Image processing is a subclass of signal processing concerned specifically with pictures. Improve image quality for human perception and/or computer interpretation.

Several fields deal with images
Computer Graphics: the creation of images.
Image Processing: the enhancement or other manipulation of the image the result of which is usually another images.
Computer Vision: the analysis of image content.

Two Principal application areas

1. Improvement of pictorial information for human interpretation
2. Processing of image data for storage, transmission, and representation for autonomous machine perception

Three types of computerized process

1. Low-level: input, output are images Primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening

2. Mid-level: inputs may be images, outputs are attributes extracted from those images
   * Segmentation
   * Description of objects
   * Classification of individual objects

3. High-level: Image analysis

Q(1) What are the elements of Digital Image Processing System?

Elements of Digital Image Processing System are:

1) Acquisition 2) Storage 3) Processing 4) Communication 5) Display
I. ACQUISITION:-

This involves acquiring a digital image. Two elements are required to acquire digital image.

(1) A physical device that produces an electrical signal output proportional to the level of energy sensed. Image sensor such as video camera CCD camera can be used.

(2) A digitizer device for converting electrical output into digital form.

II. STORAGE:-

Digital storage falls into three principal categories

(1) Short term storage for use during processing
(2) On-line storage for relatively fast recall.
(3) Archival storage.

One method for short term storage is comp memory. Another is frame buffer that store one or more image and can be accessed rapidly usually at video rate. The amount of storage on a frame buffer card is limited by the physical size of the card and by the storage density of the memory chips used.
One line storage generally uses magnetic disks. Archival storage is characterized by massive storage requirement but infrequent need for access. Magnetic tapes and optical disks are the usual media for archival application.

### III. PROCESSING :-

Preprocessing is done to improve the image. It typically deals with techniques for improving contrast, removing noise etc.

Image Enhancement is to bring out detail, or simply to highlight certain features of interest in an image.

Image Restoration is to improve the appearance of an image. Tend to be based on mathematical or probabilistic models of image degradation.

Color Image Processing is gaining in importance because of the significant increase in the use of digital images over the Internet. However, our lecture is limited to graylevel image processing.

Compression means reducing the storage required to save an image or the bandwidth required to transmit it. Ex. JPEG (Joint Photographic Experts Group) image compression standard.

Morphological processing Tools for extracting image components are useful in the representation and description of shape.

Image Segmentation separate objects from the background. It is one of the most difficult tasks. A rugged segmentation procedure brings the process a long way toward successful solution of an image problem.

Output of the segmentation stage is raw pixel data, constituting either the boundary of a region or all the points in the region itself.

**Representation & Description:**

Representation makes a decision whether the data should be represented as a boundary or as a complete region.

- Boundary representation: focus on external shape characteristics, such as corners and inflections.
- Region representation: focus on internal properties, such as texture or skeleton shape.
Recognition & Interpretation
Recognition is the process that assigns a label to an object based on the information provided by its descriptors. Interpretation assigning meaning to an ensemble of recognized objects.

IV. COMMUNICATION:
Comm. Primarily involves local comm... between image processing systems and remote systems. Digital image contain a significant amount of data. Thus the transmission of entire image is time consuming.

V. DISPLAY:-
The principal Display devices are Monochrome and color TV Monitors. Monitors are drives by the outputs of a hardware image display module.

Q(2) SHORT NOTE : Image acquisition method. [5 M, MAY07, ETRX]

Image Acquisition
An image is captured by a sensor (such as a monochrome or color TV camera) and digitized. If the output of the camera or sensor is not already in digital form, an analog-to digital converter digitizes it.

1. Camera :
Camera consists of 2 parts : A lens that collects the appropriate type of radiation emitted from the object of interest and that forms an image of the real object a semiconductor device so called charged coupled device or CCD which converts the irradiance at the image plan into an electrical signal.
2. Frame grabber:
Frame grabber only needs circuits to digitize the electrical signal from the imaging sensor to store the image in the memory (RAM) of the computer.

Q(3) Uniform sampling and non-uniform sampling.
(10M May 05 Comp) (6M May 06 Comp) (5M Dec 06 IT) (4M Dec 04 I.T)

Nonuniform sampling
For a fixed value of spatial resolution, the appearance of the image can be improved by using adaptive sampling rates.
- fine sampling is required in the neighborhood of sharp gray-level transitions.
- coarse sampling is utilized in relatively smooth regions.

