



Government of Goa  
**Goa College of Engineering**  
Farmagudi - Goa



गोवा अभियांत्रिकी महाविद्यालय, फार्मागुडी – गोवा

# Image Processing

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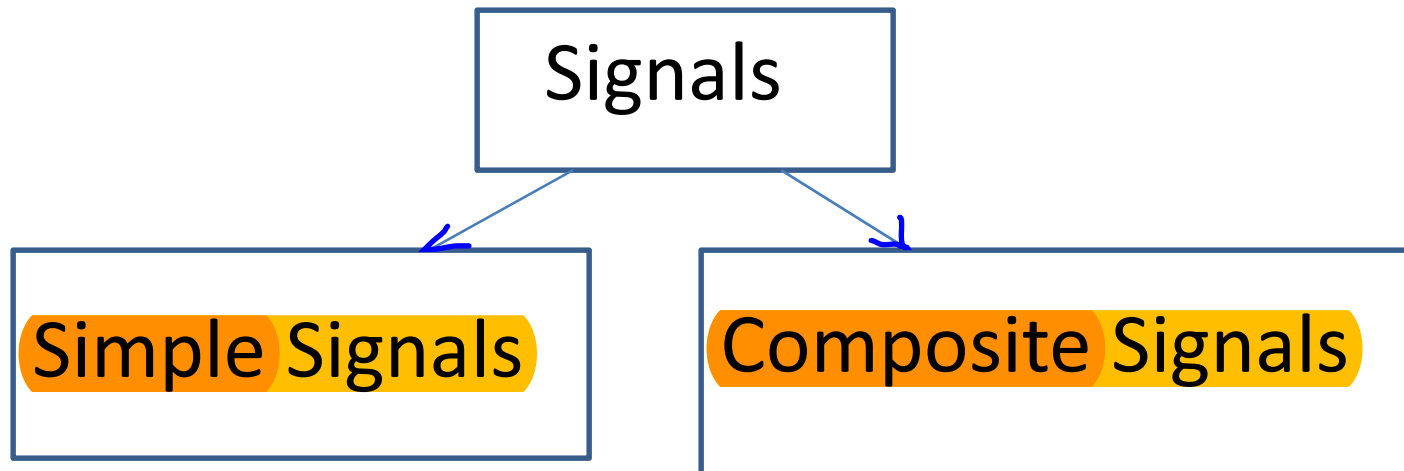
# Outline

- Analog Signals
- Digital Signals
- Need for Image digitization
- Sampling
- Quantization
- Image Digitization
- References



# Analog Signals

- Continuous variation of intensity with respect to time
- Shows time variation





# Simple Signals



Depends on 3 parameters

- **Amplitude**- maximum intensity of a wave  
- denoted as **A**
- **Period and frequency**-
  - **Period**: time for signal to travel one complete wave cycle
  - Period is denoted as **T**
  - Measured in units of **seconds**



# Simple Signals

cps

➤ **Frequency:** The number of cycles per second(cps)

