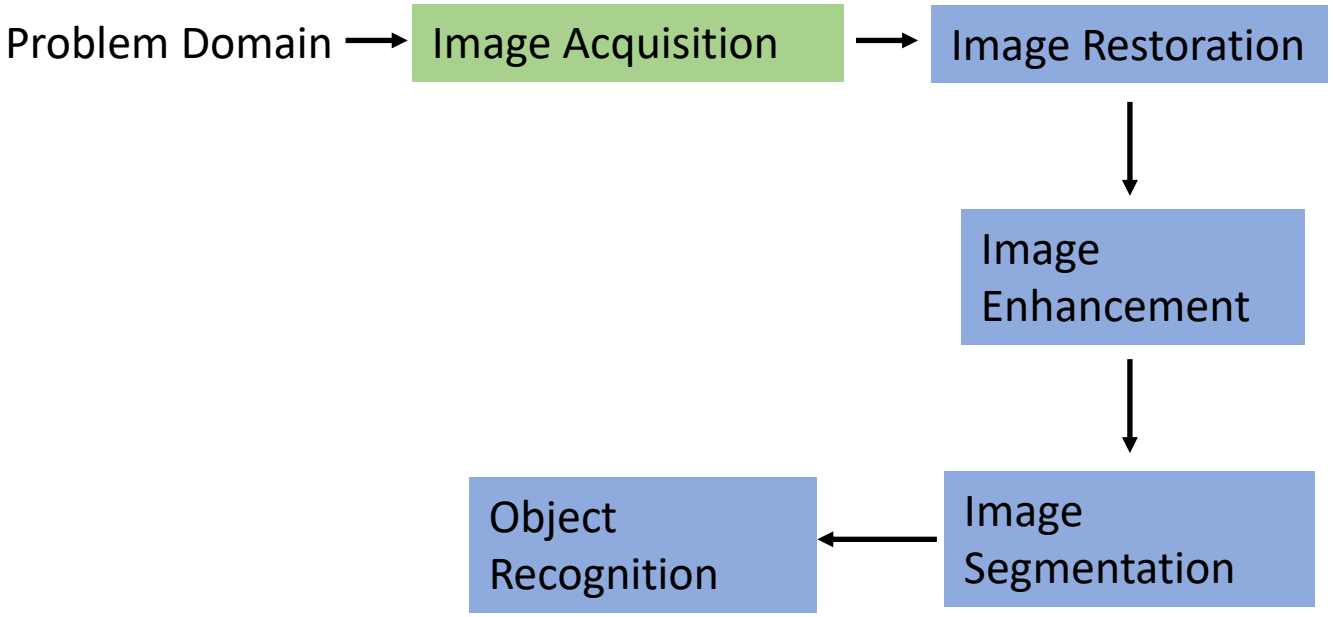
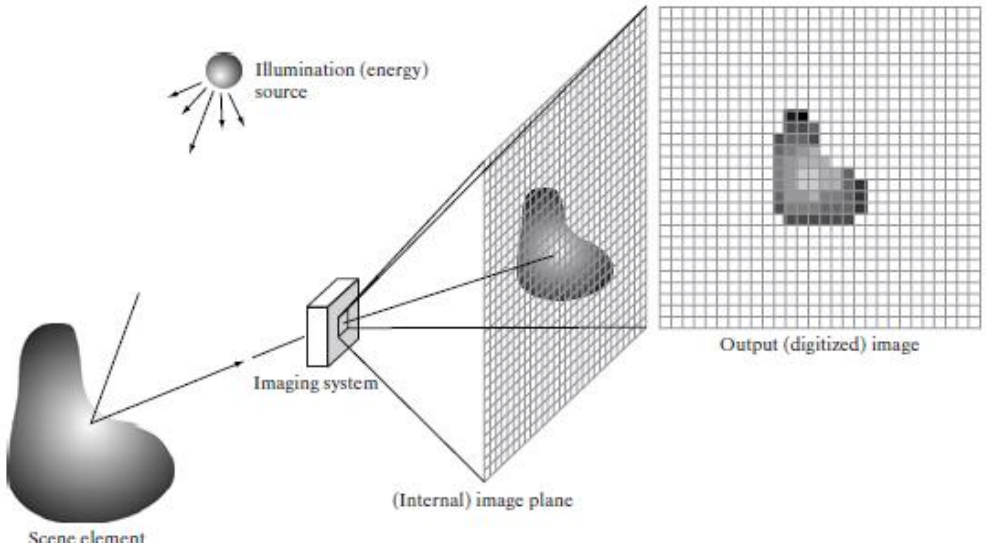
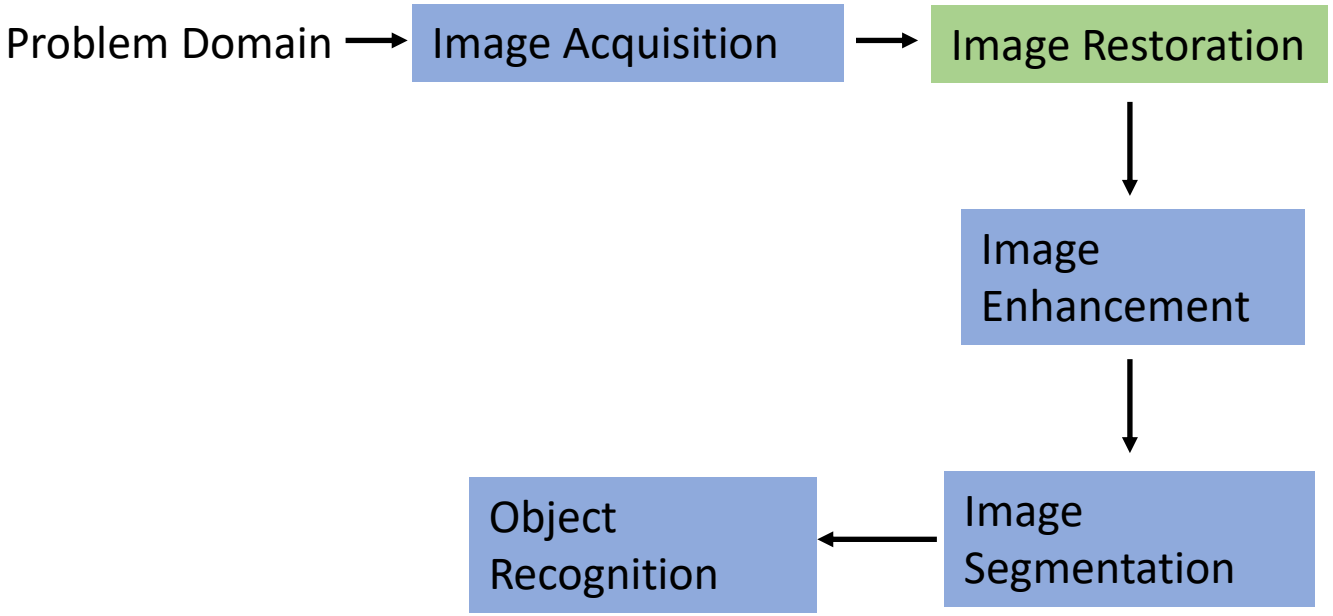
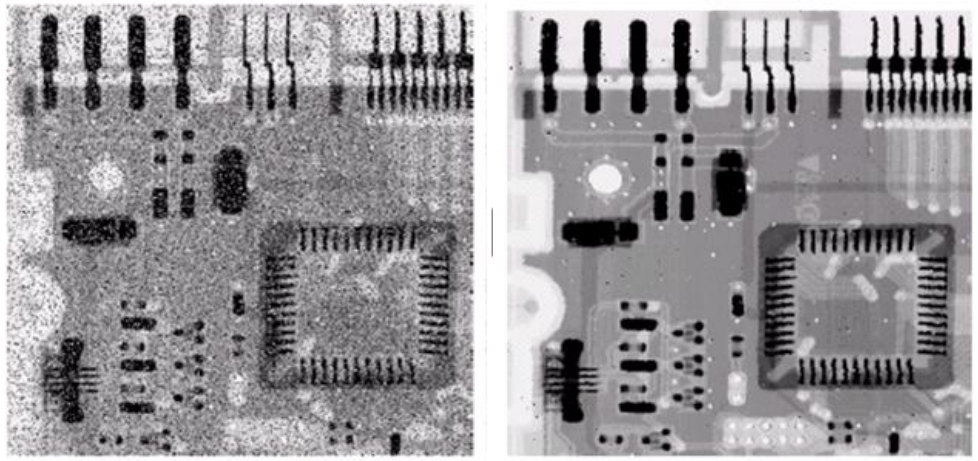
Key Stages in Digital Image Processing