Nonuniform quantization
- unequally spaced levels in quantization process influence on the decreasing the number of gray level.
- use few gray levels in the neighborhood of boundaries. Why? eye is relatively poor at estimate shades of gray near abrupt level changes.
- use more gray levels on smooth area in order to avoid the "false contouring".

Q(4) TRUE OR FALSE AND JUSTIFY (each 3M May 06 Etrx)
(a) The total range of intensity levels human visual system can discriminate simultaneously is rather small compared to the total adaption range.

(b) Reduction in gray levels produces "blocky effect" (check board) in the image

Q(5) Write short note on Sampling and Quantization.
[5M, MAY 07, ETRX] (5M Dec 04 Comp)
Q(6) Explain Connectivity of pixels. (7M May06 Etrx) (5M Dec04 Comp)

Q(7) Consider the two image subset S1 and S2 shown in figure for V={1} determine whether these two subsets are
   a) 4-adjacent       b) 8-adjacent       c) M-adjacent  (5M Dec06 IT)

Q(8) Justify The Following: [4 M, MAY 07, ETRX]
   The D4 distance between two points p and q is equal to the shortest 4-path between the points.

Q(9) Define: 1) Euclidean Distance(ED)
       2) City Block Distance(CBD)
       3) Chess-board distance.(CHBD)
   Consider the following subimage: determine ED; CBD; CHBD between p and q  (10M May05 Comp)

Q(10) Justify/contradict the following statement: “Quality of picture depends on the number of pixels and the number of gray levels that represent the picture. [5M DEC09 ELEX]
Q(11) Develop an algorithm for converting one pixel thick 8 connected path to 4 connected path. (5M Dec05 IT)

Q(12) Explain the following terms:  
* Simultaneous contrast (5M Dec06 IT)

The terms "simultaneous contrast" and "successive contrast" refer to visual effects in which the appearance of a patch of light (the "test field") is affected by other light patches ("inducing fields") that are nearby in space and time, respectively. Simultaneous Contrast is the term meaning the appearance of something being affected by the appearance of things surrounding it. There are many popular examples of this demonstrating how the eye can easily be "tricked."

The two inner squares to the left are the same color: they reflect the same amount of light. However due to simultaneous lightness contrast the two squares do not appear the same. The squares have different lightnesses because of their surroundings: the left square is lighter than the black around it so is relatively light; the right square is darker than the white around it so is relatively light. The result is the left square appearing lighter than the right square.

![Simultaneous Contrast Example](image)

Q(13) Discuss basic relationship between particular pixels of Digital Image. (10M May05 Comp)

**Basic Relationship between pixels**
- Neighbors of a pixel
- Connectivity
- Labeling of Connected Components
- Relations, Equivalences, and Transitive Closure
- Distance Measures
- Arithmetic/Logic Operations
[1] Neighbors of a pixel

Pixel $p$ at coordinate $(x,y)$ has $N_4(p)$: 4-neighbors of $p$

```
  x   
 x p x (x+1, y), (x-1,y),(x,y+1), (x,y-1) 
  x   
```

$N_D(p)$: 4-diagonal neighbors of $p$

```
  x   
 p   (x+1, y+1), (x+1,y-1),(x-1,y+1), (x-1,y-1) 
  x   
```

$N_8(p)$: 8-neighbors of $p$: a combination of $N_4(p)$ and $N_D(p)$

```
  x   
  x p x 
  x   
```

---

[2] Connectivity

Let $V$ be the set of gray-level values used to define connectivity

- **4-connectivity**: Two pixels $p$ and $q$ with values from $V$ are 4-connected if $q$ is in the set $N_4(p)$
- **8-connectivity**: Two pixels $p$ and $q$ with values from $V$ are 8-connected if $q$ is in the set $N_8(p)$
- **M-connectivity** (Mixed connectivity): Two pixels $p$ and $q$ with values from $V$ are m-connected if $q$ is in the set $N_4(p)$ or $q$ is in the set $N_D(p)$ and the set $N_4(p) \cup N_4(q)$ is empty.

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[3] Adjacent

A pixel $p$ is adjacent to a pixel $q$ if they are connected.