✓ -denoted by  $f$

➤ Period is the reciprocal of frequency,  $T=1/f$



➤ **Phase:** position that a wave offsets at the origin of the temporal axis

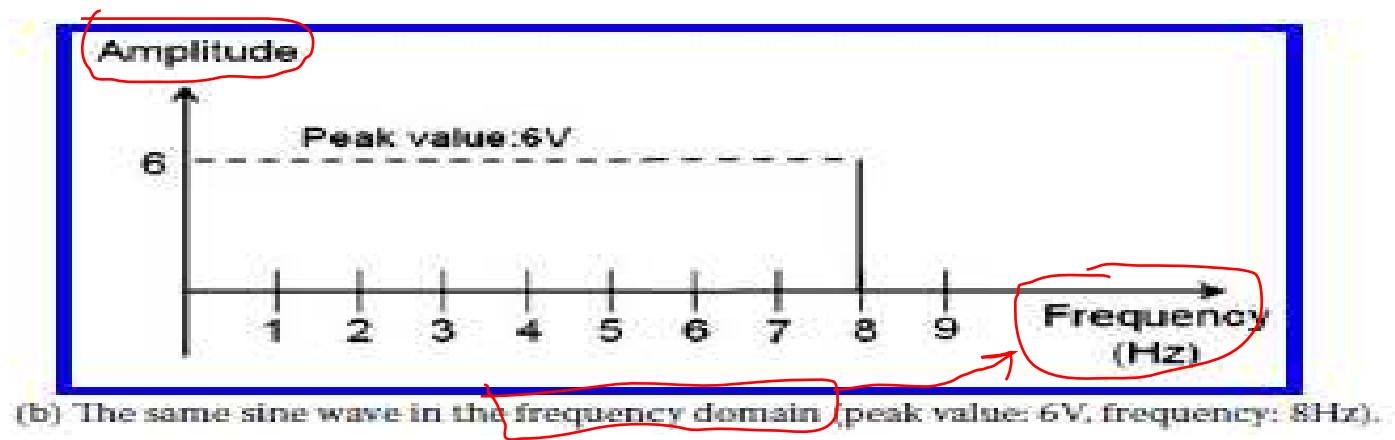
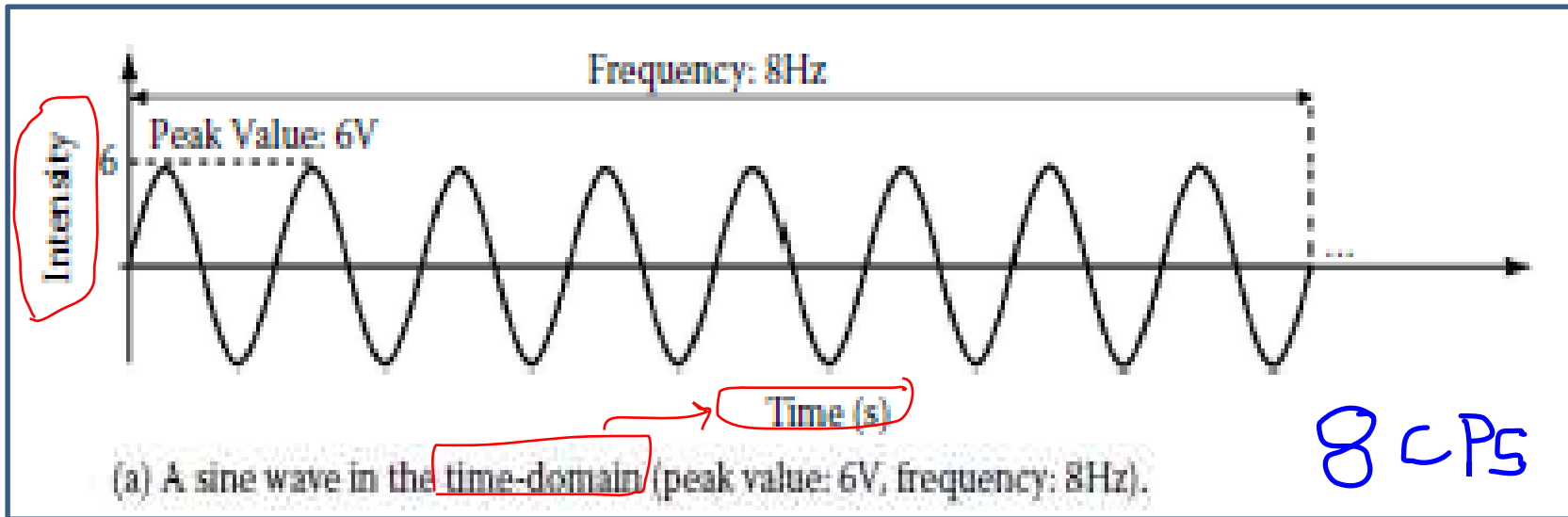
Denoted as an angle  $\phi$





