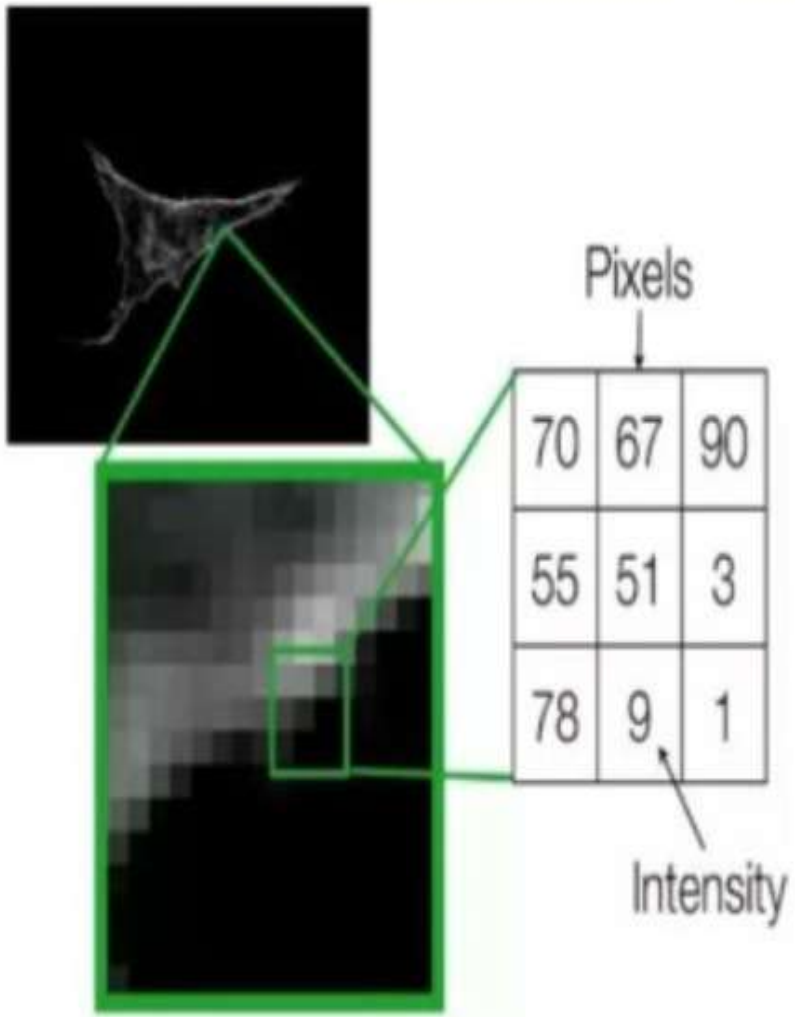
Image Processing and Computer Vision – I

WHAT IS DIGITAL IMAGE PROCESSING?

- What is an image?
  - A two-dimensional function, f(x, y):
    - x and y are spatial (plane) coordinates
    - amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point
- What is a digital image?
  - When x, y, and the intensity values of f are all finite, discrete quantities
- What is digital image processing?
  - Processing digital images using a digital computer
- What is a pixel?
  - A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called picture elements.

WHAT IS DIGITAL IMAGE PROCESSING?

- Hence, an image is a 2D matrix with a measurement of gray-scale intensity.
- You can change the image if you change the magnitude of intensity at any point in the plane.
- **Spatial Domain:** This state of 2D matrices that depict the intensity



WHAT IS DIGITAL IMAGE PROCESSING?

- What is the difference between human vision and digital images?
  - Unlike humans, imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves and not only the visual spectrum.
  - These include ultrasound, electron microscopy, and computer-generated images – wide variety of applications?
- What is image processing?
  - Low-level processing: primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening

WHAT IS DIGITAL IMAGE PROCESSING?

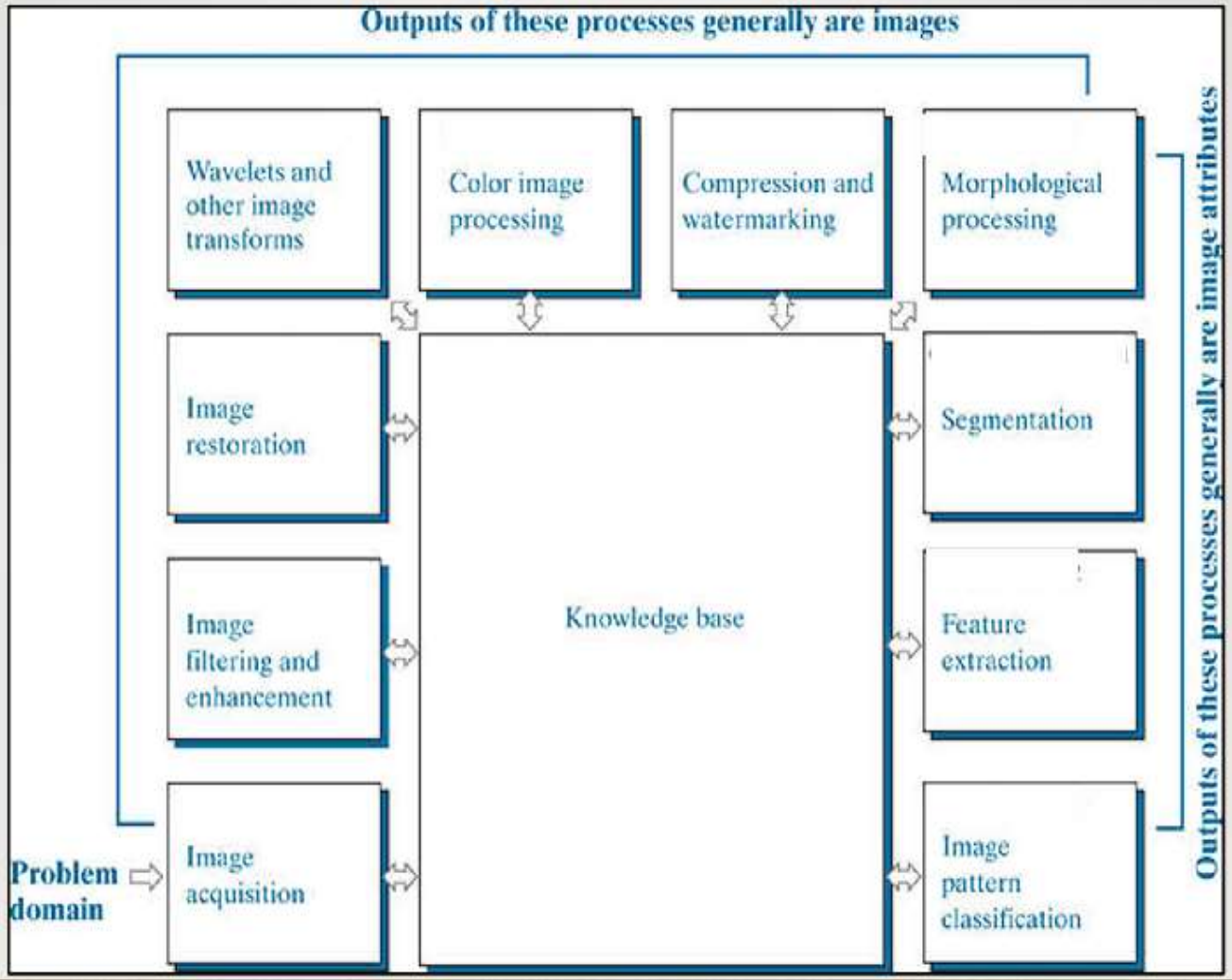
- What is image processing?
  - Mid-level processing: characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects)
    - Tasks such as segmentation, reduce them to a form suitable for computer processing, and classification (recognition) of individual objects
  - High-level processing: "making sense" of an ensemble of recognized objects
- Digital image processing uses digital computers

WHAT IS DIGITAL IMAGE PROCESSING?