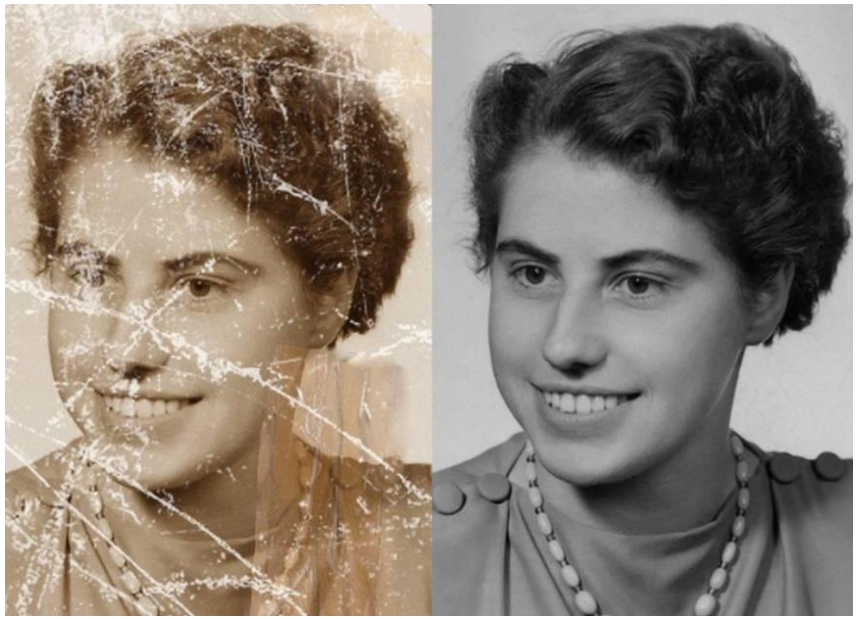




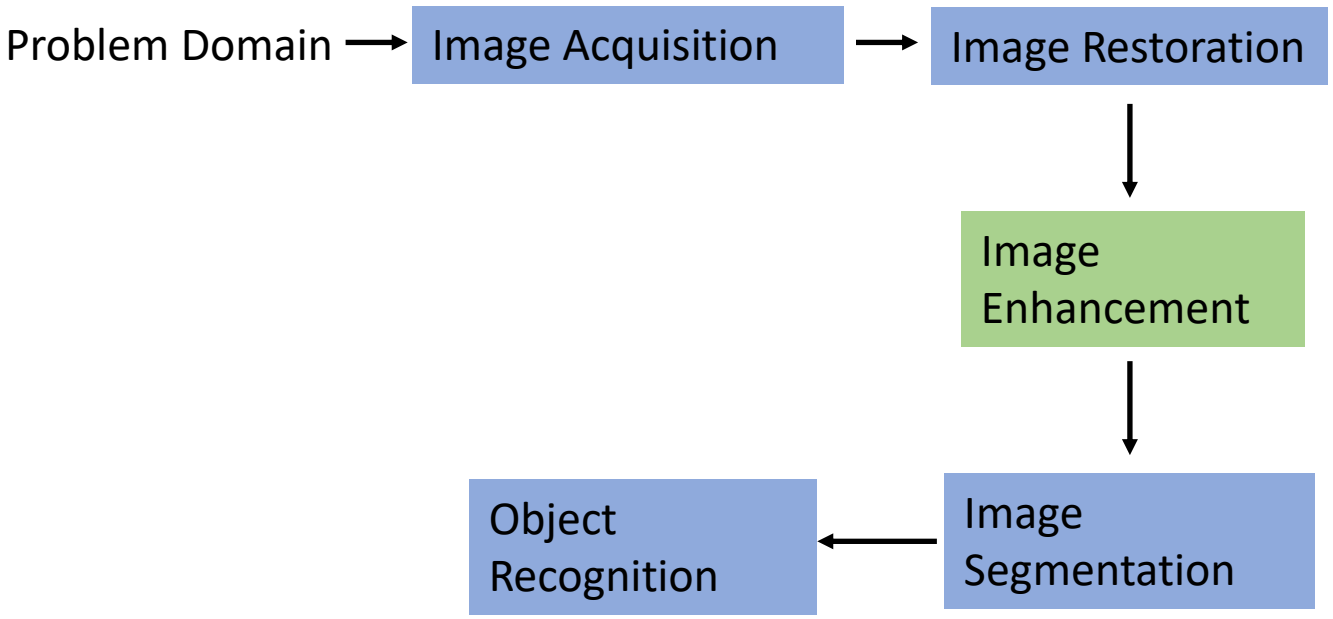
Key Stages in Digital Image Processing







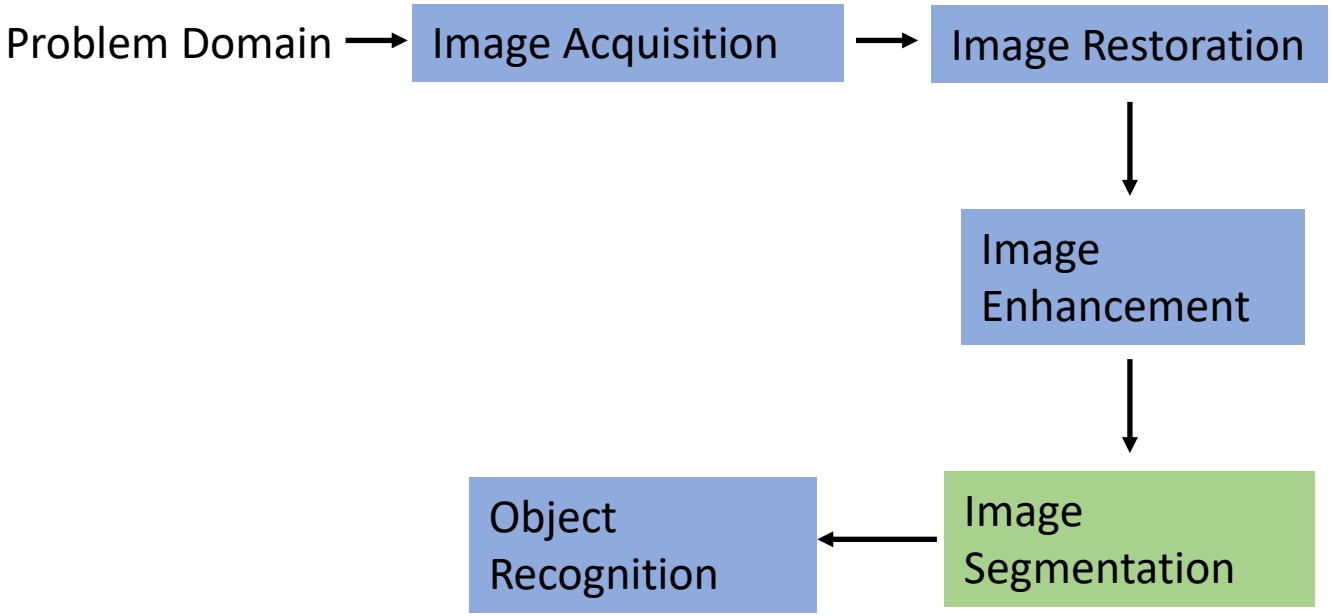
Key Stages in Digital Image Processing

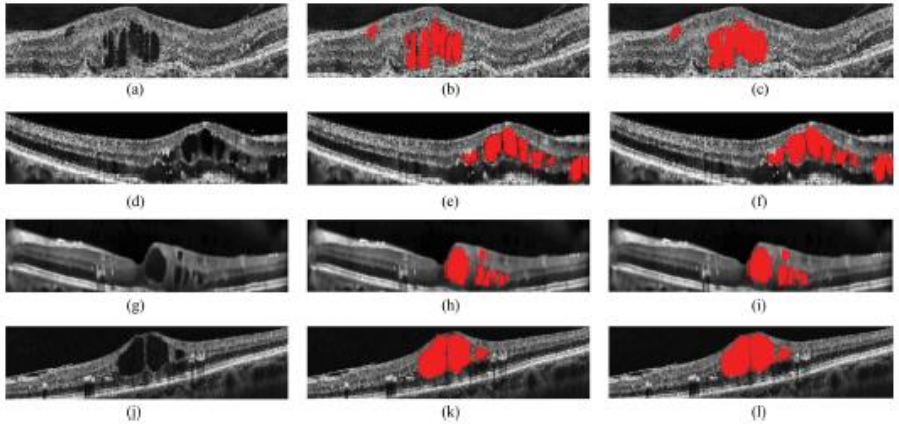


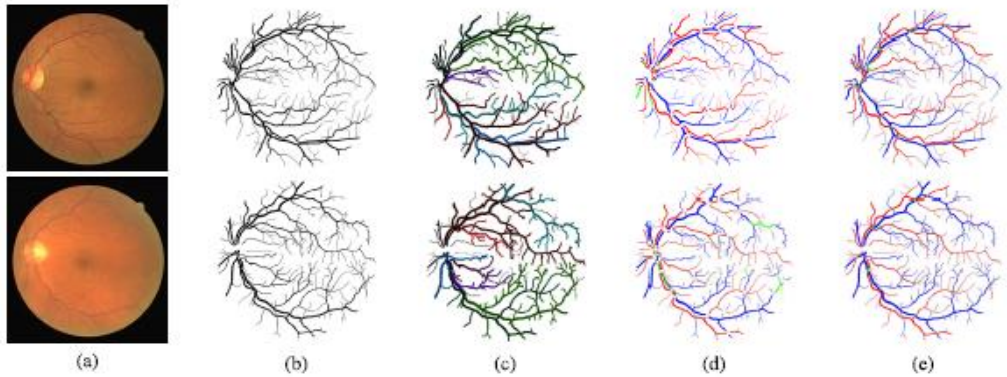
Original

Enhanced with SUACE

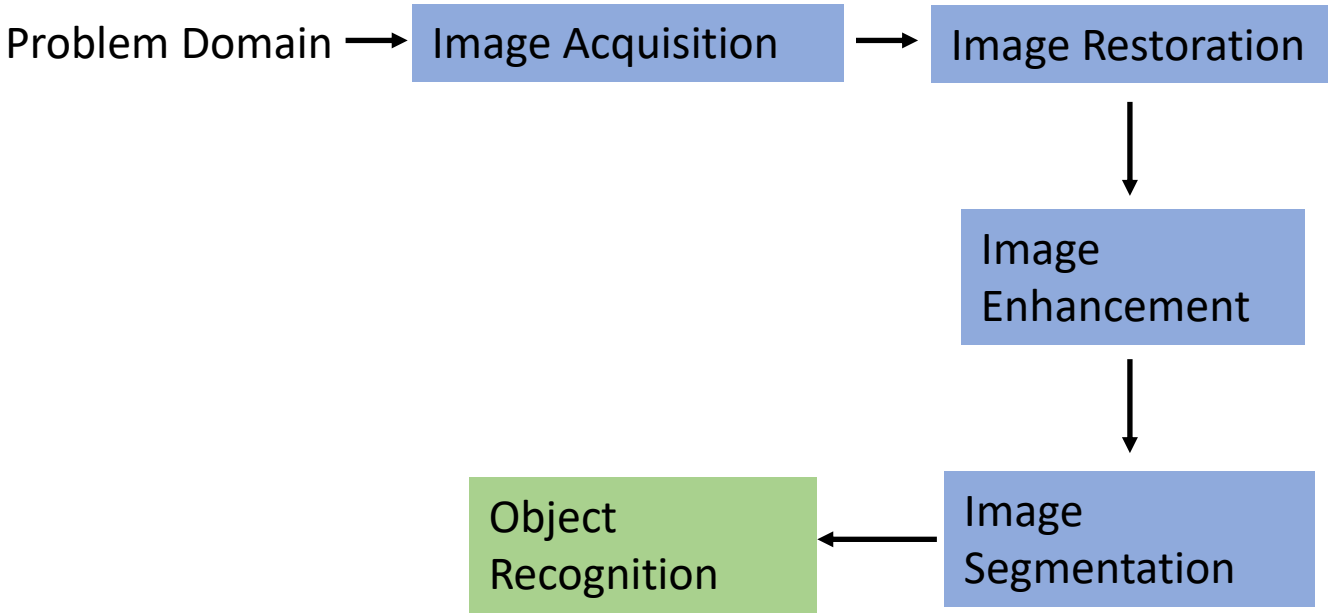