# Simple signals

$I = A \sin(2\pi f t)$

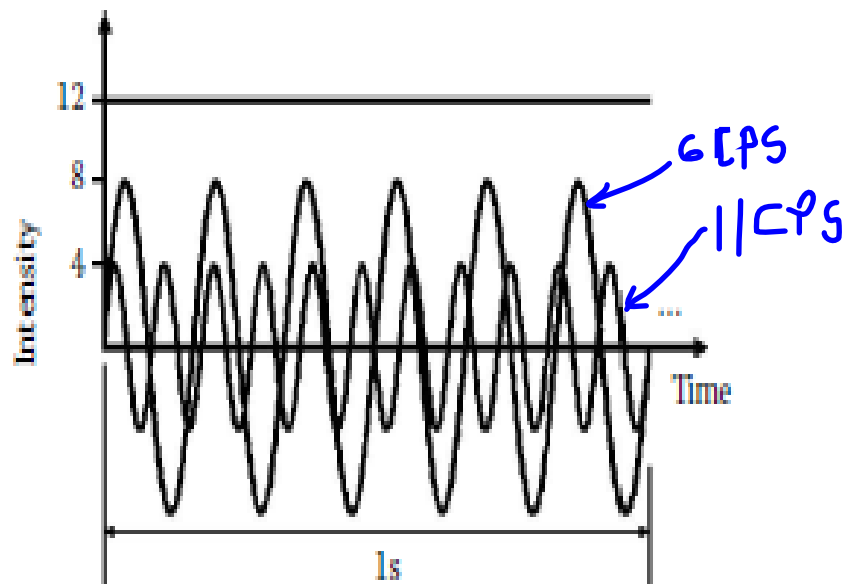




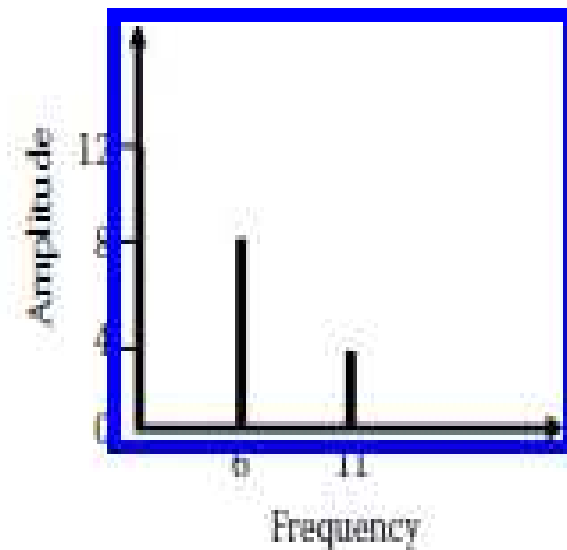
# Composite signals

- Combination of simple sine/cosine waves with different frequencies, phases and amplitudes