- What is the goal of computer vision?
  - To use computers to emulate human vision, including learning and being able to make inferences and take actions based on visual inputs
  - Actually, a part of AI

- However, there are no clear-cut boundaries between the two divisions

DIGITAL IMAGE PROCESSING STEPS



DIGITAL IMAGE PROCESSING STEPS

1. **IMAGE ACQUISITION**
   - Could be as simple as being given an image that is already in digital form
   - Generally, the image acquisition stage involves preprocessing, such as scaling

2. **IMAGE ENHANCEMENT**
   - Manipulating an image so the result is more suitable than the original for a **specific** application
   - Enhancement techniques are varied and use different approaches
   - When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works

DIGITAL IMAGE PROCESSING STEPS

3. **IMAGE RESTORATION**
   - Also deals with improving the appearance of an image
   - Difference between restoration and enhancement?
     - Enhancement is subjective while restoration is objective
   - Restoration techniques tend to be based on mathematical or probabilistic models

4. **WAVELETS**
   - Foundation for representing images in various degrees of resolution
   - Wavelet Image Processing enables computers to store an image in many scales of resolutions, thus decomposing an image into various levels and types of details
   - At a high level, this processing is the same as a human eye

DIGITAL IMAGE PROCESSING STEPS

5. **COLOR IMAGE PROCESSING**
   - Color is used also as the basis for extracting features of interest in an image

5. **COMPRESSION**
   - What is compression?
     - techniques for reducing the storage required to save an image OR
     - the bandwidth required to transmit it.
   - Image compression is familiar to most users of computers in the form of image file extensions, such as the jpg file
   - Although storage technology has improved significantly, the same cannot be said for transmission capacity.

DIGITAL IMAGE PROCESSING STEPS

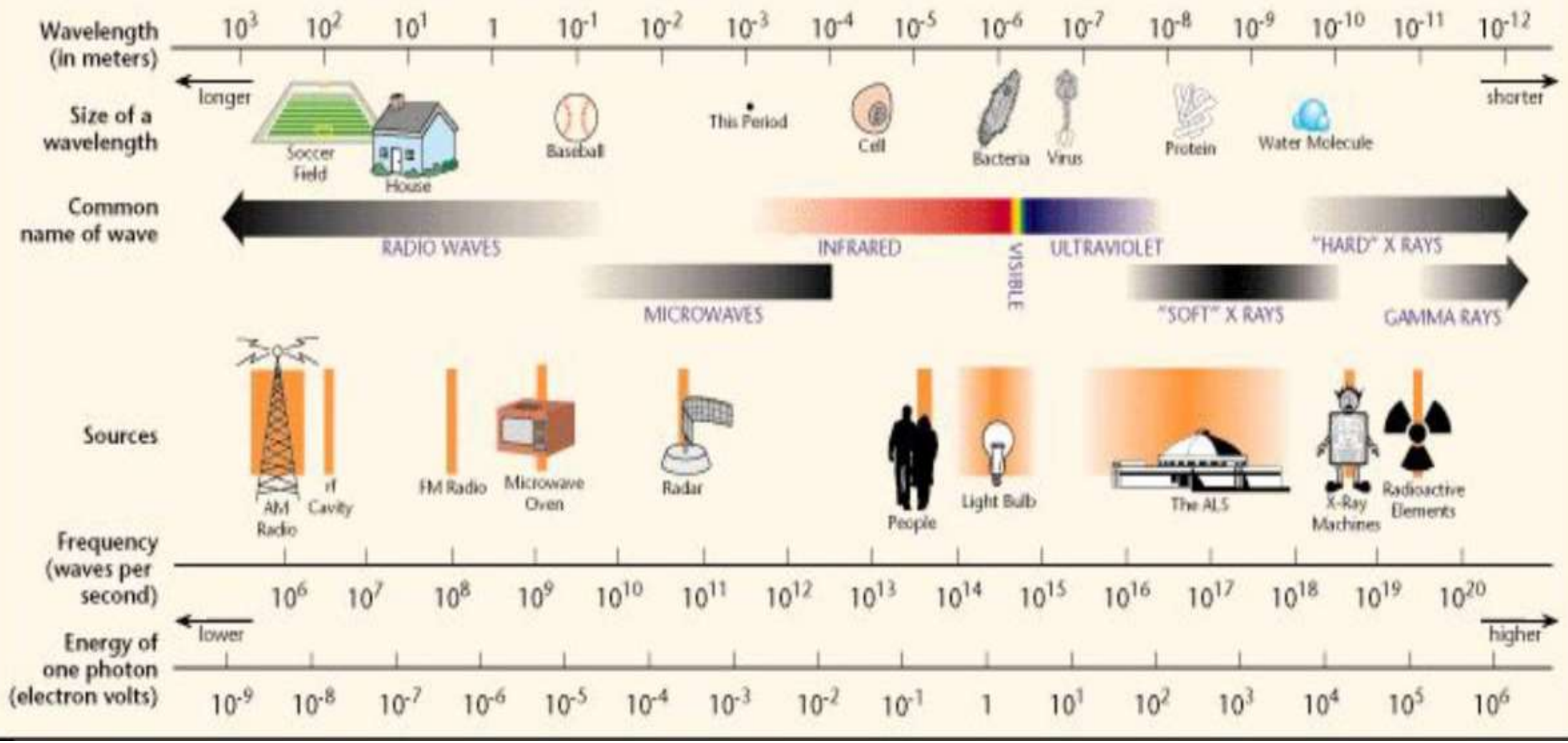
7. **MORPHOLOGICAL PROCESSING**
   - Tools for extracting image components that are useful in the representation and description of shape
8. **SEGMENTATION**
   - Partitions an image into its constituent parts
   - Autonomous segmentation is one of the most difficult tasks in digital image processing
   - The more accurate the segmentation, the more likely automated object classification is to succeed.

