.
- Film provides the highest possible resolution, but paper is the obvious medium of choice for written material.
- For presentations, images are displayed on film transparencies or in a digital medium if image projection equipment is used. T
- he latter approach is gaining acceptance as the standard for image presentations.

keralanotes.com

Networking

- Networking is almost a default function in any computer system in use today. Because of the large amount of data inherent in image processing applications, the key consideration in image transmission is bandwidth.
- In dedicated networks, this typically is not a problem, but communications with remote sites via the Internet are not always as efficient.
- Fortunately, this situation is improving quickly as a result of optical fiber and other broadband technologies

Image sampling and quantization process.

- Image Sampling and Quantization:

- The output of most sensors is a continuous voltage waveform whose amplitude and spatial behavior are related to the physical phenomenon being sensed.

- To create a digital image, we need to convert the continuous sensed data into digital form. This involves two processes: sampling and quantization

- The basic idea behind sampling and quantization is illustrated in Fig.6.1. Figure 6.1(a) shows a continuous image, f(x, y), that we want to convert to digital form.

- An image may be continuous with respect to the x- and y-coordinates, and also in amplitude.

- To convert it to digital form, we have to sample the function in both coordinates and in amplitude.

- Digitizing the **coordinate values** is called sampling. Digitizing the **amplitude values** is called quantization

keralanotes.com

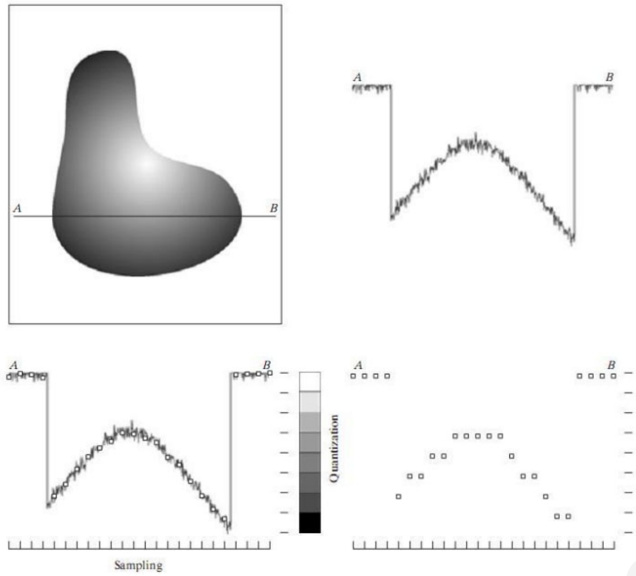


Fig.6.1. Generating a digital image (a) Continuous image (b) A scan line from A to Bin the continuous image, used to illustrate the concepts of sampling and quantization (c) Sampling and quantization. (d) Digital scan line

- The one-dimensional function shown in Fig.6.1 (b) is a plot of amplitude (gray level) values of the continuous image along the line segment AB
- In Fig. 6.1(a).The random variations are due to image noise. To sample this function, we take equally spaced samples along line AB, as shown
- in Fig.6.1 (c).The location of each sample is given by a vertical tick mark in the bottom part of the figure.
- The samples are shown as small white squares superimposed on the function. The set of these discrete locations gives the sampled function. However, the values of the samples still span (vertically) a continuous range of gray-level values.
- In order to form a digital function, the graylevel values also must be converted (quantized) into discrete quantities
- . The right side of Fig. 6.1 (c) shows the gray-level scale divided into eight discrete levels, ranging from black to white.
- The vertical tick marks indicate the specific value assigned to each of the eight gray levels. The continuous gray levels are quantized simply by assigning one of the eight discrete gray levels to each sample. The assignment is made depending on the vertical proximity of a sample to a vertical tick mark.
- The digital samples resulting from both sampling and quantization are shown in Fig.6.1 (d). Starting at the top of the image and carrying out this procedure line by line produces a two dimensional digital image

For More Study Materials : www.keralanotes.com

Spatial and Gray-Level Resolution:

- Spatial resolution:
- Spatial resolution states that the clarity of an image cannot be determined by the pixel resolution. The number of pixels in an image does not matter.
- Spatial resolution can be defined as the smallest discernible detail in an image.
- Or in other way we can define spatial resolution as the number of independent pixels values per inch.
- In short the spatial resolution refers to is that we cannot compare two different types of images(different size) to see that which one is clear or which one is not.

Gray level resolution

- Gray level resolution refers to the predictable or deterministic change in the shades or levels of gray in an image.
- In short gray level resolution is equal to the number of bits per pixel.

Mathematically

The mathematical relation that can be established between gray level resolution and bits per pixel can be given as.