FAP



Time domain representation of three sine waves with frequency 0, 6 and 11

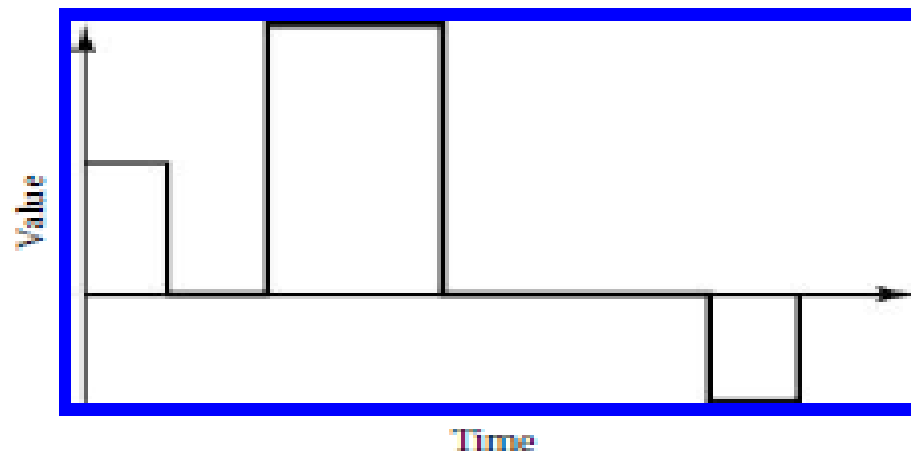


Frequency domain representation of same 3 waves



# Digital Signals

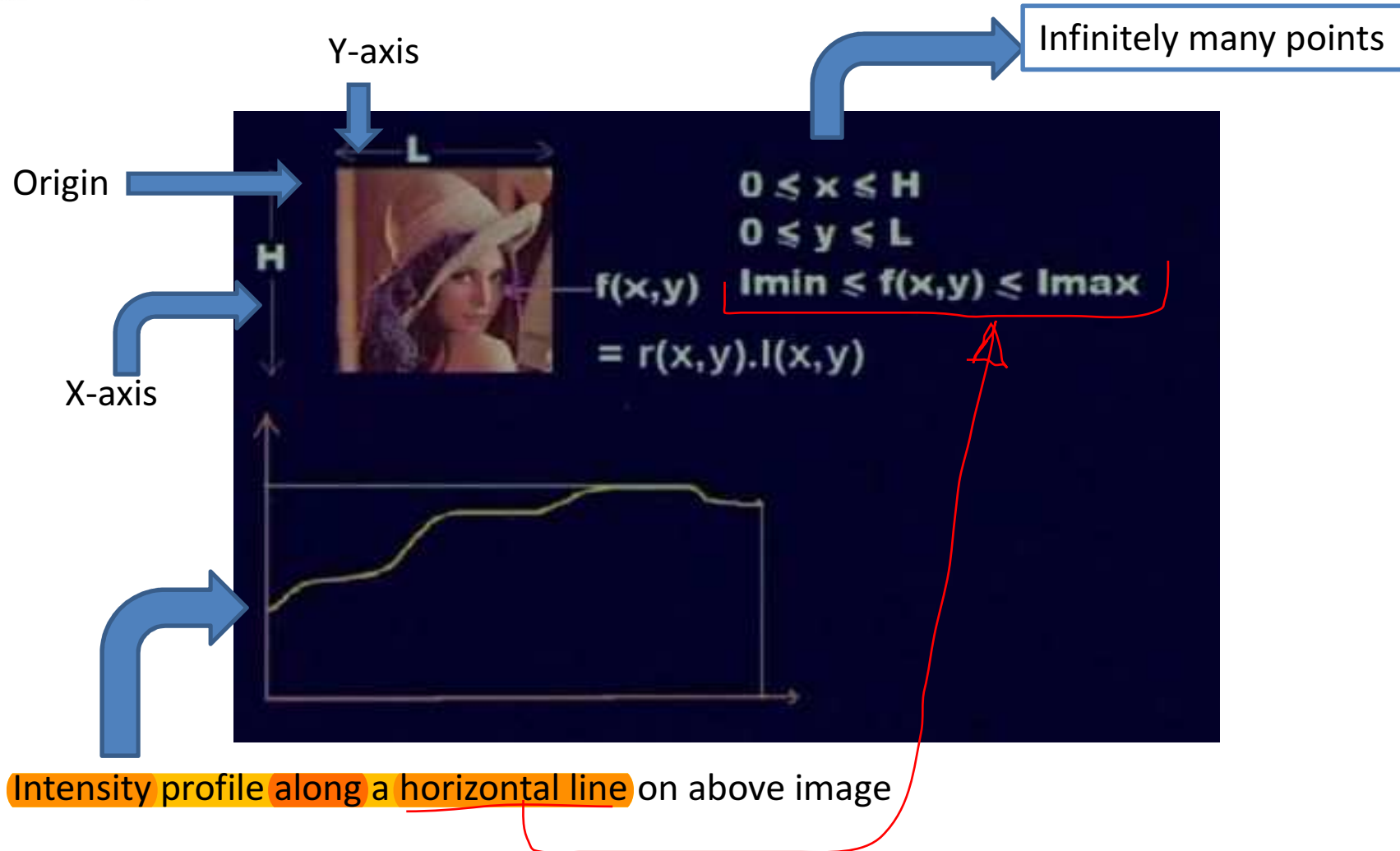
- Maintain a fixed value for a short period of time
- Intensity is restricted within a limited number of defined values
- To store analog signals on computer, we need to digitize them
- Digitization will involve sampling and quantization







# Need for Image Digitization





# Need for Image Digitization

- ✓ Should the image be represented by infinite number of points? ✗
- Can each image point contain one of the infinitely many possible intensity values?
- Each such value may require infinite number of values?
- ✓ Can we represent this on computer?

No



# Image Digitization

- Image representation by 2-D finite matrix

sampling

Quantization

- Each matrix element is represented by one of the finite set of discrete values



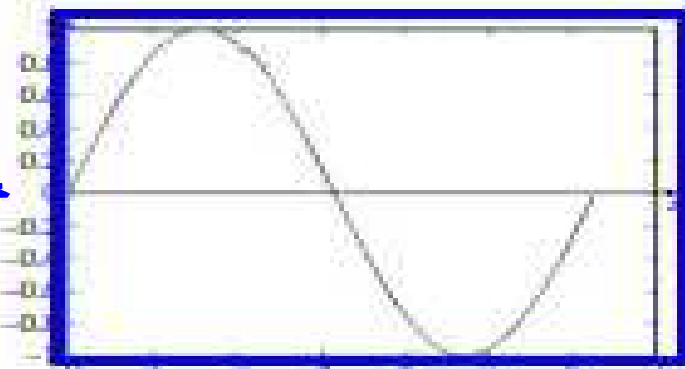
# Sampling

- Digitizing the coordinate values
- Process of measuring and preserving the signal intensity at a given time
- During analogue to digital conversion, suitable intervals must be chosen