DIGITAL IMAGE PROCESSING STEPS

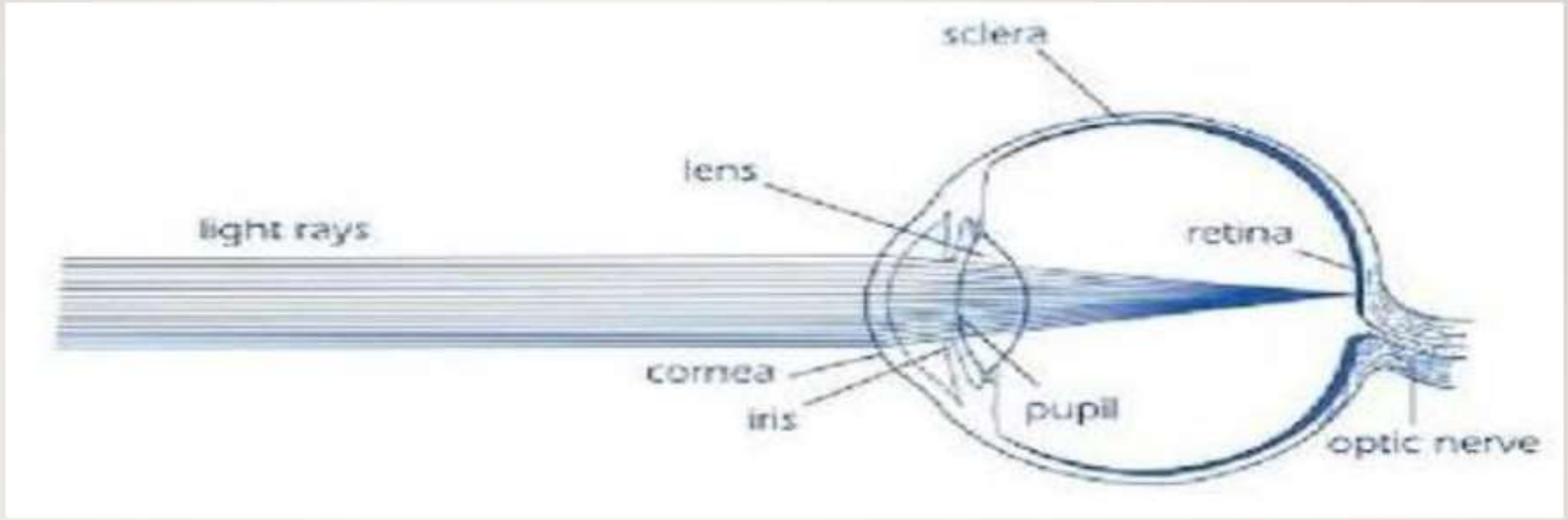
9. **FEATURE EXTRACTION**
   - Almost always follows the output of a segmentation stage
   - Constitutes either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself
   - Consists of:
     i. **Feature detection:** finding the features in an image, region, or boundary
     ii. **Feature description:** assigns quantitative attributes to the detected features