Key Stages in Digital Image Processing







Key Stages in Digital Image Processing



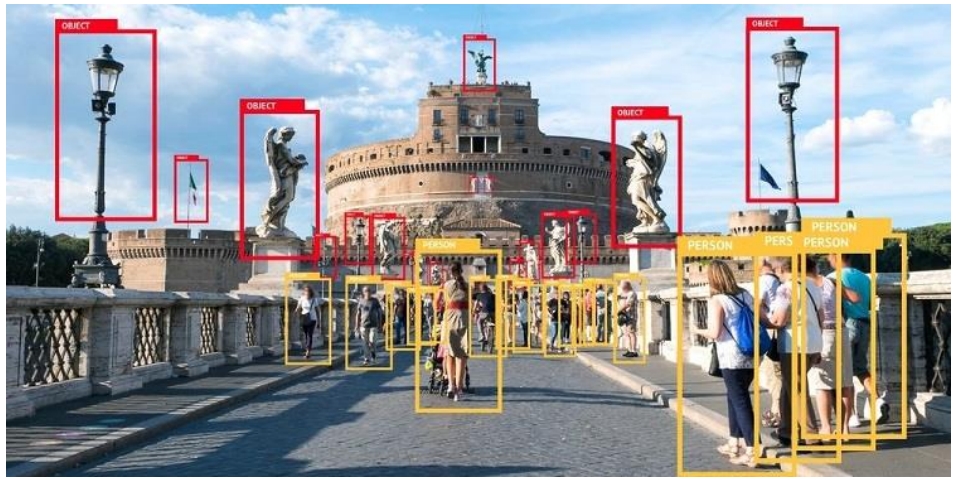


Table 1.1 Common image formats and their associated properties

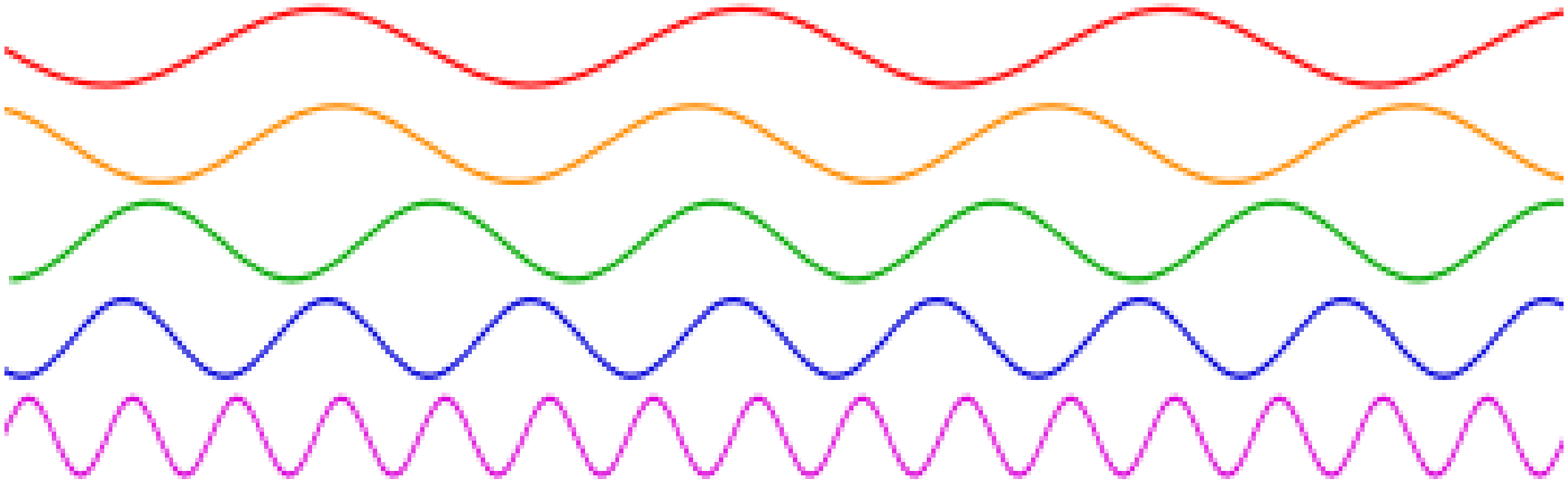
Acronym	Name	Properties
GIF	Graphics interchange format	Limited to only 256 colours (8 bit); lossless compression
JPEG	Joint Photographic Experts Group	In most common use today; lossy compression; lossless variants exist
BMP	Bit map picture	Basic image format; limited (generally) lossless compression; lossy variants exist
PNG	Portable network graphics	New lossless compression format; designed to replace GIF
TIF/TIFF	Tagged image (file) format	Highly flexible, detailed and adaptable format; compressed/uncompressed variants exist

How is an image formed?