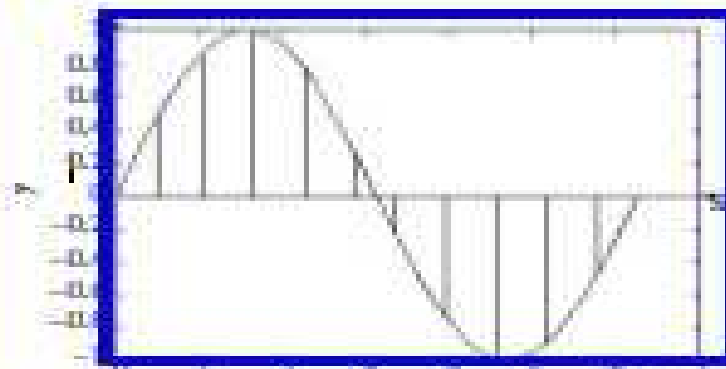


# Sampling

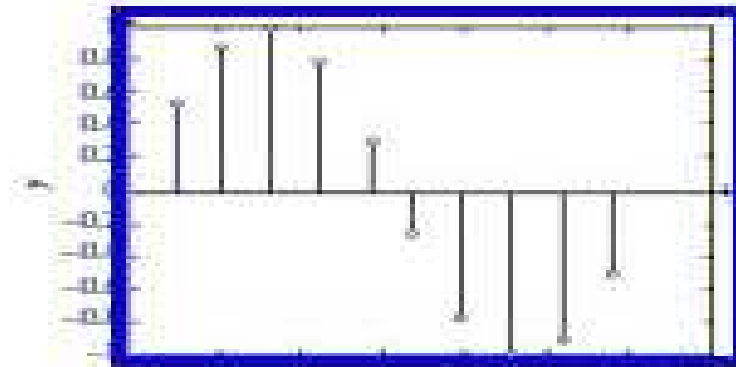
zero



(a) The Original wave



(b) Sampling process



(c) Sampling result



# Sampling

- Image to be represented by a finite 2-D matrix

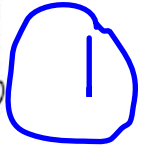
$$\begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ f(2,0) & f(2,1) & f(2,2) & \dots & f(2,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

- What values does each of these take?
- Infinite?



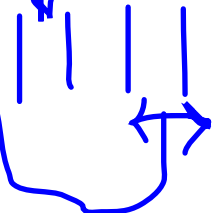
# Quantization

- After sampling, the function value at each of the discrete points is a real number.
- A finite number of quantum values are used to represent the samples.
- Use a 2-bit, 4-bit, 8-bit, 16-bit, or 24-bit memory to store these quantum values
- Given the number of bits, the signal intensity in real number at a particular set of coordinates is mapped to the corresponding quantum value fitted into the available storage space.



# Uniform Quantization

- Amplitude of a signal is  $A$  and the storage is  $b$  bits, then  $[0, A]$  is divided into  $2^b$  intervals of uniform length.
- Each interval is called a level, and the length of an interval is called the quantization step.
- $2^b$  quantum values to be stored by using  $b$  bits of memory representing  $2^b$  intervals
- The signal intensity at a given coordinate that falls into a particular interval can be approximated by using the corresponding quantum value in the interval

