## 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 $\mathrm{f}(\mathrm{x}, \mathrm{y})$, where ( $\mathrm{x}, \mathrm{y}$ ) 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 $(\mathrm{x}, \mathrm{y})$ 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 $256 \times 256$ occupies 64 K bytes of memory.
- Images of very low spatial resolution produce a checkerboard effect.


Fig 3. Images of different spatial resolution

- 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. Image acquisition: to acquire a digital image
2. Image preprocessing: to improve the image in ways that increase the chances for success of the other processes.
3. Image segmentation: to partitions an input image into its constituent parts or objects.
4. Image representation: to convert the input data to a form suitable for computer processing.
5. Image description: 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. Image recognition: to assign a label to an object based on the information provided by its descriptors.
7. Image interpretation: 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 400 nm to 700 nm , incident upon the retina.
- Visible Light is a form of electromagnetic energy consisting of a spectrum of frequencies having wavelengths range from about 400 nm for violet light to about 700 nm for red light.
- Most light we see is a combination of many wavelengths.
(b) Primaries
- 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, $\mathrm{X}, \mathrm{Y}$ and Z .

$$
\left[\begin{array}{l}
X \\
Y \\
Z
\end{array}\right]=\left[\begin{array}{lll}
2.7690 & 1.7518 & 1.1300 \\
1.0000 & 4.5907 & 0.0601 \\
0.0000 & 0.0565 & 5.5943
\end{array}\right]\left[\begin{array}{l}
R \\
G \\
B
\end{array}\right]
$$




Fig 2. CIE chromaticity diagram


Fig 3. Color pyramid

- The chromaticity coordinates are obtained from $\mathrm{x}=\mathrm{X} / \mathrm{D}, \mathrm{y}=\mathrm{Y} / \mathrm{D}, \mathrm{z}=\mathrm{Z} / \mathrm{D}$, where $\mathrm{D}=\mathrm{X}+\mathrm{Y}+\mathrm{Z}$.
- 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 2 D array of ( $\mathrm{R}, \mathrm{G}, \mathrm{B}$ ) 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.

$$
\left[\begin{array}{c}
C \\
M \\
Y
\end{array}\right]=\left[\begin{array}{l}
1-R \\
1-G \\
1-B
\end{array}\right]
$$

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

$$
\left[\begin{array}{c}
C^{\prime} \\
M^{\prime} \\
Y^{\prime}
\end{array}\right]=\left[\begin{array}{c}
C-K \\
M-K \\
Y-K
\end{array}\right] \text {, where } \mathrm{K}=\min \{\mathrm{C}, \mathrm{M}, \mathrm{Y}\}
$$

## Color models in video

$$
\begin{aligned}
& \mathrm{U}=0.565(\mathrm{~B}-\mathrm{Y}) \\
& \mathrm{V}=0.713(\mathrm{R}-\mathrm{Y})
\end{aligned}
$$

- YIQ and YUV are the 2 commonly used color models in video.
(a). YIQ Model
- YIQ is used in color TV broadcasting, which is downward compatible with B/W TV where only Y is used.

$$
\left[\begin{array}{l}
Y \\
I \\
Q
\end{array}\right]=\left[\begin{array}{lll}
0.299 & 0.587 & 0.114 \\
0.596 & 0.275 & 0.321 \\
0.212 & 0.528 & 0.311
\end{array}\right]\left[\begin{array}{l}
R \\
G \\
B
\end{array}\right]
$$

- Y (luminance) is the CIE Y primary.
(b). $Y U V\left(Y C_{b} C_{r}\right)$ model
- They are initially for PAL analog video, but it's now used in CCIR 601 standard for digital video.
- $\mathrm{Y}=0.299 \mathrm{R}+0.587 \mathrm{G}+0.114 \mathrm{~B}$
$\mathrm{C}_{\mathrm{b}}=\mathrm{B}-\mathrm{Y}$
$\mathrm{C}_{\mathrm{r}}=\mathrm{R}-\mathrm{Y}$
- $\mathrm{Y}=0.299 \mathrm{R}+0.587 \mathrm{G}+0.114 \mathrm{~B}$
(c). Chroma subsampling

- 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.

