# Ch-2 Digital Image Fundamentals



## Image Sensing and Acquisition

- Using a single sensing element

  In order to generate a 2-D image using a single sensing element, there has to be relative displacements in both x- and y- directions between sensors and area to be imaged.

- Using sensor strips.
  - In-line sensor strips – provide imaging in one direction.

  An imaging strip gives one line of an image at a time, and the motion of the strip relative to the scene completes the other dimension of a 2D image.

- using sensor arrays.

## A simple image formation model.

- An image is denoted by a 2-D function of the form $f(x, y)$.
- The value of $f$ at spatial co-ordinates $(x, y)$ is a scalar quantity whose physical meaning is determined by source of the image, & whose values are proportional to energy radiated by a physical source.

$$\therefore \quad 0 \leq f(x, y) < \infty$$

$f(x, y)$ is characterized by two components:

(i) Amount of source illumination incident on the scene being viewed.
(illumination component)

(ii) Amount of illumination reflected by objects in the scene.
(reflectance component)

$$\therefore \quad f(x, y) = i(x, y)\, r(x, y)$$

where $0 \leq i(x, y) < \infty$

$0 \leq r(x, y) \leq 1$

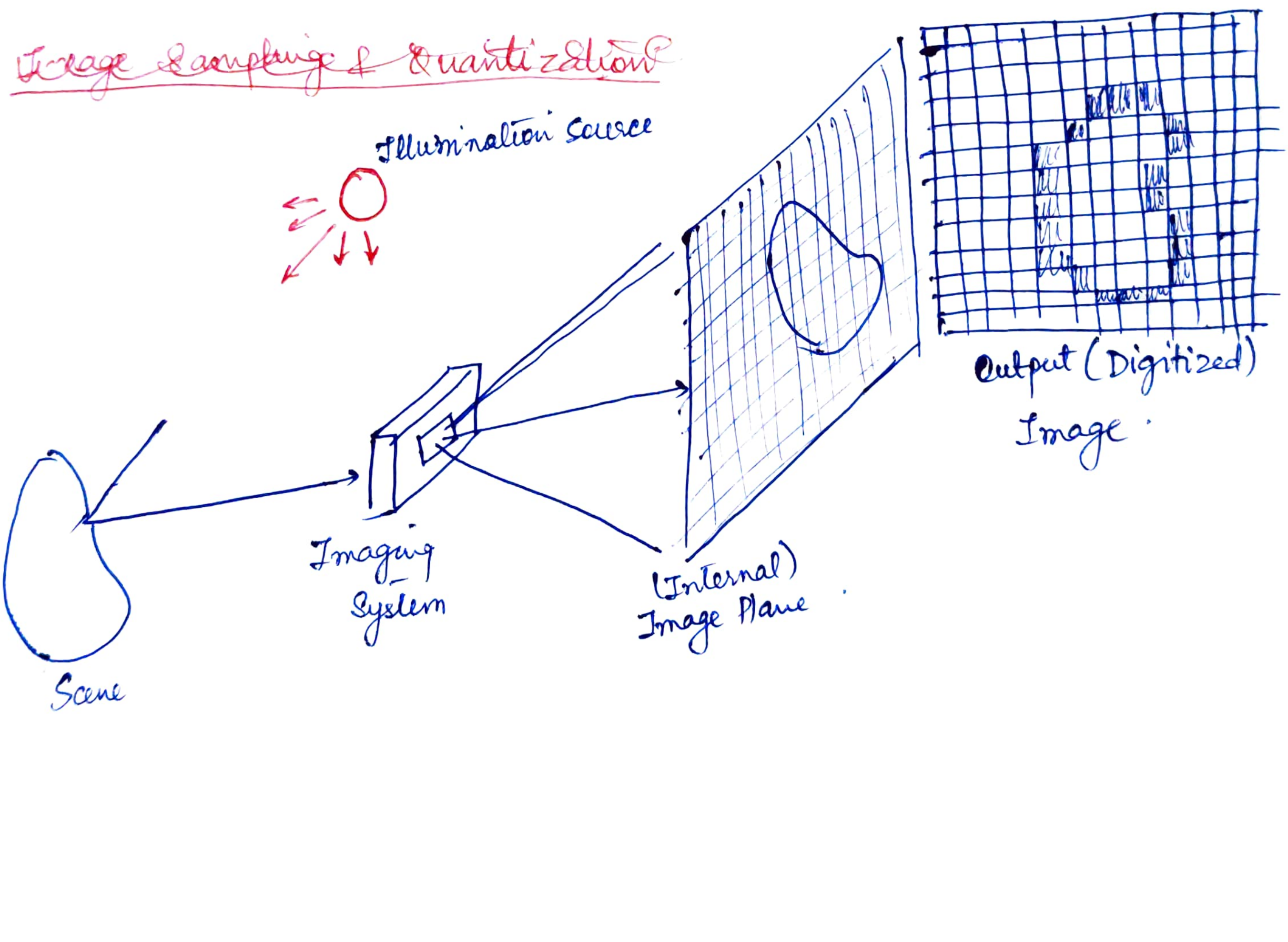
- The reflectance is bounded by 0 (total absorption) and 1 (total reflectance)
- Let the intensity (gray-level) of a monochrome image at any coordinates $(x, y)$ be denoted by —

$$l = f(x, y)$$

where $L_{min} \le l \le L_{max}$.