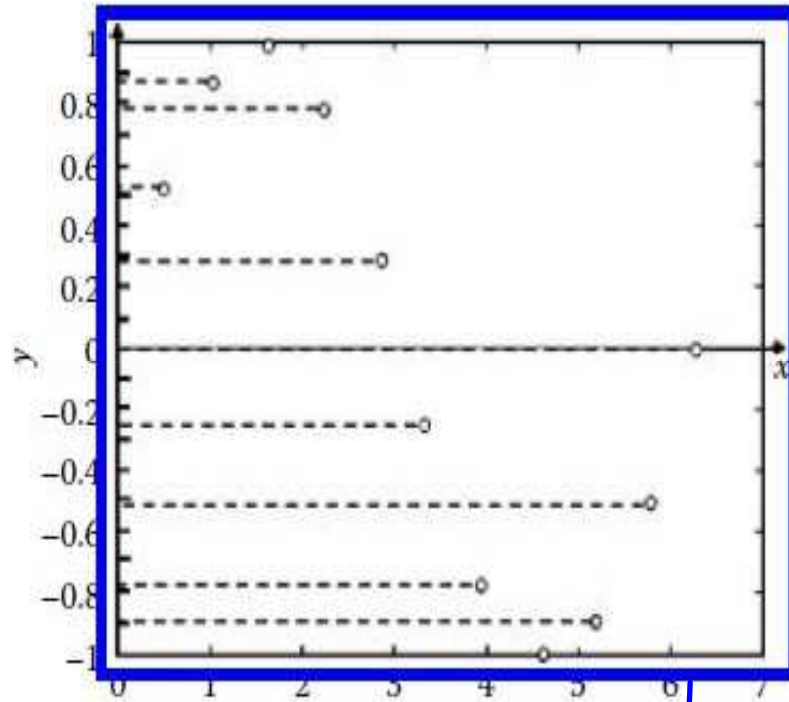




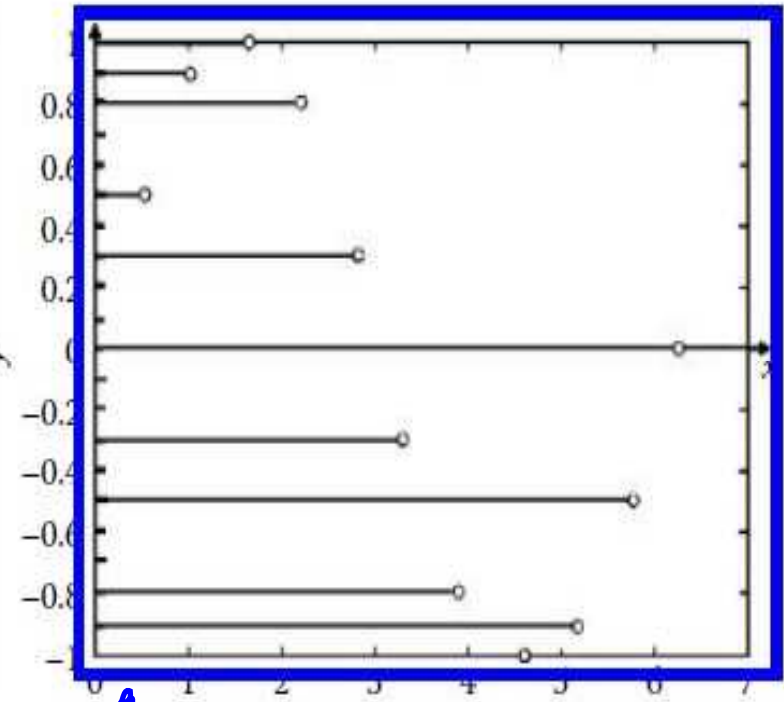


# Uniform Quantization

zero →



Quantization Process



Quantization Result



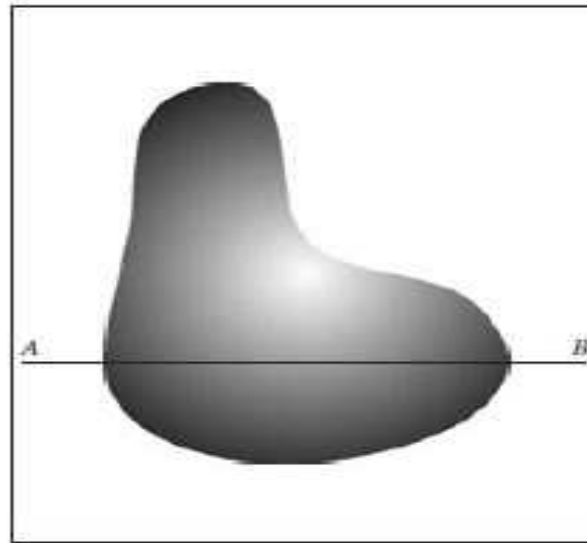
# Non-uniform Quantization

- Length of one interval, that is, the quantisation step, is not necessarily equal to that of another interval.