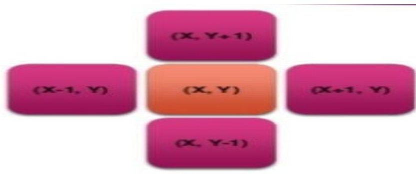
$$L = 2^k$$

In this equation L refers to number of gray levels. It can also be defined as the shades of gray. And k refers to bpp or bits per pixel. So the 2 raise to the power of bits per pixel is equal to the gray level resolution.

For More Study Materials : www.keralanotes.com

RELATIONSHIP BETWEEN PIXELS:

- We consider several important relationships between pixels in a digital image.
- **NEIGHBORS OF A PIXEL**
  - A pixel *p* at coordinates (*x*,*y*) has four *horizontal* and *vertical* neighbors whose coordinates are given by:
    - (x+1,y), (x-1, y), (x, y+1), (x,y-1)

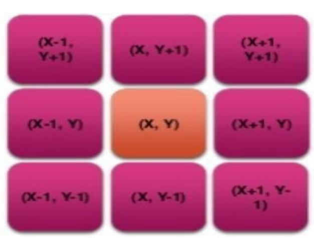


This set of pixels, called the 4-*neighbors* of p, is denoted by $N_4(p)$. Each pixel is a unit distance from (x, y), and some of the neighbor locations of p lie outside the digital image if (x, y) is on the border of the image.

The four *diagonal* neighbors of p have coordinates

$$(x + 1, y + 1), (x + 1, y - 1), (x - 1, y + 1), (x - 1, y - 1)$$

and are denoted by $N_D(p)$. These points, together with the 4-neighbors, are called the 8-*neighbors* of p, denoted by $N_8(p)$. As before, some of the neighbor locations in $N_D(p)$ and $N_8(p)$ fall outside the image if (x, y) is on the border of the image.



Adjacency, Connectivity, Regions and boundaries

- Let V be the set of intensity values used to define adjacency.
- In binary image v={1} if we are referring to adjacency of pixels with value 1.
- In a gray-scale image, the idea is the same, but V typically contains more elements, for example, V = {180, 181, 182, …, 200}
- If the possible intensity values 0 – 255, V set can be any subset of these 256 values.

Relationship between Pixels

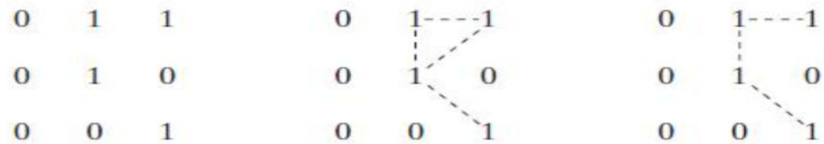
Types of Adjacency

- 4-adjacency:
  - Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.
- 8-adjacency:
  - Two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$.
- m-adjacency:
  - Two pixels p and q with values from V are m-adjacent if :
    - q is in $N_4(p)$.
    - q is in $N_D(p)$ *and* the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V.

For More Study Materials : www.keralanotes.com

Relationship between Pixels

Types of Adjacency



(a) Arrangement of pixels; (b) pixels that are 8-adjacent (shown dashed) to the center pixel; (c) *m*-adjacency.

- Mixed adjacency is a modification of 8-adjacency. It is introduced to eliminate the ambiguities that often arise when 8-adjacency is used.
- In the above example, we can note that to connect between two pixels (finding a path between two pixels):
  - In 8-adjacency way, you can find multiple paths between two pixels
  - While, in m-adjacency, you can find only one path between two pixels

Relationship between Pixels

A DIGITAL PATH

- A digital path (or curve) from pixel p with coordinate (x,y) to pixel q with coordinate (s,t) is a sequence of distinct pixels with coordinates (x0,y0), (x1,y1), …, (xn,yn)
  - where (x0,y0) =(x,y) and (xn,yn) = (s,t) and
  - pixels (xi,yi) and (xi-1,yi-1) are adjacent for 1 ≤ i ≤ n is the length of the path
  - If (x0,y0)=(xn,yn) , the path is closed.

keralanotes.com

Connectivity

- Let S represent a subset of pixels in an image. Two pixels p and q are said to be connected in S if there exists a path between them consisting entirely of pixels in S.
- For any pixel p in S, the set of pixels that are connected to it in S is called a connected component of S. If it only has one connected component, then set S is called a connected set.

Relationship between Pixels

REGION AND BOUNDARY

- If R happens to be an entire image, then its boundary is defined as the set of pixels in the first and last rows and columns in the image.
- This extra definition is required because an image has no neighbors beyond its borders
- Normally, when we refer to a region, we are referring to subset of an image, and any pixels in the boundary of the region that happen to coincide with the border of the image are included implicitly as part of the region boundary.

keralanotes.com

Relationship between Pixels

REGION AND BOUNDARY

- Region

- Let R be a subset of pixels in an image, we call R a region of the image if R is a connected set.