Two image area subsets $S_1$ and $S_2$ are adjacent if some pixel in $S_1$ is adjacent to some pixel in $S_2$.

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[3] Path

A path from pixel $p$ with coordinates $(x,y)$ to pixel $q$ with coordinates $(s,t)$ is a sequence of distinct pixels with coordinates $(x_0,y_0),(x_1,y_1),...,(x_n,y_n)$ where $(x_0,y_0) = (x,y)$, $(x_n,y_n) = (s,t)$ and $(x_i,y_i)$ is adjacent to $(x_{i-1},y_{i-1})$ and $n$ is the length of the path.
[4] Labeling of Connected Components

Scan the image from left to right.

Let p denote the pixel at any step in the scanning process.

Let r denote the upper neighbour of p and t denote the left-hand neighbours of p, respectively. When we get to p, points r and t have already been encountered and labeled if they were 1’s.

\[ \text{r} \]

\[ \text{t} \]

\[ \text{p} \]

If the value of p = 0, move on.

If the value of p = 1, examine r and t.

If they are both 0, assign a new label to p.

If only one of them is 1, assign its label to p.

If they are both 1

1. if they have the same label, assign that label to p.
2. if not, assign one of the labels to p and make a note that the two labels are equivalent. (r and t are connected through p).

At the end of the scan, all points with value 1 have been labeled.

Do a second scan, assign a new label for each equivalent labels.

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Labeling of 8 Connected components?

Do the same way but examine also the upper diagonal neighbors of p.

1) If the value of p = 0, move on.

2) If p is 1
   • if all four neighbors are 0, assign a new label to p.
   • if only one of the neighbors is 1, assign its label to p. and make a note of equivalent classes.
   • after complete the scan, do the second round and introduce a unique label to each equivalent class.

-------------------------------------------------------------------------------------------------

[5] Distance Measures

For pixels p, q and z with coordinates (x,y), (s,t) and (u,v) respectively, D is a distance function or metric if

\[ D(p,q) \geq 0 ; D(p,q) = 0 \text{ iff } D=q \]

\[ D(p,q) = D(q,p) \]

\[ D(p,z) \leq D(p,q) + D(q,z) \]
D4 and D8 distances
We can consider both D4 and D8 distances between p and q regardless of whether a connected path exists between them because the definitions of these distances involve only the coordinates.

m-connectivity’s distance: Distances of m-connectivity of the path between 2 pixels depends on values of pixels along the path.

Arithmetic operations between two pixels p and q:

1) Addition: p+q used in image average to reduce noise.
2) Subtraction: p-q basic tool in medical imaging.
3) Multiplication: p x q (to correct gray-level shading result from on uniformities in illumination or in the sensor used to acquire the image.)
4) Division: p.q

Arithmetic Operation on entire images is carried out pixel by pixel.

[7] Logic operations

1) AND: p AND q (p•q)
2) OR: p OR q (p+q)
3) COMPLEMENT: NOT q ()

Logic operations apply only to binary images. Arithmetic operations apply to multivalued pixels.

Logic operations are used for tasks such as masking, feature detection, and shape analysis. Logic operations perform pixel by pixel.
**Q(14)** Differentiate between Image Processing and Image Analysis.

<table>
<thead>
<tr>
<th><strong>Image Processing</strong></th>
<th><strong>Image Analysis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The term image processing denotes the processing of a 2 – D picture by digital computer.</td>
<td>1. Image analysis is concerned with making quantitative measurements from an image, to produce a description of it.</td>
</tr>
<tr>
<td>2. Image processing involves steps like Image acquisition, preprocessing, segmentation, feature selection, Recognition.</td>
<td>2. Image analysis involves techniques that require extraction of certain features that aid in the identification of the object such as segmentation techniques and quantitative measurements.</td>
</tr>
<tr>
<td>3. Image Processing has a large number of applications areas like geographical mapping, weather, remote sensing, medical processing, radar, sonar robotics etc.</td>
<td>3. Applications of Image analysis involves reading a label, sorting of objects, measuring the size and orientation in medical imaging. Advanced image analysis application involves the use of qualitative information to make sophisticated decisions.</td>
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</tbody>
</table>

