Fundamentals of Digital Image Processing

- Applications of image processing
- What's an image?
- A simple image model
- Fundamental steps in image processing
- Elements of digital image processing systems

Applications of image processing:

- Interest in digital image processing methods stems from 2 principal application areas:
 - (1) improvement of pictorial information for human interpretation, and
 - (2) processing of scene data for autonomous machine perception.
- In the second application area, interest focuses on procedures for extracting from an image information in a form suitable for computer processing.
- Examples include automatic character recognition, industrial machine vision for product assembly and inspection, military recognizance, automatic processing of fingerprints etc.

What's an image?

- An image refers to a 2D light intensity function f(x,y), where (x,y) denote spatial coordinates and the value of f at any point (x,y) is proportional to the brightness or gray levels of the image at that point.
- A digital image is an image f(x,y) that has been discretized both in spatial coordinates and brightness.
- The elements of such a digital array are called image elements or pixels.

A simple image model:

- To be suitable for computer processing, an image f(x,y) must be digitalized both spatially and in amplitude.
- Digitization of the spatial coordinates (x,y) is called *image sampling*.
- Amplitude digitization is called *gray-level quantization*.

- The storage and processing requirements increase rapidly with the spatial resolution and the number of gray levels.
- Example: A 256 gray-level image of size 256x256 occupies 64K bytes of memory.
- Images of very low spatial resolution produce a checkerboard effect.



• The use of insufficient number of gray levels in smooth areas of a digital image results in false contouring.



Fig 4. Images of different amplitude resolution

Fundamental steps in image processing:

- 1. <u>Image acquisition:</u> to acquire a digital image
- 2. <u>Image preprocessing</u>: to improve the image in ways that increase the chances for success of the other processes.
- 3. <u>Image segmentation:</u> to partitions an input image into its constituent parts or objects.
- 4. <u>Image representation</u>: to convert the input data to a form suitable for computer processing.
- 5. <u>Image description</u>: to extract features that result in some quantitative information of interest or features that are basic for differentiating one class of objects from another.
- 6. <u>Image recognition</u>: to assign a label to an object based on the information provided by its descriptors.
- 7. <u>Image interpretation</u>: to assign meaning to an ensemble of recognized objects.
- Knowledge about a problem domain is coded into an image processing system in the form of a knowledge database.



Fig 1. Fundamental steps in digital image processing

Elements of digital image processing systems:

• The basic operations performed in a digital image processing systems include (1) acquisition, (2) storage, (3) processing, (4) communication and (5) display.



Fig 2. Basic fundamental elements of an image processing system

Color processing

- Basics of color
- Color models in images
- Color models in video

Basics of color

(a) *Light and spectra*

- Color is the perceptual result of light in the visible region of the spectrum, having in the region of 400nm to 700nm, incident upon the retina.
- Visible Light is a form of electromagnetic energy consisting of a spectrum of frequencies having wavelengths range from about 400nm for violet light to about 700nm for red light.
- Most light we see is a combination of many wavelengths.

(b) <u>Primaries</u>

- Any color can be matched by proper proportions of three component colors called primaries.
- The most common primaries are red, blue and green.

- The following terms are used to define color light:
 - 1. *Brightness* or *Luminance*: This is the amount of light received by the eye regardless of color.
 - 2. *Hue*: This is the predominant spectral color in the light.
 - 3. *Saturation*: This indicates the spectral purity of the color in the light.



Fig 1. Color attributes

• In 1931, the CIE adopted a set of nonphysical primaries, X, Y and Z.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 2.7690 & 1.7518 & 1.1300 \\ 1.0000 & 4.5907 & 0.0601 \\ 0.0000 & 0.0565 & 5.5943 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$





Fig 3. Color pyramid

- The chromaticity coordinates are obtained from x=X/D, y=Y/D, z=Z/D, where D=X+Y+Z.
- The edges represent the "pure" colors.
- When added, any two colors produce a point on the line between them.

Color models in images:

- A color image is a 2D array of (R,G,B) integer triplets.
- CRT displays have 3 phosphors (RGB) which produce a combination of wavelengths when excited with electrons.
- CMY model, which uses Cyan, Magenta and Yellow primaries, is mostly used in printing devices where the color pigments on the paper absorb certain colors.

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 - R \\ 1 - G \\ 1 - B \end{bmatrix}$$

• Sometimes, an alternative CMYK model (K stands for black) is used in color printing to produce a darker black than simply mixing CMY.

$$\begin{bmatrix} C' \\ M' \\ Y' \end{bmatrix} = \begin{bmatrix} C - K \\ M - K \\ Y - K \end{bmatrix}, \text{ where } K = \min\{C, M, Y\}$$

Color models in video

• YIQ and YUV are the 2 commonly used color models in video.

(a). <u>YIQ Model</u>

• YIQ is used in color TV broadcasting, which is downward compatible with B/W TV where only Y is used.

 $\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & 0.275 & 0.321 \\ 0.212 & 0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$

• Y (luminance) is the CIE Y primary.

(b). $\underline{YUV(YC_bC_r) model}$

- They are initially for PAL analog video, but it's now used in CCIR 601 standard for digital video.
- Y = 0.299R+0.587G+0.114BC_b = B-Y C_r = R-Y
- Y = 0.299R + 0.587G + 0.114B

- U = 0.565(B-Y)V = 0.713(R-Y)
- (c). <u>Chroma subsampling</u>



- 4:2:2 Horizontally subsampled color signals by a factor of 2.
- 4:1:1 Horizontally subsampled by a factor of 4
- 4:2:0 Subsampled in both the horizontal and vertical axes by a factor of 2 between pixels as shown in the figure.
- 4:1:1 and 4:2:0 are mostly used in JPEG and MPEG.