10. **IMAGE PATTERN CLASSIFICATION**
    - Process that assigns a label (e.G., "Vehicle") to an object based on its feature descriptors

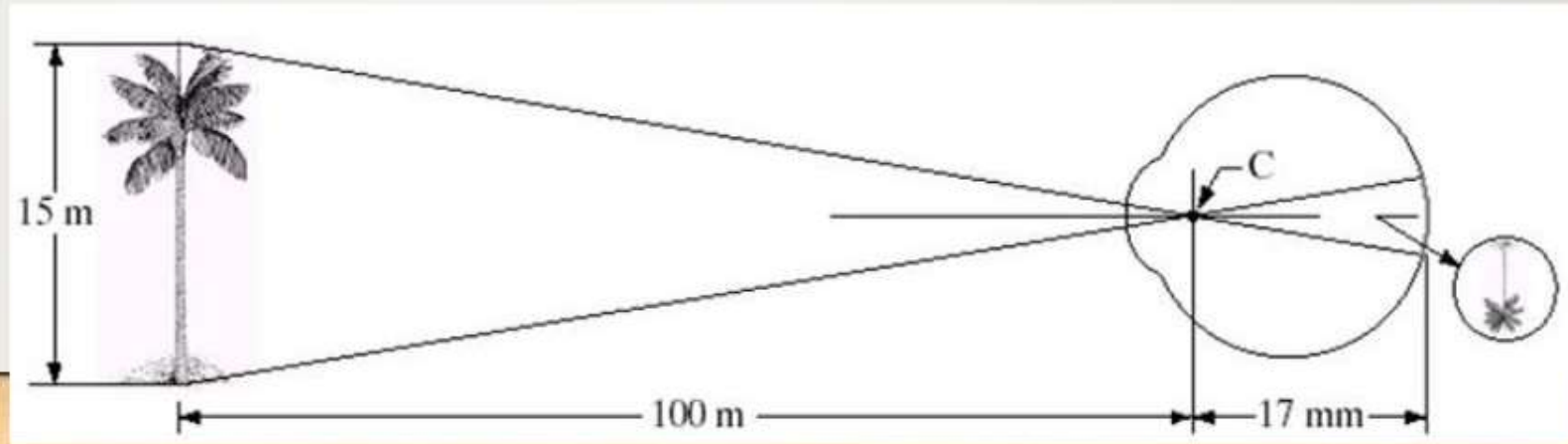
THE ELECTROMAGNETIC SPECTRUM



BASICS OF VISUAL SYSTEM



C: Optical center of the lens



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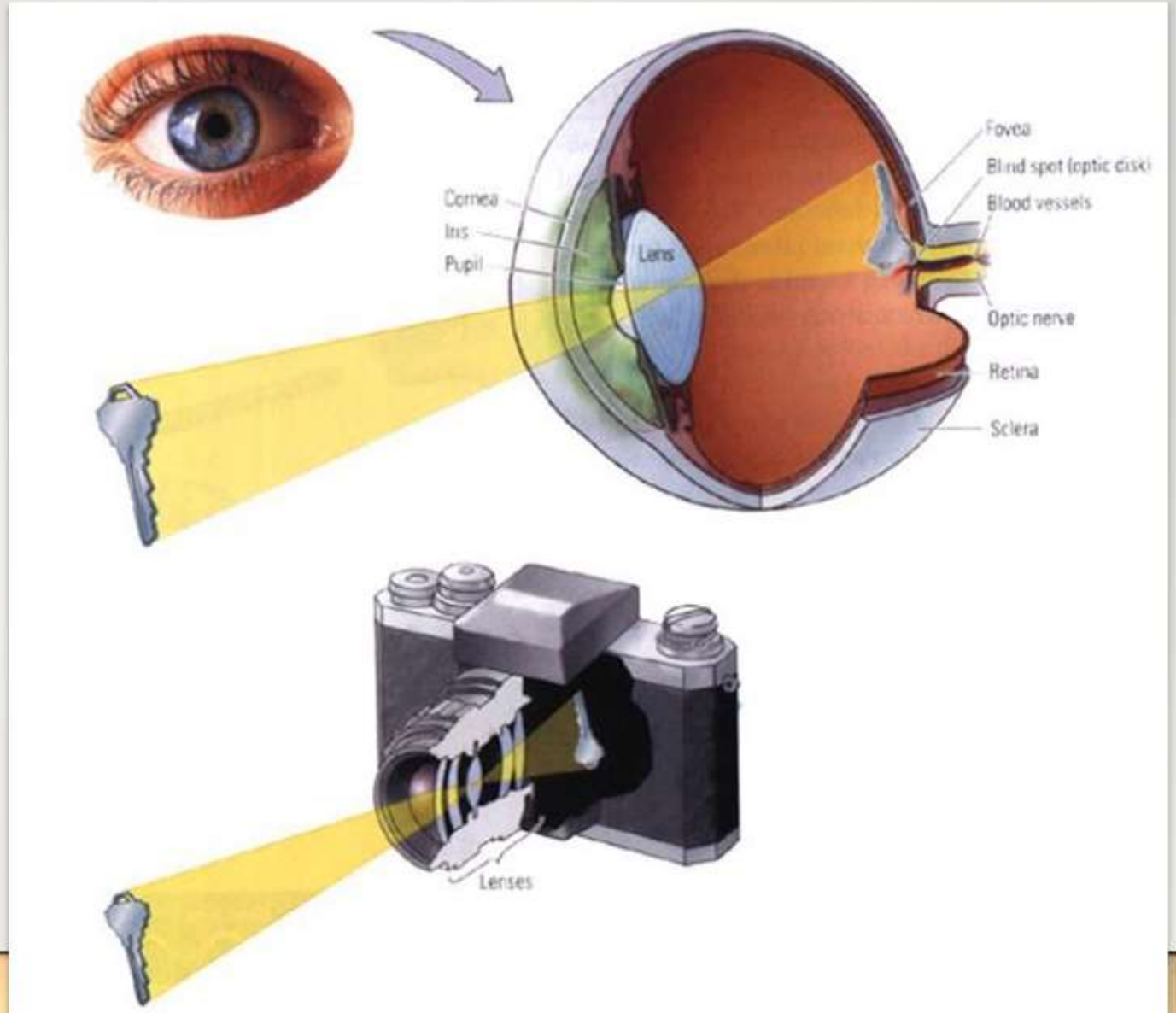
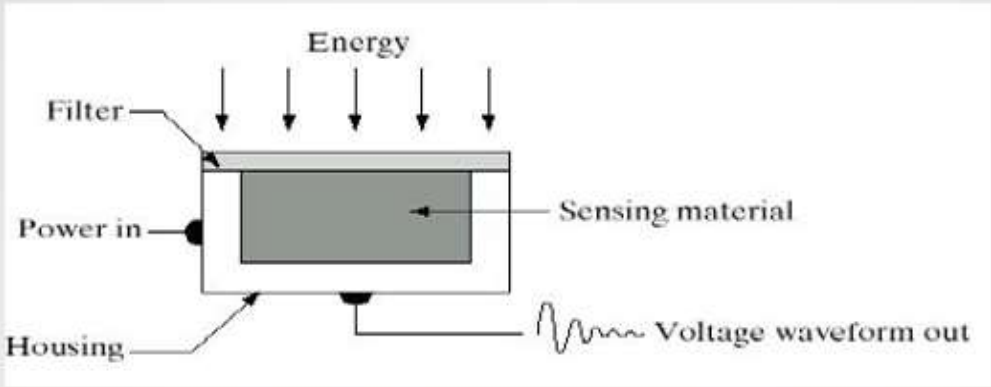
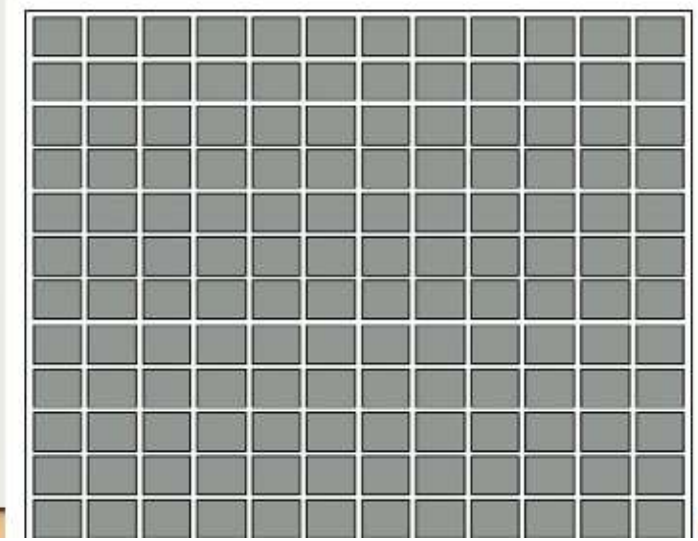