**Q(15)** Differentiate between Image Enhancement and image Restoration:

<table>
<thead>
<tr>
<th><strong>Image Enhancement</strong></th>
<th><strong>Image Restoration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Image Enhancement refers to the attenuation or sharpening of image features such as edges, boundaries or contract to make a graphic display more useful for display of analysis.</td>
<td>1. Image Restoration refers to removal or minimization of known degradation in an image.</td>
</tr>
<tr>
<td>2. Image enhancement increases the dynamic range of the chosen feature, so that they can be detected easily.</td>
<td>2. It involves improvement in degraded images due to the limitation of the sensor e.g. pictures of a moving vehicle.</td>
</tr>
<tr>
<td>3. Image Enhancement includes gray level and contrast manipulation, noise reduction, edge crispener, sharpening interpolation and magnification.</td>
<td>3. It includes deblurring of images degraded by the limitation of sensor or its environment, noise filtering and correction of geometric distortion or non-linearities due to sensor.</td>
</tr>
<tr>
<td>4. The greatest difficulty in image enhancement is quantifying criterion for enhancement.</td>
<td>4. In this the problem is to find an estimate of the analog image given the PSF of the blurred image and its statistical properties of the noise process.</td>
</tr>
</tbody>
</table>
Q(16) Differentiate between Difference between Spatial Resolution and Tonal Resolution :-

The resolution of a digital image depends on two parameters.

(i) No. of samples of the digital image (N)
(ii) No. of gray levels (m).

The more these parameters are increased, the closer the digitized array approximates the original image. However, the amount of memory space and the processing requirements increase drastically as function of these two factors.

A good image is difficult to define, because image quality not only is highly subjective, but is also strongly dependent on the requirements of a given application. The quality of an image is greatly varied by variation in the above mentioned factors. Thus the two methods of varying the quality of the image are -

**Spatial Resolution** : Here the number of samples of digital image is changed as a power of two keeping the display area used for each image the same, and maintaining a constant gray level; the pixels in the lower resolution images are duplicated in order to fill the entire display. This pixel replication produced a checkerboard effect, which is particularly visible in images of lower resolution.

**Tonal Resolution** : In Total resolution, the quality of image is varied by decreasing the number of bits used to represent the no. of gray levels in an image. The effects on image quality produced by varying n & M are subjectively analyzed by the level of detail pertaining to an image. The general conclusions that can be drawn from such a subjective study are :-

(i) In most cases, the quality of the image tends to increase as N and M are increased. In a few cases, for a fixed N, the quality improved by decreasing M’ the reason being that a decrease in M generally increases the apparent contrast of an image.

(ii) For images with a large amount of detail only a few gray levels are needed. Increased gray levels for an image of a mob. For e.g. may increase the obscurity of the image.
Q(17) Given \( f[x, y] = \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \) \( h[x, y] = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \) Find Linear Convolution.

\[
g(x, y) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} f(m, n) h(x - m, y - n)
\]

\[
g[0,0] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 4
\]

\[
g[0,1] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 9
\]

\[
g[0,2] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix} = 11
\]

\[
g[0,3] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} = 6
\]

\[
g[1,0] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} = 11
\]

\[
g[1,1] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix} = 24
\]

\[
g[1,2] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix} = 28
\]

\[
g[1,3] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} = 15
\]

\[
g[2,0] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} = 7
\]

\[
g[2,1] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix} = 4
\]

\[
g[2,2] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 1 \end{bmatrix} = 17
\]

\[
g[2,3] = \sum_{m=0}^{\infty} \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} = 9
\]

The output image is given by \( g[x, y] = \begin{bmatrix} 4 & 9 & 11 & 6 \\ 11 & 24 & 28 & 15 \\ 7 & 4 & 17 & 9 \end{bmatrix} \) ANS
Q(18) What is the advantage of storing images in frame buffers

Frame buffer are storage modules, (memory) capable of storing an entire digital image.

The advantage of storing image in frame buffers is that the contents of this memory can be loaded or read at TV rates (of the order of 30 image per second). This feature allows the image acquisition module to deposit a complete image into storage as fast as it is being grabbed, conversely, the memory can be addressed at TV rates by a display module, which outputs the image to a TV monitor other memory addressing modes allow virtually instantaneous image zoom as well as scroll (virtual shifts) and pan (horizontal shifts).