- Suppose that an image contains K disjoint regions, $R_k, k = 1, 2, \ldots, K$, none of which touches the image border.† Let R_u denote the union of all the K regions, and let $(R_u)^c$ denote its complement (recall that the *complement* of a set S is the set of points that are not in S). We call all the points in R_u the *foreground*, and all the points in $(R_u)^c$ the *background* of the image.

Boundary

- The boundary (also called the border or contour) of a region R is the set of points that are adjacent to points in the complement of R.

keralanotes.com

Relationship between Pixels

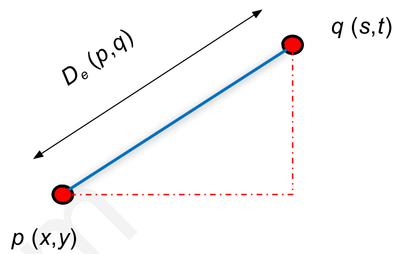
DISTANCE MEASURES

- For pixels p, q and z, with coordinates (x,y), (s,t) and (v,w), respectively, D is a distance function if:

  (a) D (p,q) ≥ 0 (D(p,q) = 0 ifv p = q),

  (b) D(p,q) = D(q, p), and

  (c) D(p,z) ≤ D(p,q) + D(q,z).



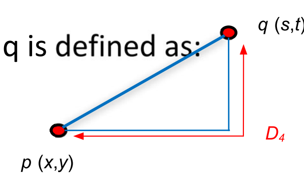
- The Eucli $D_e(p,q) = [(x-s)^2 + (y-t)^2]^{1/2}$ fined as:

Relationship between Pixels

DISTANCE MEASURES

- The D4 distance (also called city-block distance) between p and q is defined as:

  (p,q) = | x – s | + | y – t |



- Pixels having a D4 distance from (x,y), less than or equal to some value r form a Diamond centered at (x,y)

- Example:

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

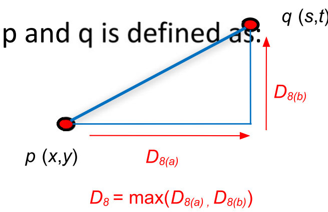
keralanotes.com

Relationship between Pixels

DISTANCE MEASURES

- The D8 distance (also called chessboard distance) between p and q is defined as:

  (p,q) = max(| x – s |,| y – t |)



- Example:
  - D8 distance ≤ 2 from (x,y) form the following contours of constant distance.

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2

keralanotes.com

Relationship between Pixels

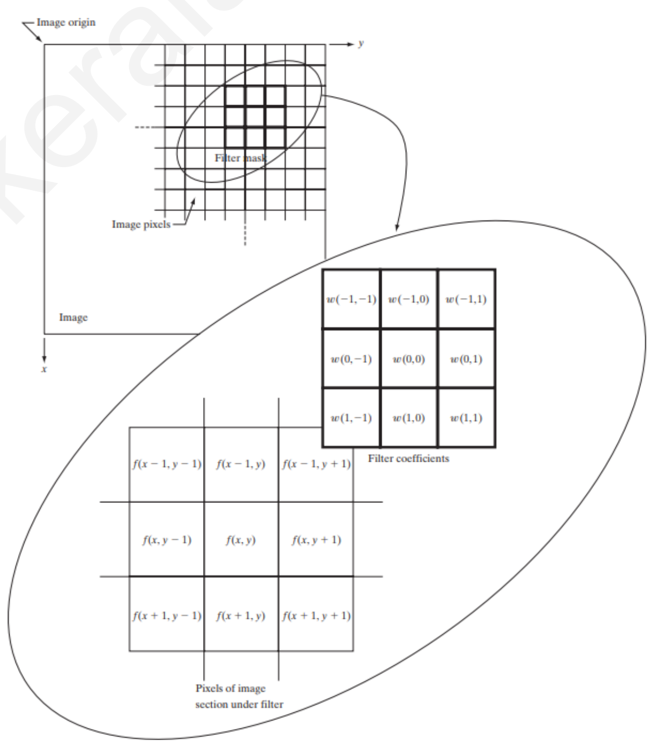
DISTANCE MEASURES

- Dm distance is defined as the shortest m-path between the points.
- In this case, the distance between two pixels will depend on the values of the pixels along the path, as well as the values of their neighbors.