IMAGE SENSORS



SINGLE SENSOR

LINE SENSOR



ARRAY SENSOR

IMAGE FORMATION

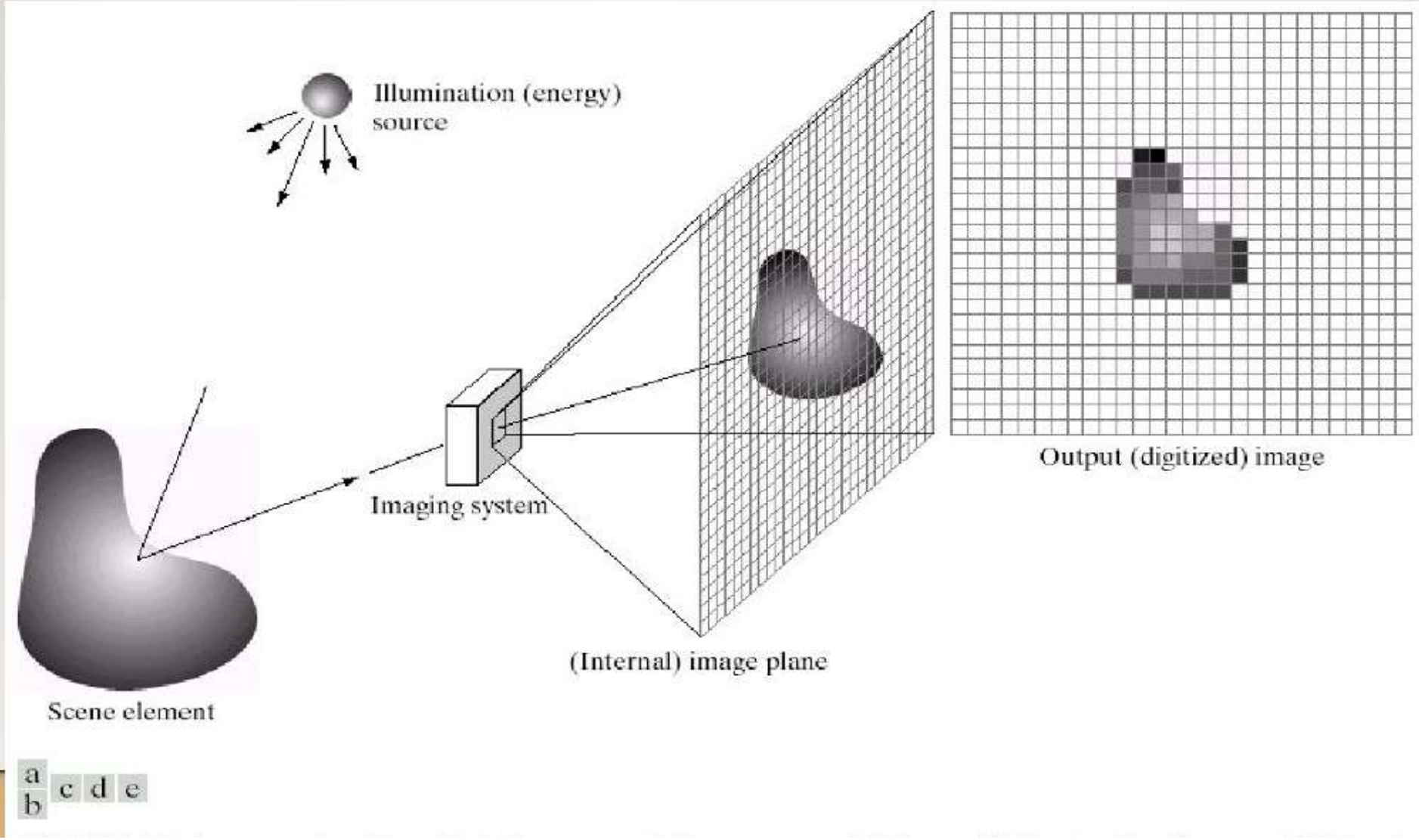


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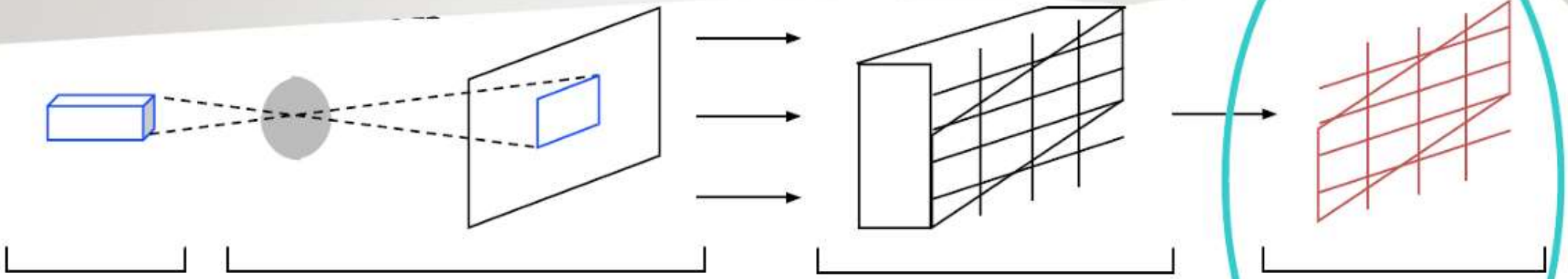
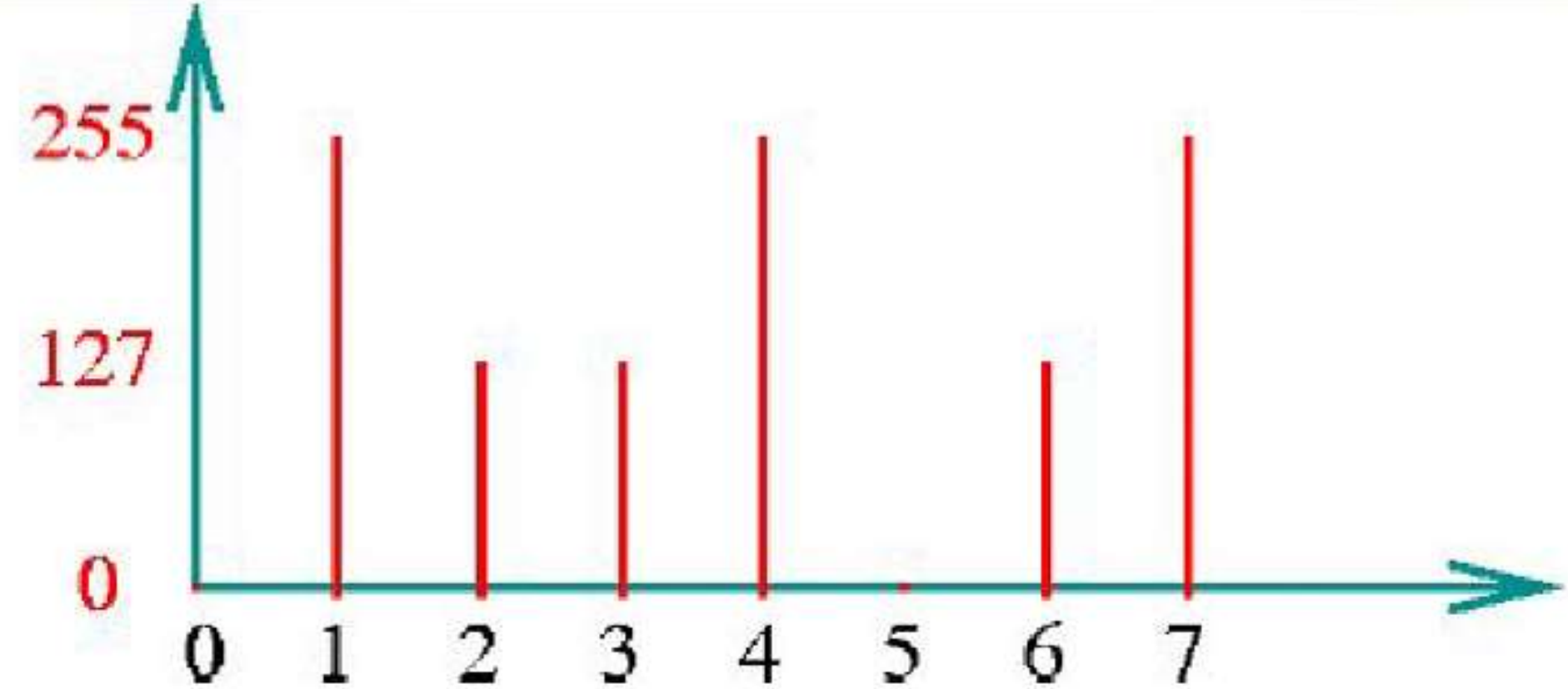
IMAGE ACQUISITION PROCESS



0	10	10	15	50	70	80
0	0	100	120	125	130	130
0	35	100	150	150	80	50
0	15	70	100	10	20	20
0	15	70	0	0	0	15
5	15	50	120	110	130	110
5	10	20	50	50	20	250

PIXEL
(picture element)

Typically:
0 = black
255 = white



Two alternate representations

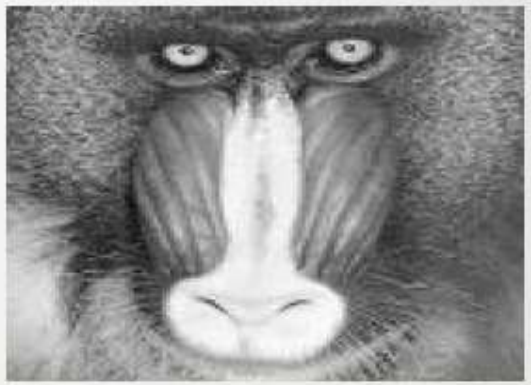
THREE TYPES OF IMAGES

Binary Image

- $I(x, y) \in \{0 , 1\}$

Gray-scale Image

- $I(x, y) \in [0..255]\}$



Color Image

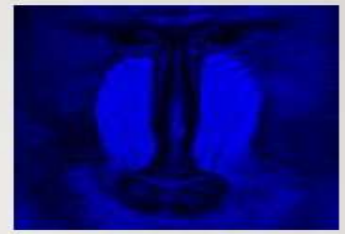
- $IR(x, y)\ IG(x, y)\ IB(x, y)$

PIXELS AND THEIR COLORS

R(x, y)

G(x, y)

B(x, y)



BASIC MEASURES OF A DIGITAL IMAGE

- **Terminology: "dpi" and "ppi**
  - "dpi" (dots per inch)
  - printing term that describes # dots in a print
  - Different from square pixels per inch ("ppi") in the digital image
  - "dpi" has been commonly adopted to describe the resolution of digital images as well; "dpi" is used here in place of "ppi"