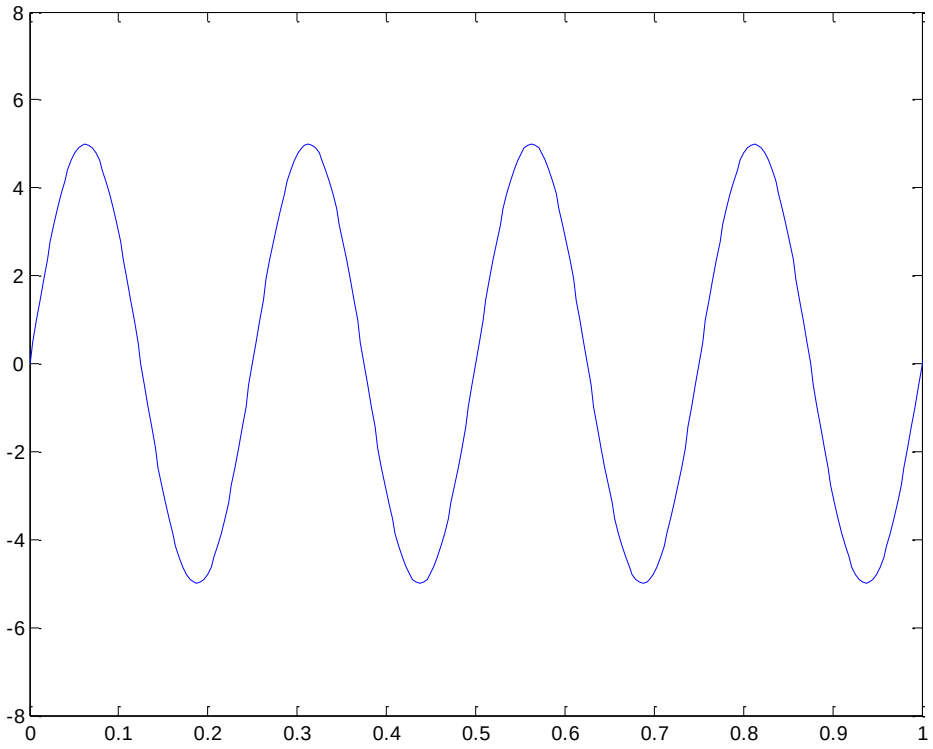
Image s can be formalized as a mathematical model comprising a functional representation of the scene (the object function o) and that of the capture process (the point spread function (PSF) p).

$$\text{Image} = \text{PSF} * \text{object function} + \text{noise}$$
$$s = p * o + n$$

- The **point spread function (PSF)** describes the response of an imaging system to a point source or point object.
- **Object function :** This describes the object (or scene) that is being imaged (its surface or internal structure, for example) and the way light is reflected from that structure to the imaging instrument.
- **Noise** : This is a nondeterministic function which can, at best, only be described in terms of some statistical noise distribution (e.g. Gaussian).
- **Convolution operator :** * A mathematical operation which convolves one function with another.



A sine wave



seconds

Amplitude = 5

Frequency = 4 Hz

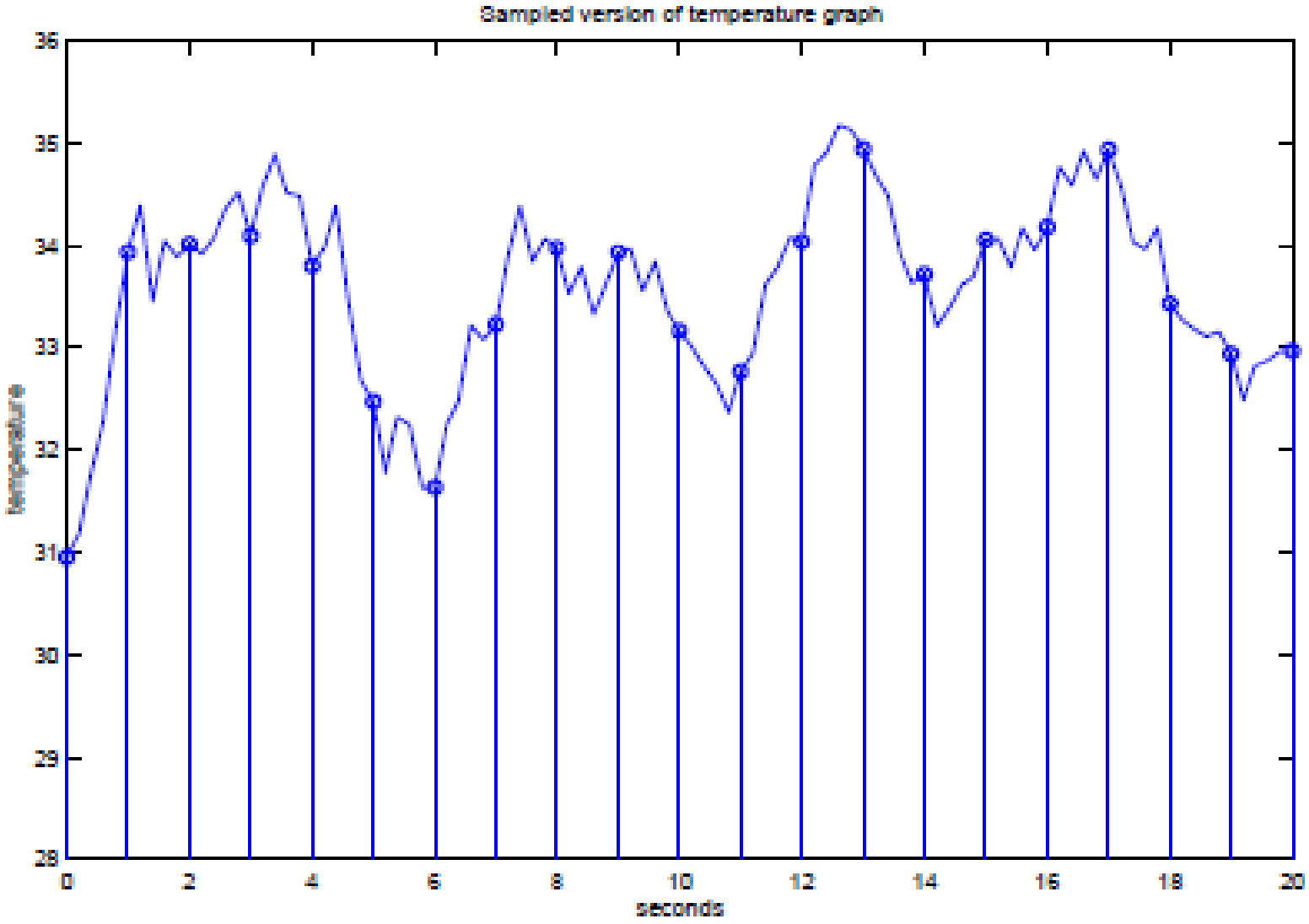


Figure 5.1: Sampling an analog signal.