SPATIAL CONVOLUTION AND CORRELATION

Spatial filtering

- Filtering is technique for modifying or enhancing an image
- Filtering helps to identify certain features or remove other features
- Image processing operation implemented with filtering include smoothening, sharpening and edge enhancement
- It may be applied either in
- Spatial Domain
- Frequency Domain



For More Study Materials : www.keralanotes.com

Basics of Spatial Filtering

- Spatial Filtering term is the filtering operations that are performed directly on pixel images
- Spatial filters used different masks (kernels, templates, and windows).
- The Process consists simply of moving the filter mask from point to point in an image
- This mask is moved on the image such that the center of the mask traverses all image pixels
- At each xy the response of the filter at the point is calculated using a predefined relationship

- Spatial Filter can be used for linear and non linear filtering
- Spatial filter consists of
- (1) a neighborhood, (typically a small rectangle), and
- (2) a predefined operation that is performed on the image pixels encompassed by the neighborhood.
- If the operation performed on the image pixels is linear, then the filter is called a linear spatial filter. Otherwise, the filter is nonlinear.

keralanotes.com

Linear Spatial Filtering

- For linear spatial filtering, the response is given by a sum of products of the filter coefficients and the corresponding image pixels in the area spanned by the filter mask. For the 3 X 3 mask shown in the previous figure, the result (response), of linear filtering with the filter mask at a point (x,y) in the image is:

$g(x,y) = w(-1,-1)\, f(x-1, y-1) + w(-1,0)\, f(x-1, y) + \dots + w(0,0)\, f(0,0) + \dots + w(1,0)\, f(x+1, y) + w(1,1)\, f(x+1, y+1)$

which we see is the sum of products of the mask coefficients with the corresponding pixels directly under the mask.

keralanotes.com

SPATIAL CONVOLUTION AND CORRELATION

Correlation & Convolution

- Correlation & Convolution are two closely related concepts used in linear spatial filtering .
- Both are used to extract information from images.
- Both are basically linear and shift invariant operations.
- Term linear indicates that a pixel is replaced by the linear combination of its neighbours.
- Term shift variant means that same operations are performed at every point in the image.

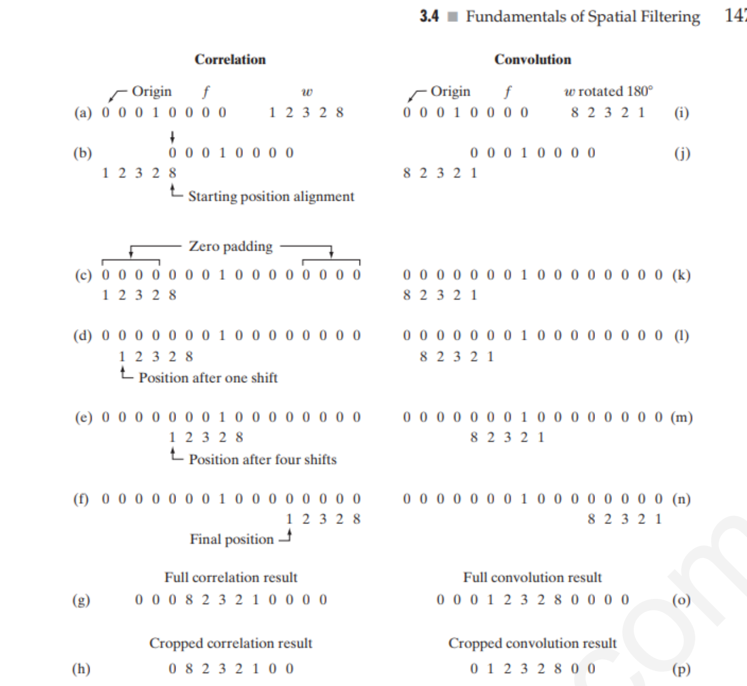

3.4 ■ Fundamentals of Spatial Filtering 147

FIGURE 3.29 Illustration of 1-D correlation and convolution of a filter with a discrete unit impulse. Note tha correlation and convolution are functions of *displacement*.

- Figure 3.29(a) shows a 1-D function, f, and a filter, , and Fig. 3.29(b) shows the starting position to perform correlation. The first thing we note is that thereare parts of the functions that do not overlap.
- The solution to this problem is to pad f with enough 0s on either side to allow each pixel in to visit every pixel in f.
- If the filter is of size m, we need 0s on either side of f. Figure 3.29(c) shows a properly padded function.
- .

keralanotes.com

- The first value of correlation is the sum of products of f and for the initial position shown in Fig. 3.29(c) (the sum of products is 0).
- This corresponds to a displacement
- To obtain the second value of correlation, we shift one pixel location to the right (a displacement of) and compute the sum of products. The result again is 0.
- In fact, the first nonzero result is when , in which case the 8 in overlaps the 1 in f and the result of correlation is 8.
- Proceeding in this manner, we obtain the full correlation result in Fig. 3.29(g).
- Note that it took 12 values of x (i.e.,) to fully slide past f so that each pixel in visited every pixel in f.
- Often, we like to work with correlation arrays that are the same size as f, in which case
- we crop the full correlation to the size of the original function, as Fig. 3.29(h) shows

keralanotes.com