IMAGE PROCESSING SYSTEM COMPONENTS

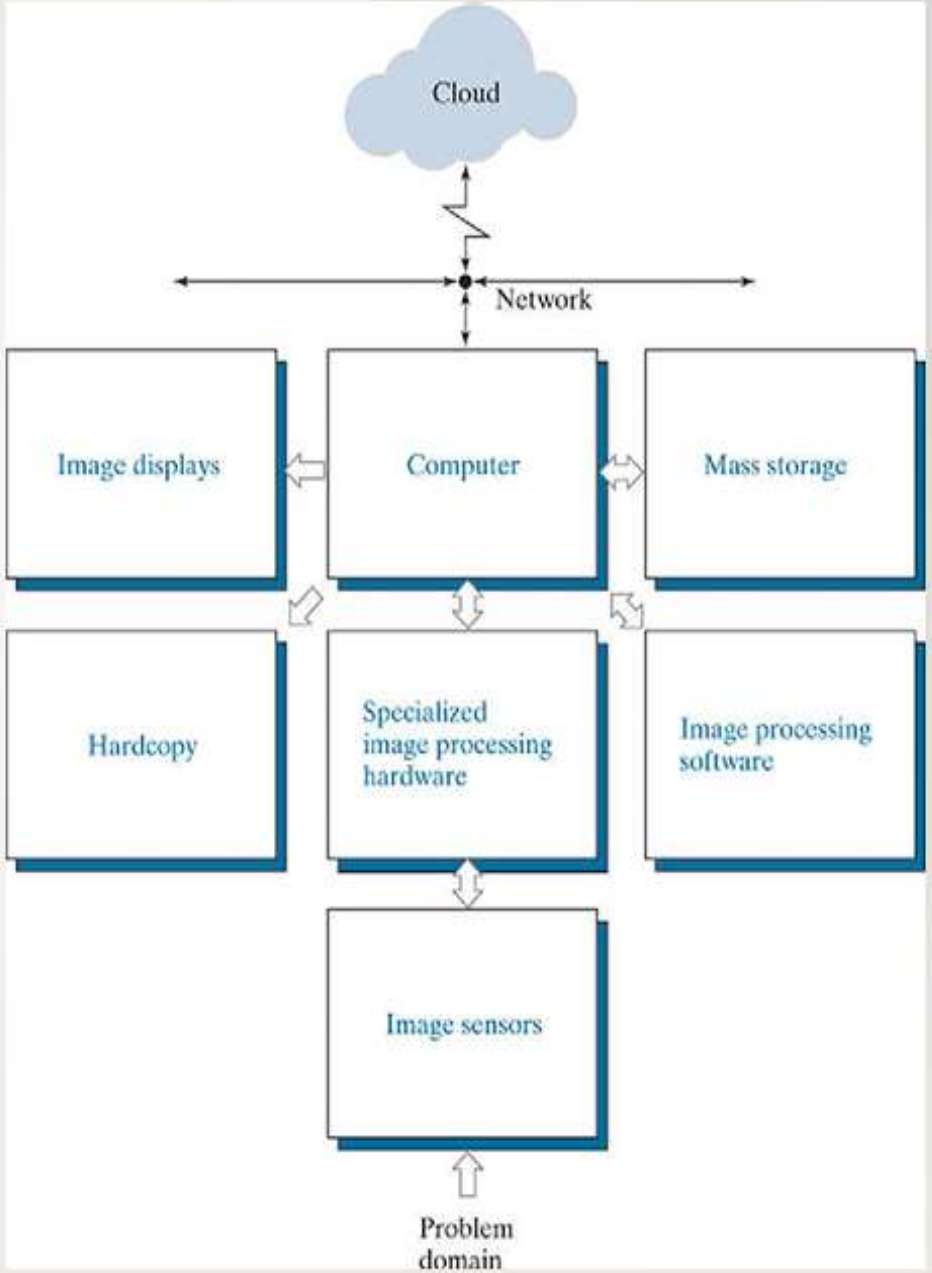


IMAGE PROCESSING SYSTEM COMPONENTS

- 2 subsystems are required to **acquire digital images**:
  1. **Physical sensor:** responds to the energy radiated by the object
  2. **Digitizer:** device for converting the output of the physical sensing device into digital form

- **SPECIALIZED IMAGE PROCESSING H/W:**
  - Consists of:
    - Digitizer
    - H/W for parallel or immediate primitive operations like ALU
  - Can be called **front-end subsystem**
  - Performs functions that require fast data throughputs that the typical main computer cannot handle

IMAGE PROCESSING SYSTEM COMPONENTS

- **COMPUTER**
  - A general-purpose computer and can range from a PC to a supercomputer
  - For offline image processing tasks
  - In dedicated applications, sometimes custom computers are used to achieve a required level of performance

- **SOFTWARE**
  - Specialized modules that perform specific tasks
  - A well-designed package also includes the capability for the user to write code that, as a minimum, utilizes the specialized modules
  - More sophisticated software packages allow the integration of those modules and general-purpose software commands from at least one computer language

IMAGE PROCESSING SYSTEM COMPONENTS

- **MASS STORAGE**
  - Storage space needed for an image of 1024 x 1024 pixels, with the intensity of each pixel of 8-bit?
    - 1 MB
  - Categories for digital storage for image processing applications:
    1. Short-term storage:
       - Used during processing
       - Can be provided with computer memory OR
       - Specialized boards called **frame buffers:**
         - store one or more images and can be accessed rapidly, usually at video rates (e.g., at 30 complete images per second)
         - Allow virtually instantaneous image zoom and scroll
         - Usually housed in the specialized image processing hardware unit

IMAGE PROCESSING SYSTEM COMPONENTS

- **MASS STORAGE**
  2. On-line storage:
     - Used for relatively fast recall
     - In magnetic disks or optical-optical media storage
     - Frequent access to the stored data
  3. Archival storage:
     - Massive storage requirements but infrequent need for access
     - Magnetic tapes and optical disks housed in “jukeboxes”
  - Storage is measured from bytes to terabytes

IMAGE PROCESSING SYSTEM COMPONENTS

- **IMAGE DISPLAYS**
  - Mainly color, flat screen monitors
  - Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system
  - Sometimes in the form of headgear containing two small displays embedded in goggles worn by the user

- **HARDCOPY DEVICES**
  - laser printers, film cameras, heat-sensitive devices, ink-jet units, and digital units, such as optical and CD-ROM disks
  - For presentations, images are displayed on film transparencies or in a digital medium

IMAGE PROCESSING SYSTEM COMPONENTS

- **NETWORKING AND CLOUD**
  - Key consideration in image transmission is bandwidth
  - In dedicated networks, this typically is not a problem, but communications with remote sites via the internet are not always as efficient

IMAGE SAMPLING AND QUANTIZATION

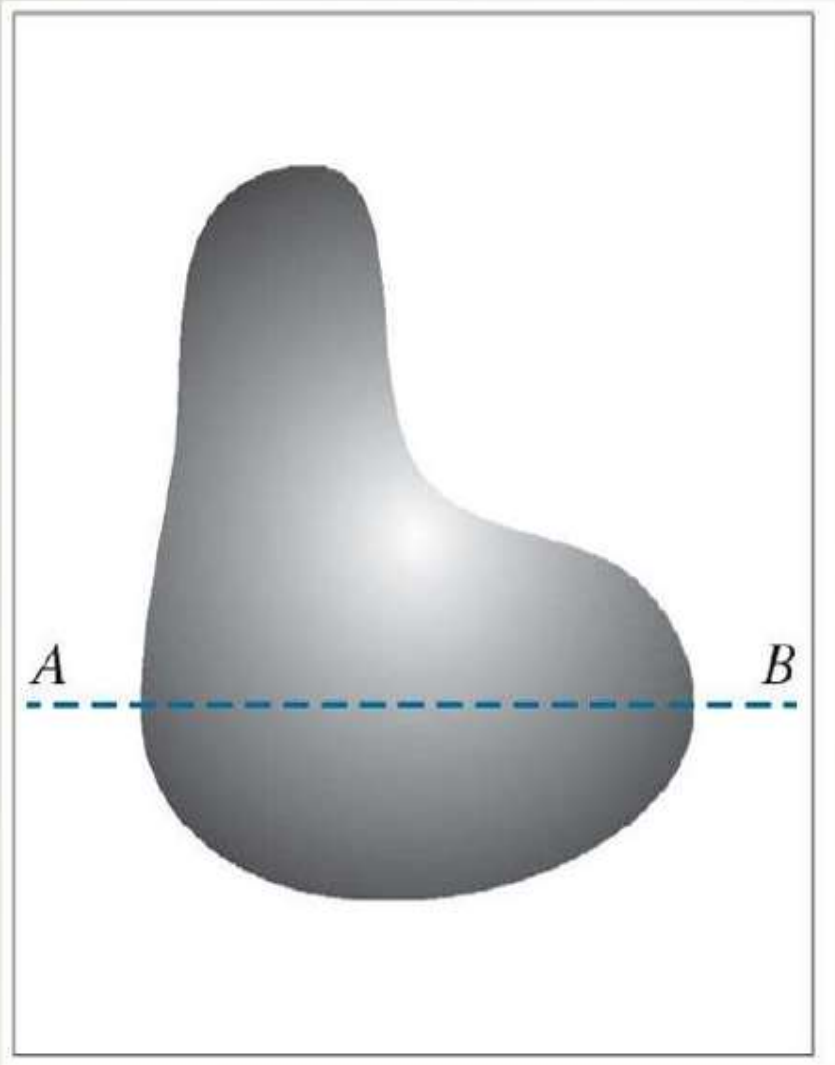
- The output of most sensors is a continuous voltage waveform whose amplitude and spatial behavior are related to the physical phenomenon being sensed

