Digital Image formation

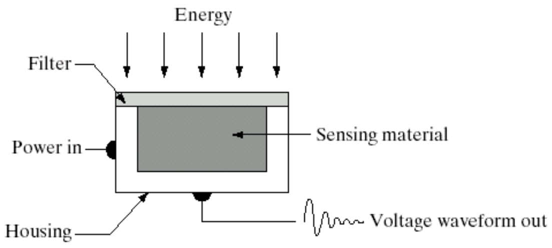
Sampling & Quantization

Fundamental steps in DIP

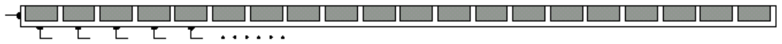
- Image Acquisition
- Image Filtering & Enhancement
- Image Restoration (dealing with any degradation)
- Color Image Processing
- Wavelets & Multiresolution Processing
- Compression
- Morphological Processing
- Segmentation
- Representation & Description
- Object Recognition

Image sensing and acquisition

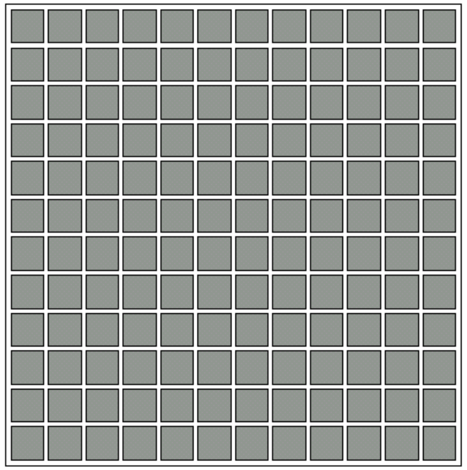
- Photoconvertor – energy into visible light



Single sensor



Line sensor



Array sensor

A simple image formation model

$f(x,y)$, $f>0$

The function f may represent intensity (for monochrome images) or color (for color images) or other associated values.

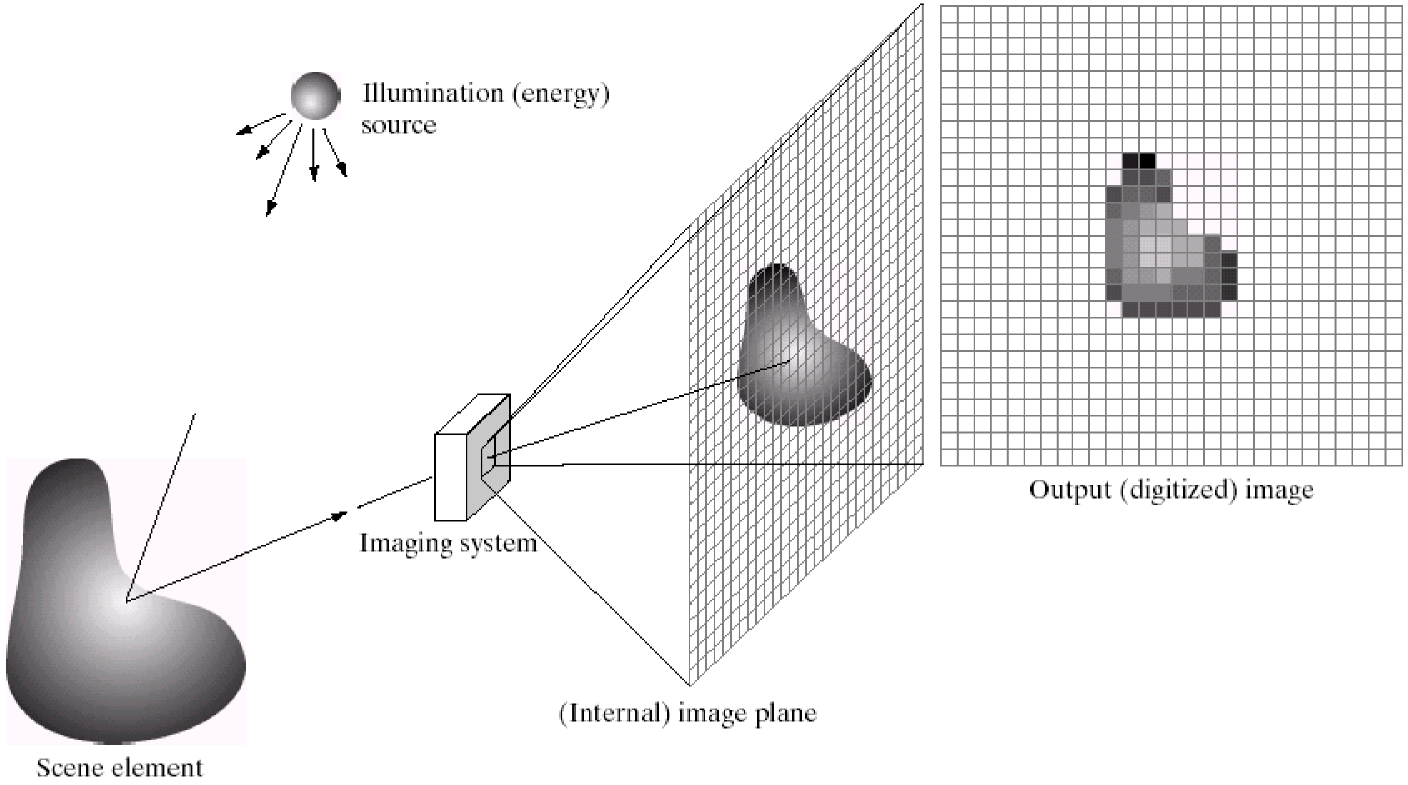
Intensity values are proportional to energy radiated by physical source