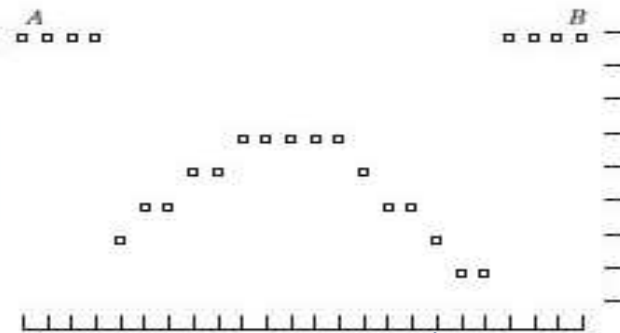
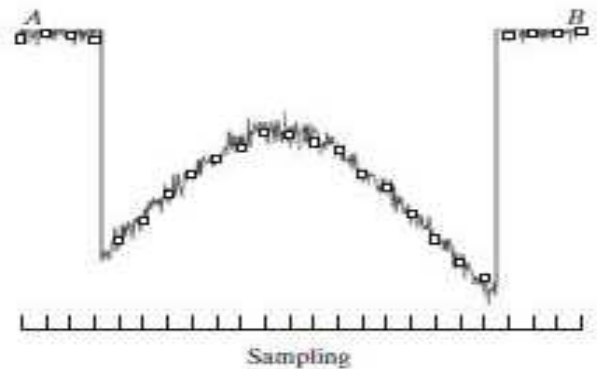
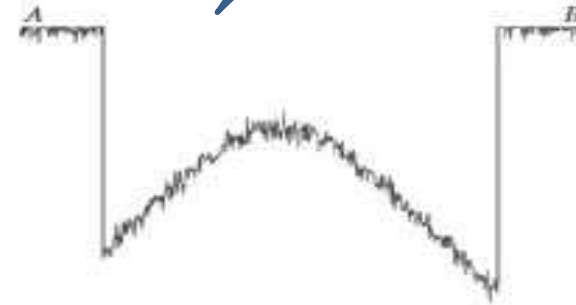