- To create a digital image, we need to convert the continuous sensed data into a digital format

- **SAMPLING:** Digitizing the coordinate values

- **QUANTIZATION:** Digitizing the amplitude values

IMAGE SAMPLING AND QUANTIZATION



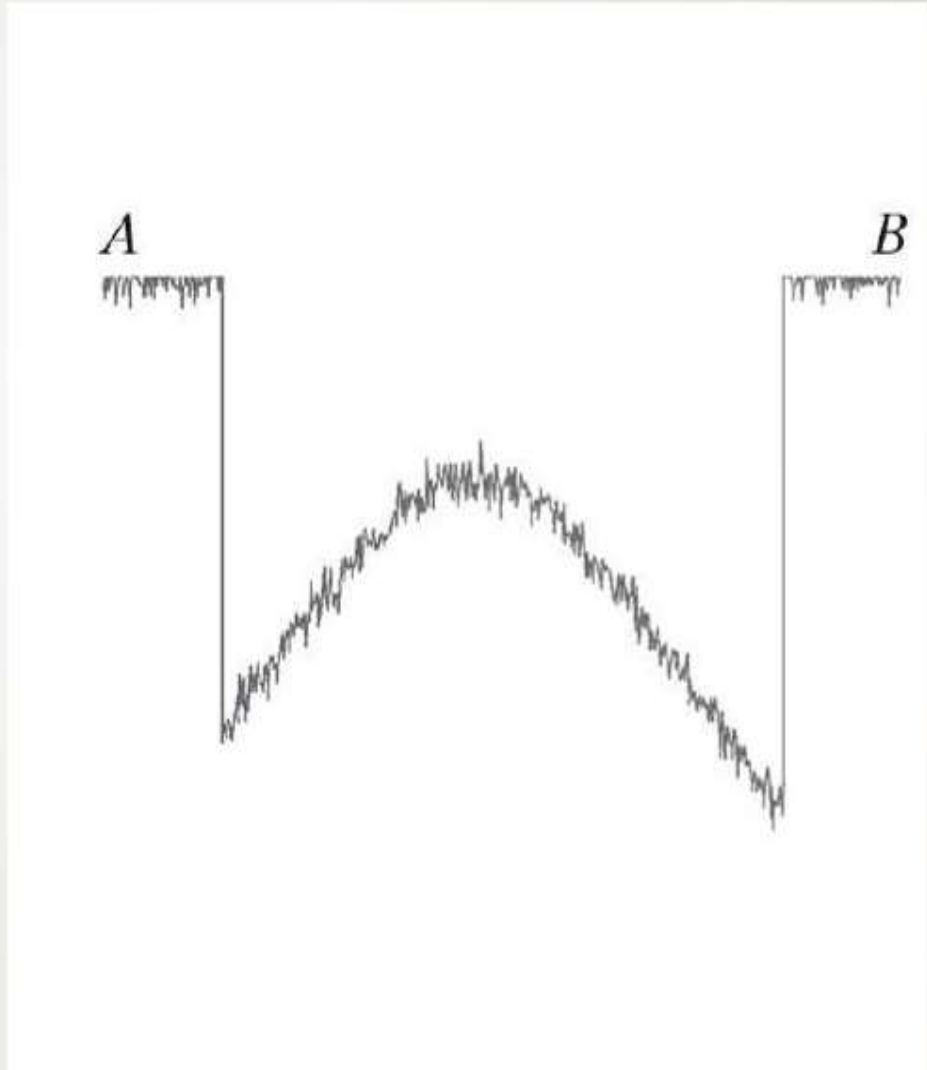
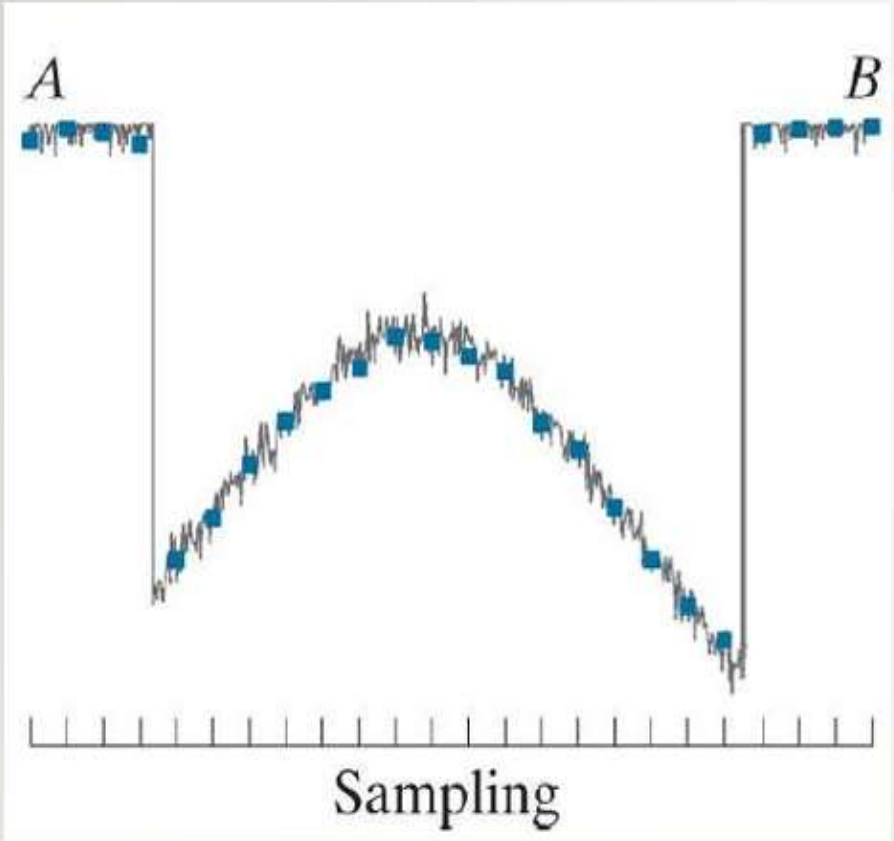