- The interval $[L_{min}, L_{max}]$ is called the intensity (gray) scale. commonly, $[0, 1]$ or $[0, C]$ where $l = 0$ is considered black and $l = 1$ (or $C$) is considered white.
  - All intermediate values are shades of gray varying from black to white.

## Image Sampling & Quantization

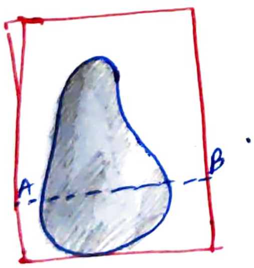


# Image Sampling and Quantization

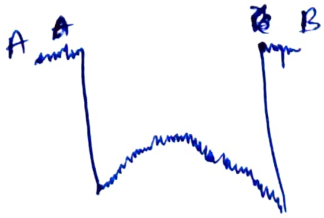
- There are numerous ways to acquire images, but objective is to generate digital images from sensed data.
- The output of most sensors is continuous voltage forms whose amplitude and spatial behaviour are related to physical phenomenon being sensed.
- To create a digital image, we need to convert the continuous sensed data into digital format.
- This requires sampling and quantization.

## Basic concepts in Sampling & Quantization

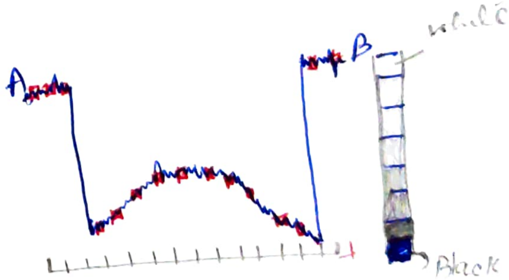
- An image may be continuous w.r.t. x- and y-coordinates and also in amplitude.
- To digitize, we have to sample the function in both coordinates and amplitude.
- Digitizing the coordinates - sampling
- Digitizing the amplitude - quantization




(a) Continuous image




(b) Scan-line showing intensity variations along line AB in continuous image



# Representing Digital Images

- Let $f(s,t)$ represent continuous image function.
We convert it into a digital image using sampling and quantization to $f(x,y)$ containing M rows and N columns.
where $x = 0, 1, 2, \ldots, M-1$
$y = 0, 1, 2, \ldots, N-1$

- The section of real plane spanned by the coordinates of an image is called spatial domain.

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \ddots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

$\therefore$ Sampling may be viewed as partitioning the x-y plane into a grid.

Image digitization requires decision regarding values of M, N and L i.e discrete intensity levels.

$$L = 2^k$$

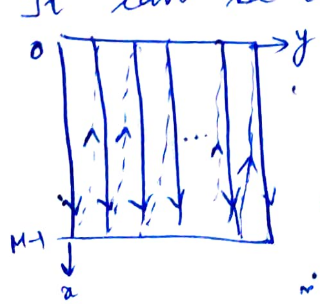
where k is an integer. for gray-scale $2^8 = 256$ intensity values
ranging $[0 \text{ to } L-1]$ ranging $[0, 255]$

## Linear vs Coordinate Indexing

Representing an image by its x, y coordinates as a $f(x,y)$ is called coordinate indexing [2D matrices].

In linear indexing, the whole image is indexed as 1-D string of non-negative integers.
It can be done column wise or row wise.

Eg




a scan of 1st column (left most) yields indices 0 to M-1.
a scan of second column yields M to 2M-1.

$\therefore$ Indexing goes from $0, 1, 2, \ldots, MN-1$.

Formula for generating linear indices based on column-scan is

$\alpha = My + x$. $\quad \alpha \Rightarrow$ linear index.

and

$x = \alpha \bmod M$.

$y = (\alpha - x)/M$.

## Spatial and Intensity Resolution

- Spatial Resolution is measure of smallest discernible detail in an image,

  eg dots per unit distance.

  dpi $\rightarrow$ dots per inch.

Image size by itself does not give a meaningful statement without stating the spatial dimensions encompassed by the image.

Intensity Resolution refers to the smallest discernible change in intensity level.