$0<f(x,y)<\infty$

$f(x,y) = i(x,y)*r(x,y)$

$0<i(x,y)<\infty$ and $0<r(x,y)<1$

Digital image acquisition



Generating a digital image

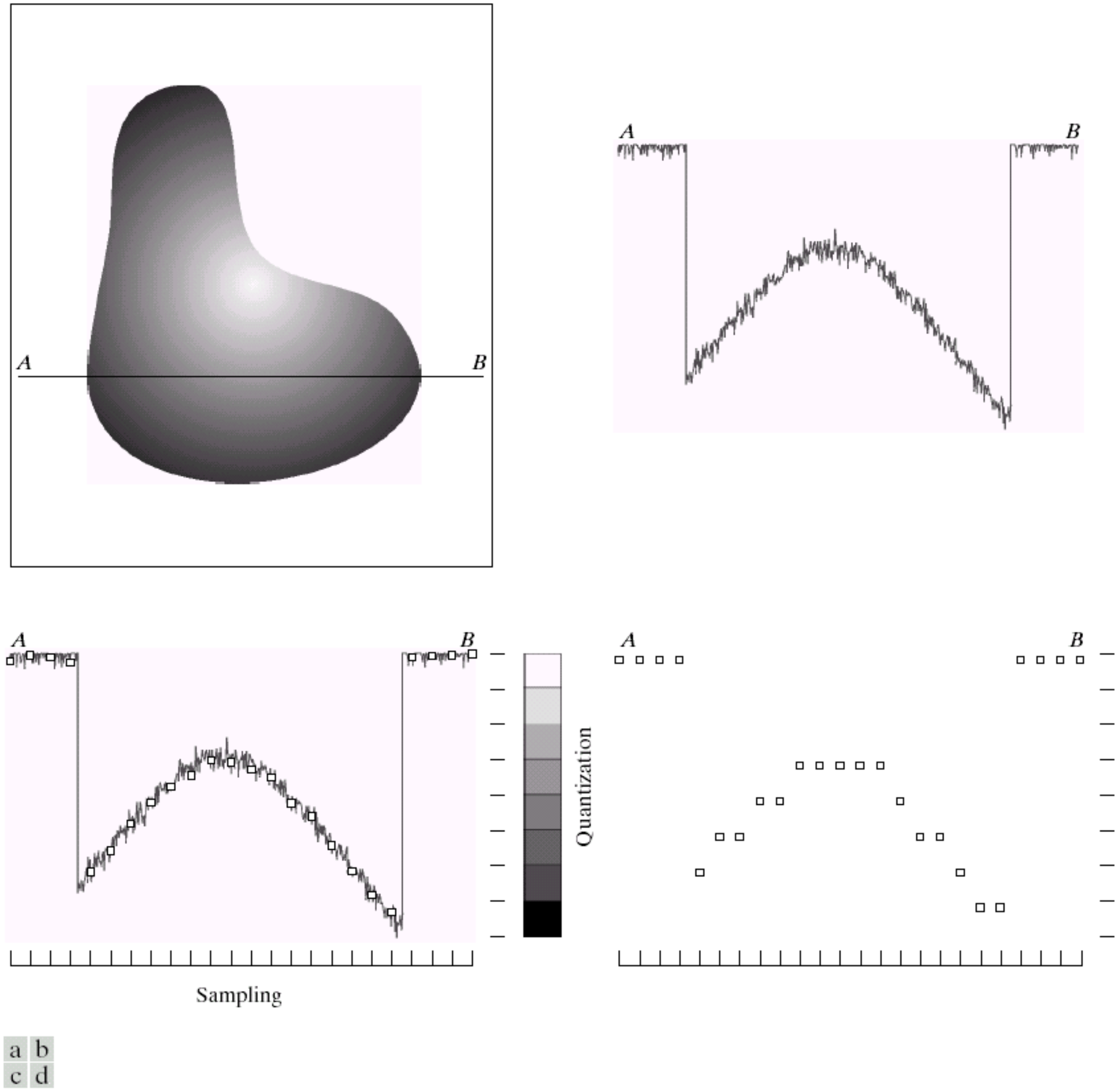


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image sampling and quantization