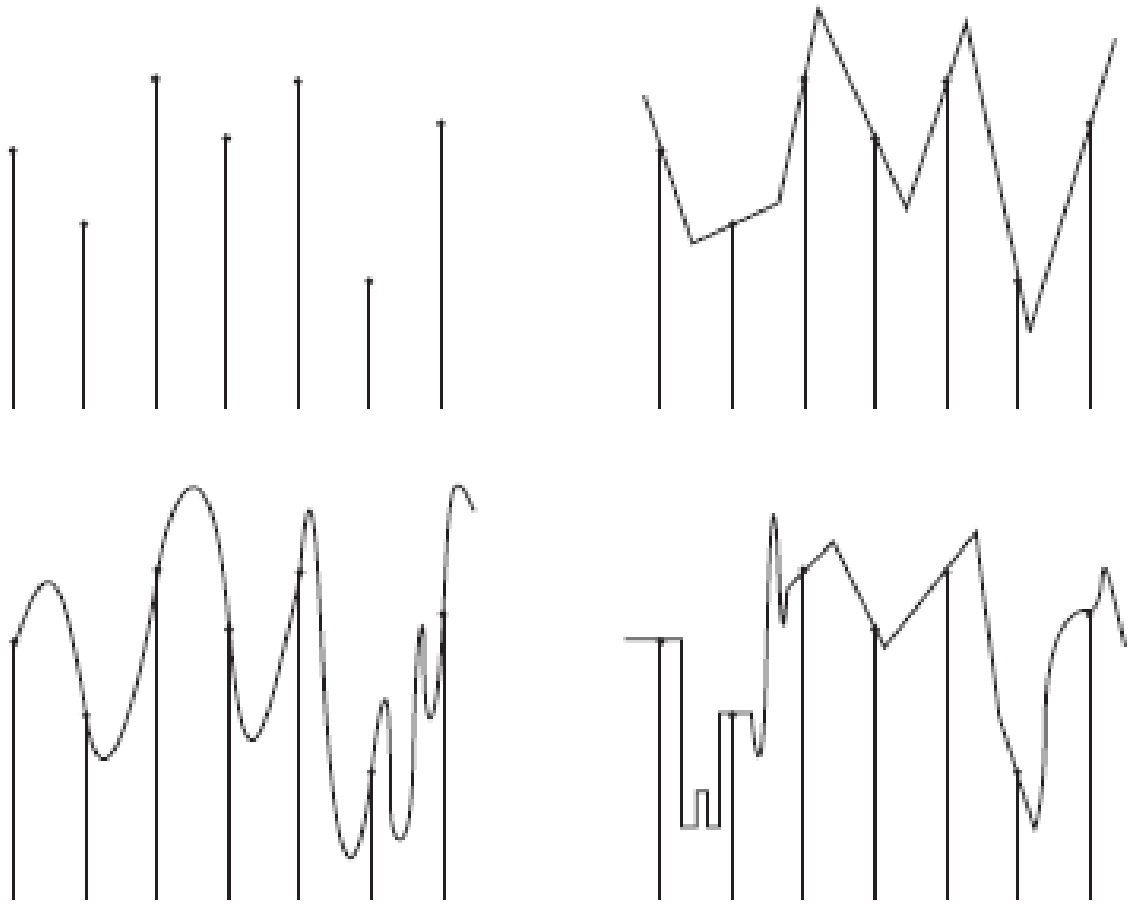
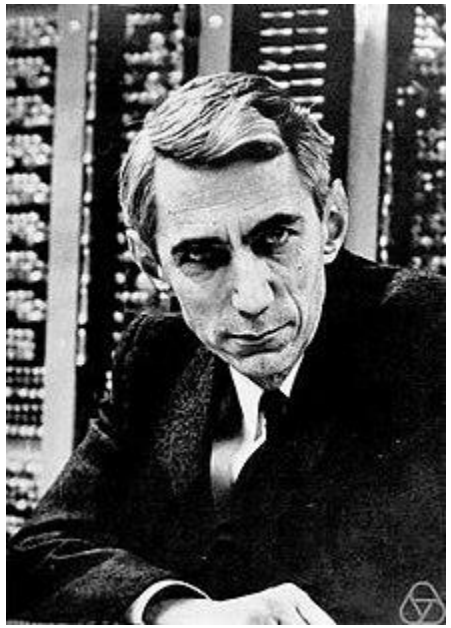


Figure 5.2: Possible continuous-time functions corresponding to samples.

$$\text{sampling interval} \leq \frac{1}{\text{Nyquist frequency}}$$

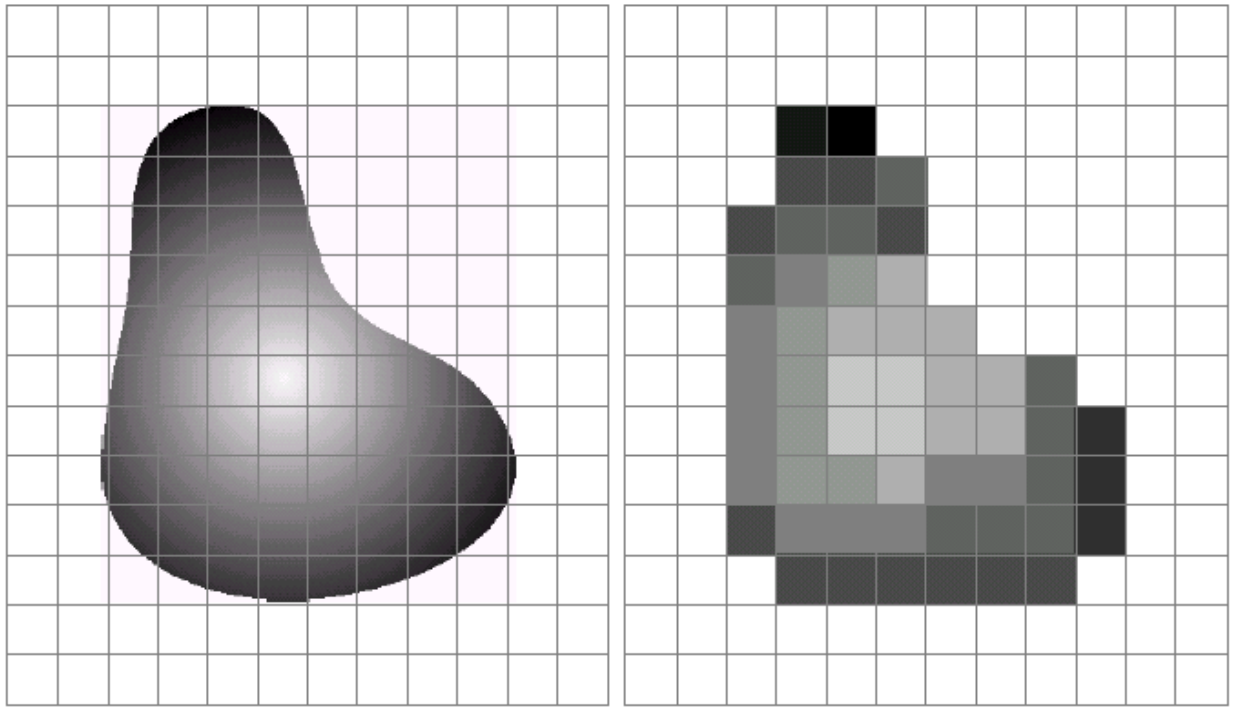
$$\text{Nyquist frequency} = 2 \times (\text{Maximum frequency in image})$$