IMAGE SAMPLING AND QUANTIZATION



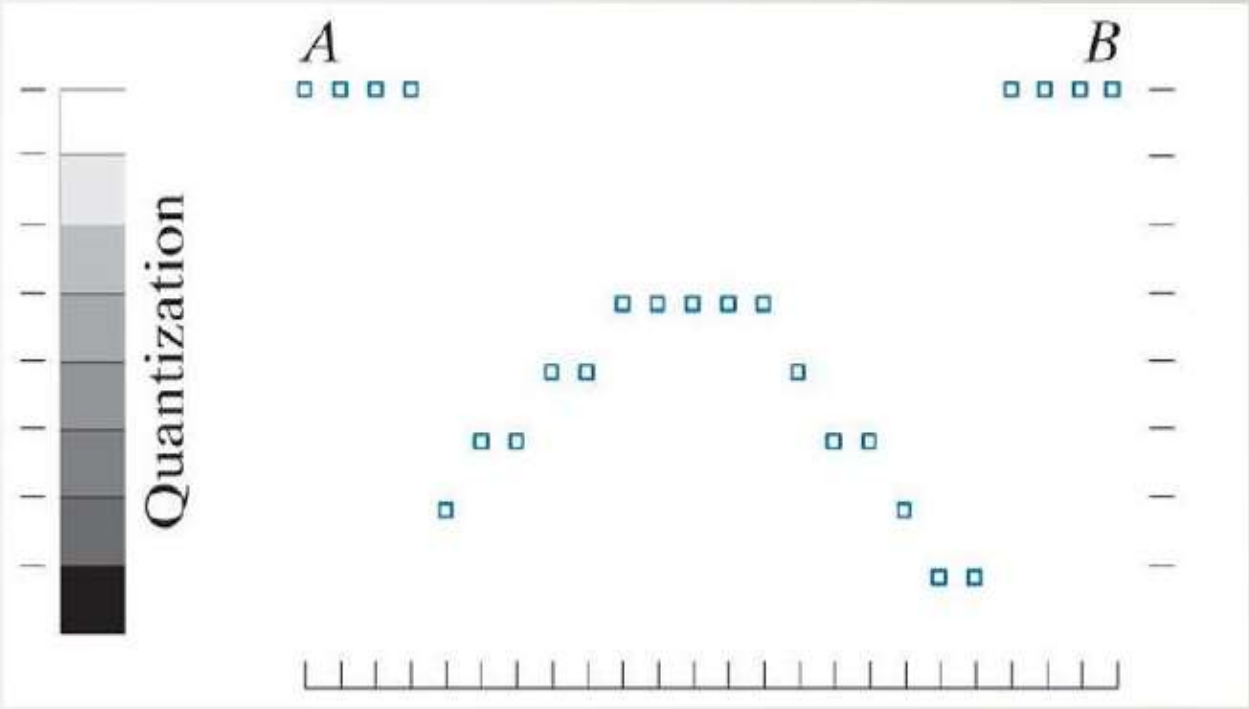
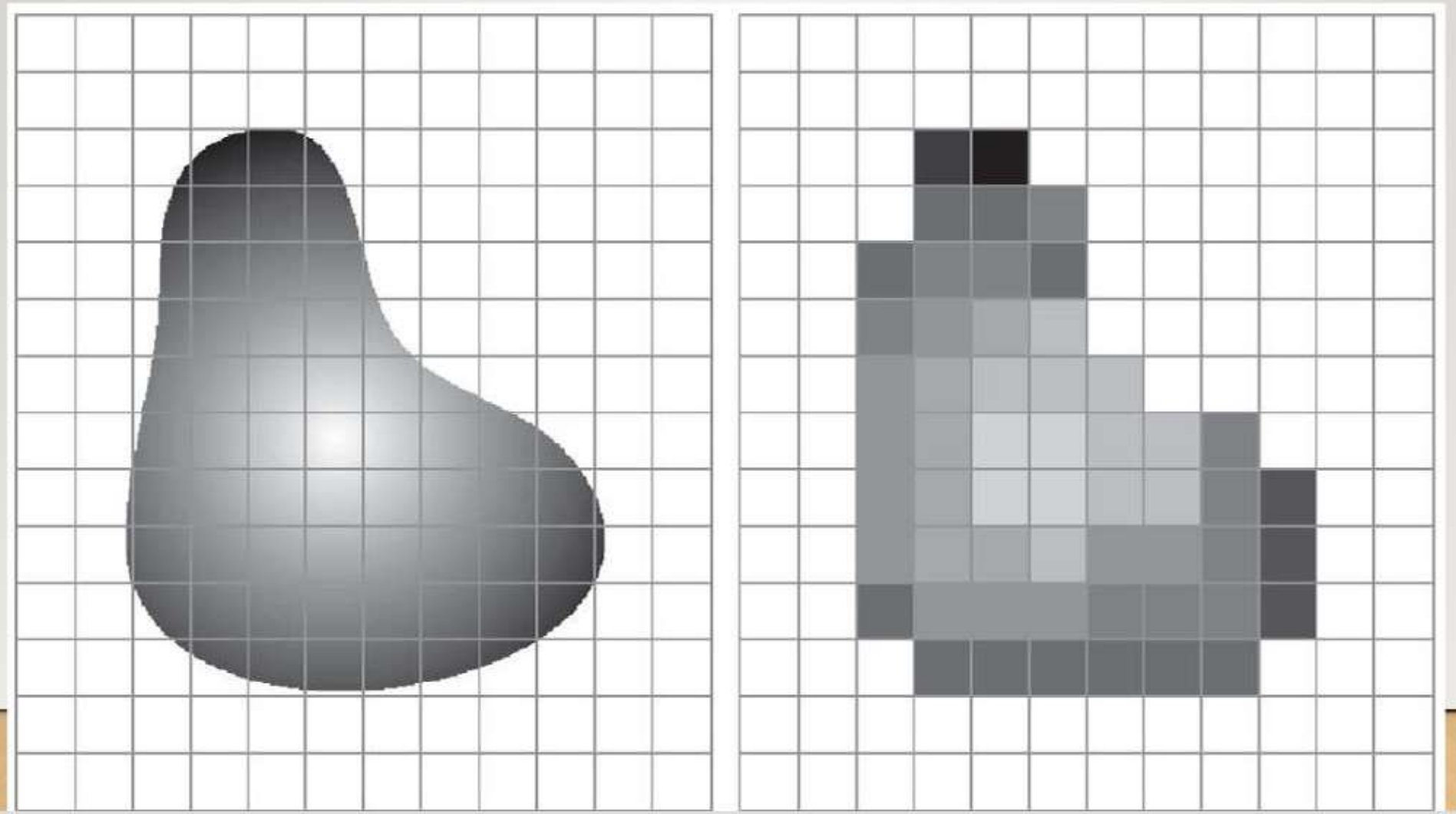


IMAGE SAMPLING AND QUANTIZATION

Continuous image projected onto the plane of a 2-D sensor



COMMON TERMINOLOGIES

- **Dynamic range** = (maximum measurable intensity) / (minimum detectable intensity)
- Dynamic range = saturation / noise
- As a rule, the upper limit is determined by saturation and the lower limit by noise, although noise can be present also in lighter intensities
- **Saturation** is the highest value beyond which all intensity values are clipped
  - The entire saturated area has a high, constant intensity level
- The dark background is noisier, but the **noise** is difficult to see
- **Image contrast** = (Highest intensity level) – (Lowest intensity level)
- **Contrast ratio** = (Highest intensity level) / (Lowest intensity level)
- High dynamic range -> high contrast
- Low dynamic range image -> dull, washed-out look

Assignment

1. What is Digital Image Processing. List out the elements of a digital image processing systems and explain along with diagram.
2. Steps in Digital Image Processing.
3. Explain the concepts of Image Sampling and Quantization.