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

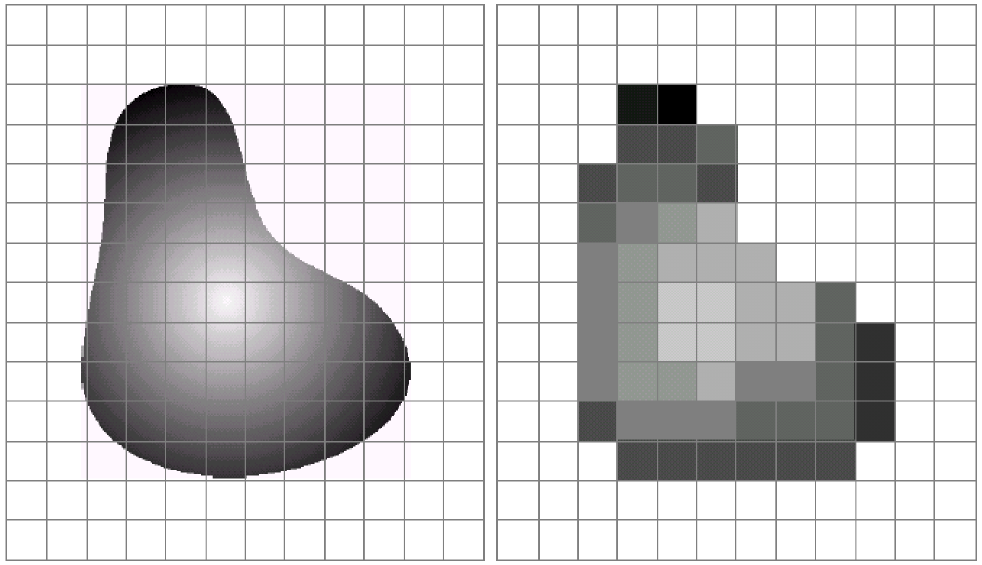


FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Spatial resolution / image resolution: pixel size or number of pixels