Harry Nyquist



Claude Shannon

http://www2.egr.uh.edu/~glover/applets/Sampling/Sampling.html#:~:text=As%20the%20sampling%20frequency%20decreases,will%20crossover%20and%20cause%20aliasing.



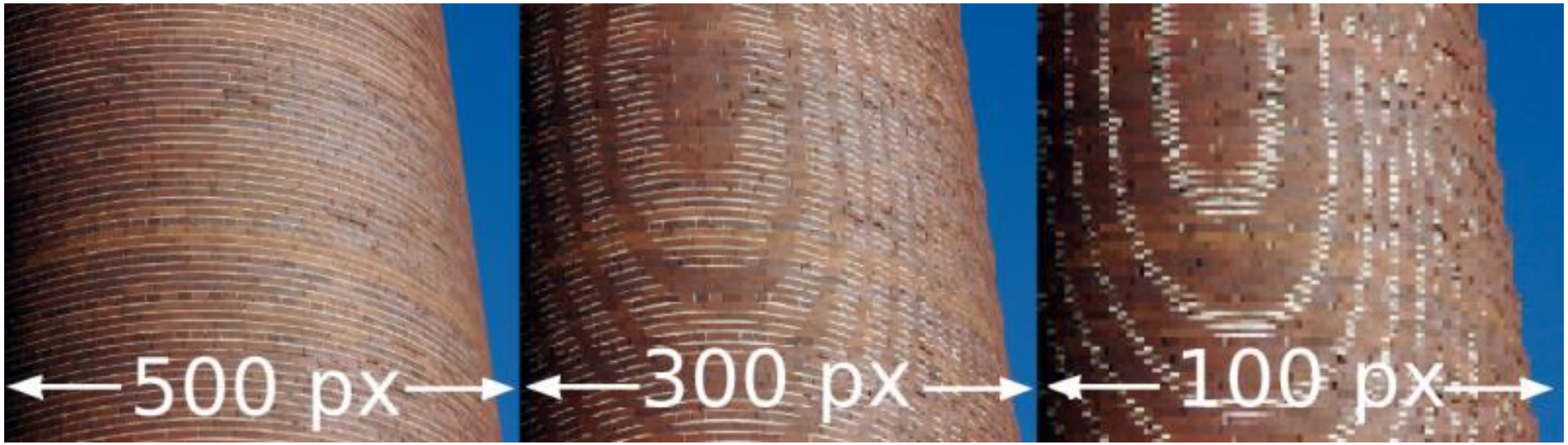
a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

a b

(a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

the imaging sample rate (or pixel) size should be 1/2 the size of the smallest object you wish to record.

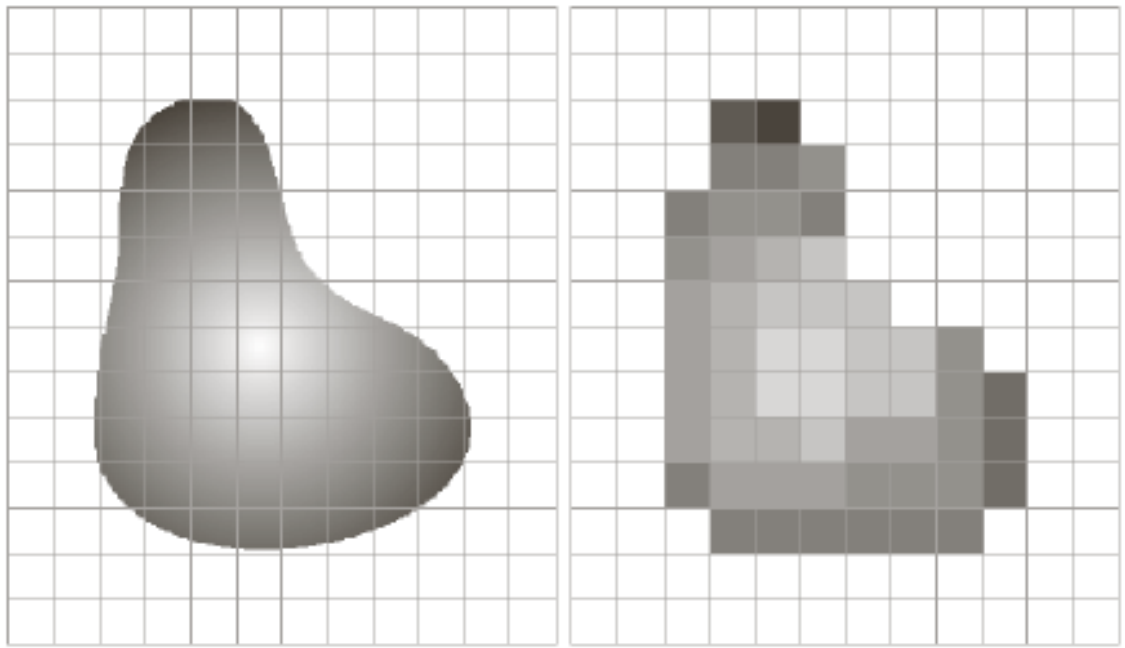


•Alaising is a phenomenon observed when the sample interval is not sufficiently brief to capture the higher range of frequencies in a signal.

•Aliasing can happen in space, as well as in time. When the pixels in this image are larger than half the width of the bricks, we see these beautiful curved artifacts.

- Digitalization of an analog signal involves two operations:
  - Sampling, and
  - Quantization.
- Both operations correspond to a discretization of a quantity, but in different domains.