# Image Digitization

Continuous  
Image



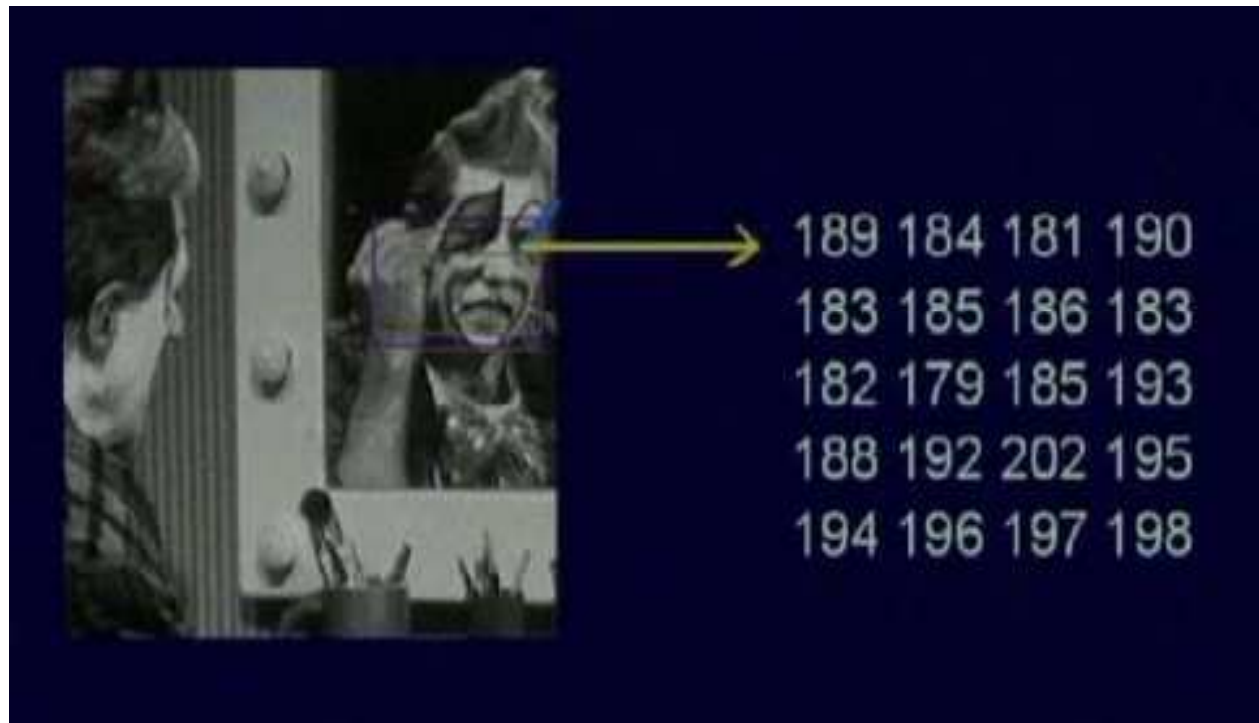
scan line  
from A to B



Digital scan  
line



# Image Digitization



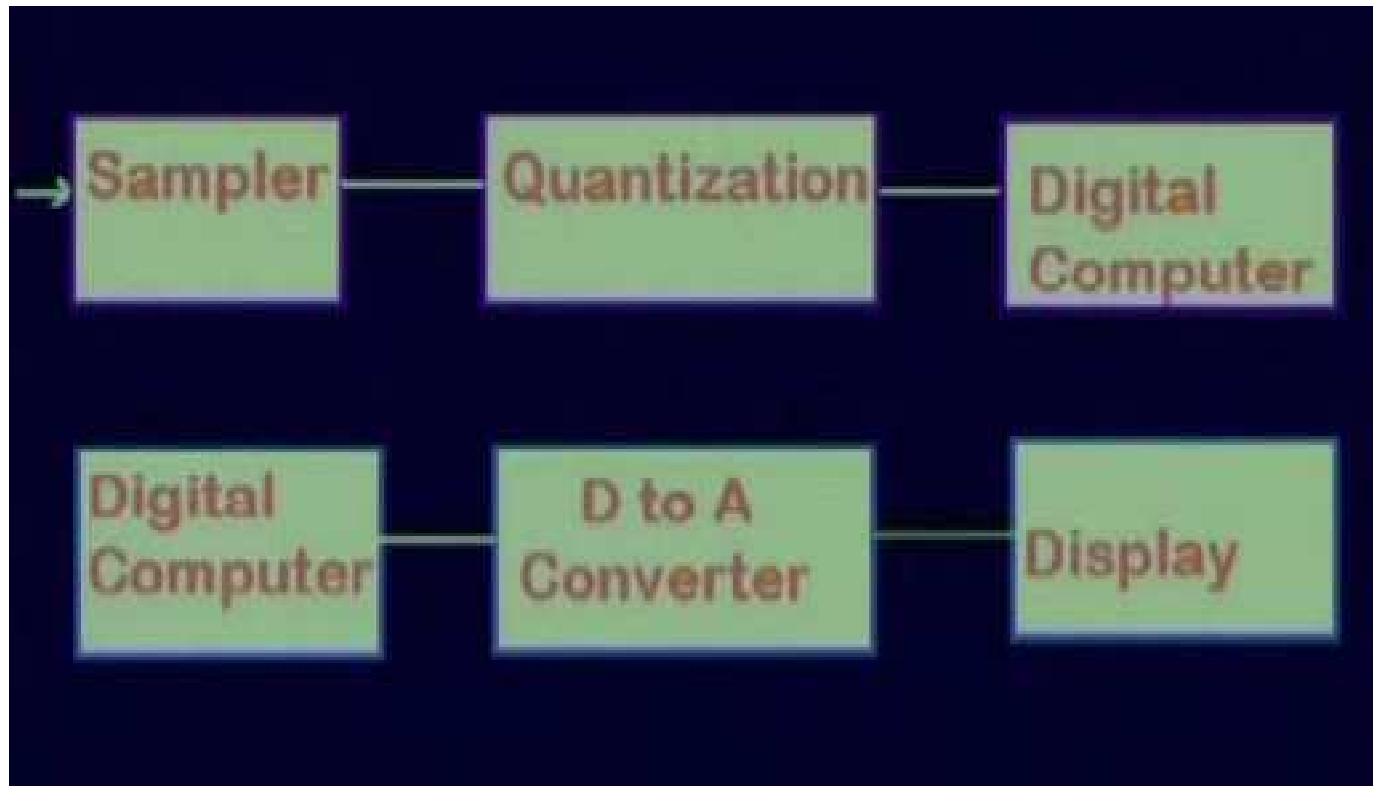


# Image Digitization

- **Sampling:** Digitizing the coordinate values
- **Quantization:** Digitizing the amplitude values



# Image Digitization





# Summary

- Analog Signals- simple, composite
- Digital Signals
- Need for Image digitization
- Sampling
- Quantization
- Image Digitization



# References

- Meiqing Wang, Choi-Honglai; A Concise Introduction to Image Processing Using C++;Chapman & Hall/CRC.
- Digital Image Processing, by Rafael Gonzalez and Richard Woods
- Digital Image Processing ,NPTEL course by Prabir Kumar Biswas, IIT Kharagpur