Representing digital images

f(s,t) : cont. image function of cont. variables s and t

Sample in 2-D array f(x,y) with M rows and N columns x = 0,1,…M-1

y=0,1,…N-1

f(0,0) : origin

Spatial domain

Spatial coordinates/spatial variables

Bits required to store a k-bit digitized image: b= k*M*N

- Dynamic range: max measurable intensity (saturation level)/min detectable intensity (noise)
- Image contrast : diff in intensity between highest and lowest intensity levels in an image
- Spatial resolution: Smallest discernible detail in image
- Intensity resolution: Smallest discernible change in intensity levels
- False contouring: Very low intensity levels contribute in “Ridge” like structure

Effect of spatial resolution


256x256 pixels


128x128 pixels


64x64 pixels

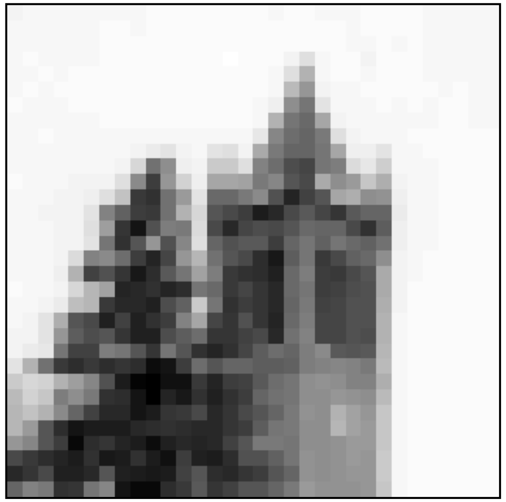

32x32 pixels

FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

Effect of spatial resolution

a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

Food for thought!

1. How does a camera convert light coming from a real object into a digital image that we see on a screen?
2. Why do we need to divide an image into small squares called pixels instead of storing it as one continuous picture?
3. What do you think happens to an image when the number of pixels is very small?
4. Why can two images of the same scene look different when one uses fewer brightness levels than the other?
5. Why does an image sometimes show artificial bands or step-like patterns instead of smooth shading?

AI supported self-learning on **Sampling & Quantization** (Prompts compatible with ChatGPT)

Active Learners (Learning by Doing)

1. Give me a small practice exercise on sampling and quantization in digital images. Ask me to predict the effect first, then explain the correct answer.
2. Create a simple numerical example showing how sampling and quantization work and let me solve part of it before you explain.

Reflective Learners (Learning by Thinking)

1. Explain sampling and quantization carefully and step by step, and summarize the key ideas at the end.
2. Explain why sampling and quantization are necessary in digital image formation, and how each step affects image quality.

Sensing Learners (Concrete & Practical)

1. Explain sampling and quantization using real numerical values and simple grayscale examples. Avoid abstract theory.
2. Show practical examples of under-sampling and low-bit quantization and explain the visible effects.

Intuitive Learners (Concepts & Patterns)

1. Explain the concepts behind sampling and quantization and the patterns they create in digital images. Focus on ideas, not formulas.
2. Explain how sampling and quantization relate to information representation and why these ideas are important beyond image processing.

Visual Learners (Diagrams & Structure)

1. Explain sampling and quantization using diagrams, tables, or structured layouts. Show how a continuous image becomes a digital image.
2. Use visual representations or stepwise illustrations to show the effect of changing sampling rate and bit depth.

Verbal Learners (Words & Explanation)

1. Explain sampling and quantization in clear, simple language using everyday analogies and descriptions.
2. Explain the difference between sampling and quantization as if teaching it to someone with no background in image processing.

Sequential Learners (Step-by-Step Logic)

1. Explain the formation of a digital image step by step, starting from a continuous scene to a fully digital image, clearly separating sampling and quantization.
2. List the steps involved in sampling and quantization and explain the effect of each step

Global Learners (Big Picture First)

1. First explain the overall idea of digital image formation, then explain how sampling and quantization fit into the big picture.
2. Explain why sampling and quantization are critical to digital imaging systems before going into detailed explanations.