- Sampling corresponds to a discretization of the space. That is, of the domain of the function, into $f : [1, \ldots, N] \times [1, \ldots, M] \longrightarrow \mathbb{R}^m$.



a b

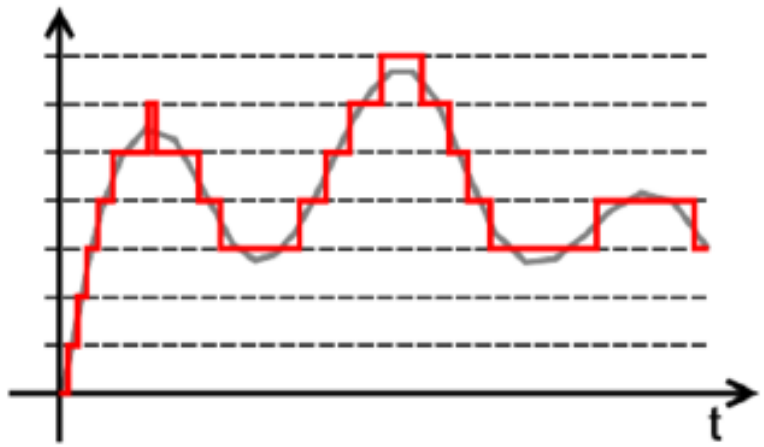
FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

- Thus, the image can be seen as matrix,

$$f = \begin{bmatrix} f(1,1) & f(1,2) & \cdots & f(1,M) \\ f(2,1) & f(2,2) & \cdots & f(2,M) \\ \vdots & \vdots & \ddots & \vdots \\ f(N,1) & f(N,2) & \cdots & f(N,M) \end{bmatrix}.$$

- The smallest element resulting from the discretization of the space is called a pixel (picture element).
- For 3-D images, this element is called a voxel (volumetric pixel).

- Quantization corresponds to a discretization of the intensity values. That is, of the co-domain of the function.



- After sampling and quantization, we get
  $f : [1, \ldots, N] \times [1, \ldots, M] \longrightarrow [0, \ldots, L]$.

Sampling

1024

512

256

128

64

32

Quantization

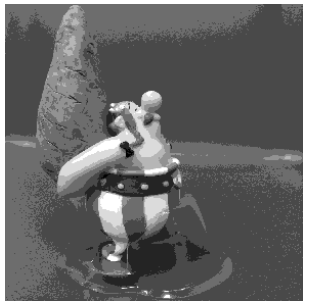
8-bit

7-bit

6-bit

5-bit

4-bit



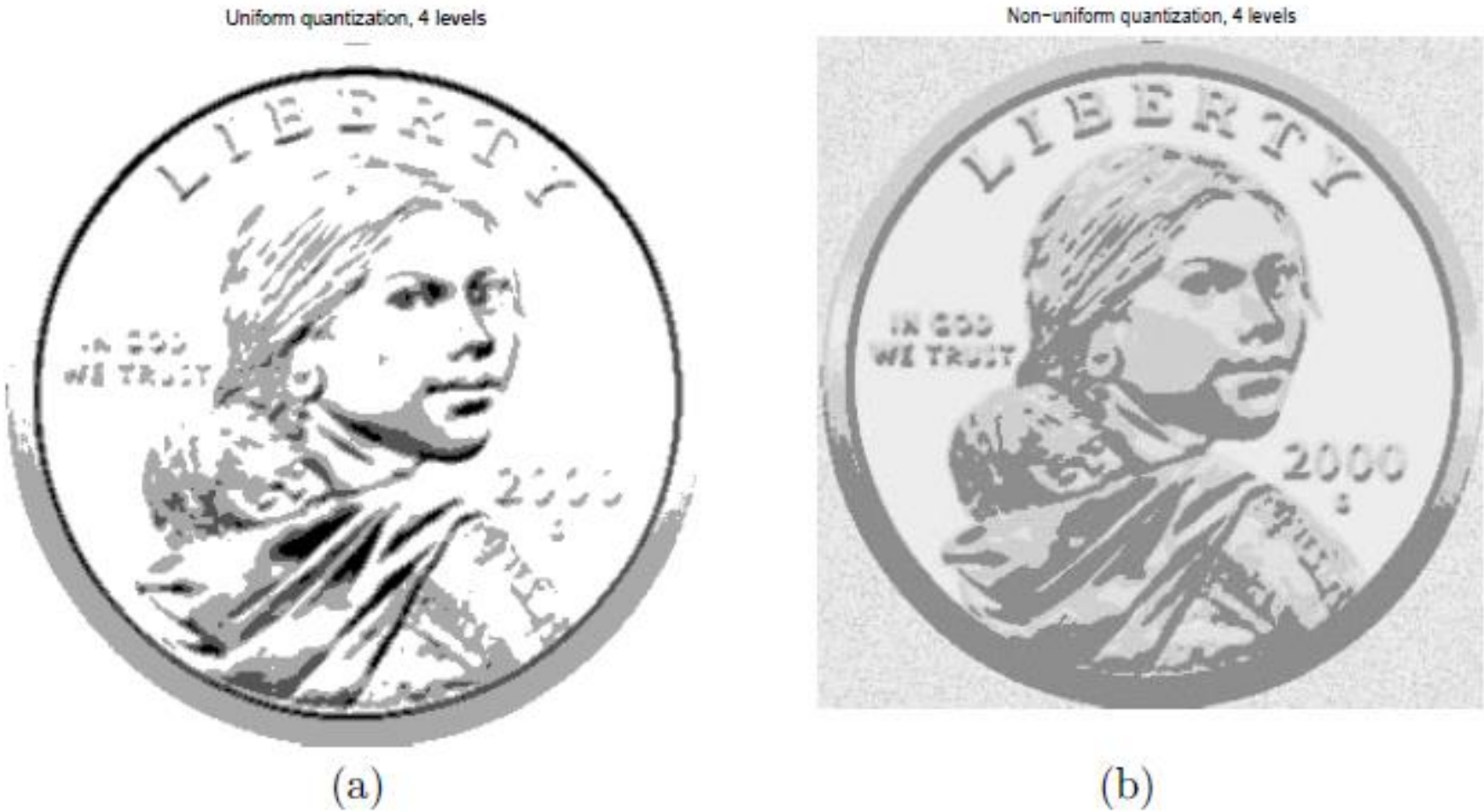
3-bit

2-bit

1-bit

(a) (b)

Figure 5.15: (a) Original image. (b) Image histogram.



(a) (b)

Figure 5.16: (a) Uniformly quantized image. (b) Non-uniformly quantized image