CSC 447
Digital Image Processing

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Team

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ILOs

- A working knowledge of the most commonly used methods and procedures for image processing.??
- Understanding of the mathematics/theory behind the procedures as well as the ability to write software to implement the mathematics.
- Make use of data structures, linear algebra, and signal processing in the implementations.
- Given an image and a goal for its processing the student should be able to select and implement an appropriate procedure to achieve that goal.
- The ability to explain results in writing is essential for a successful engineer→ reports/papers.

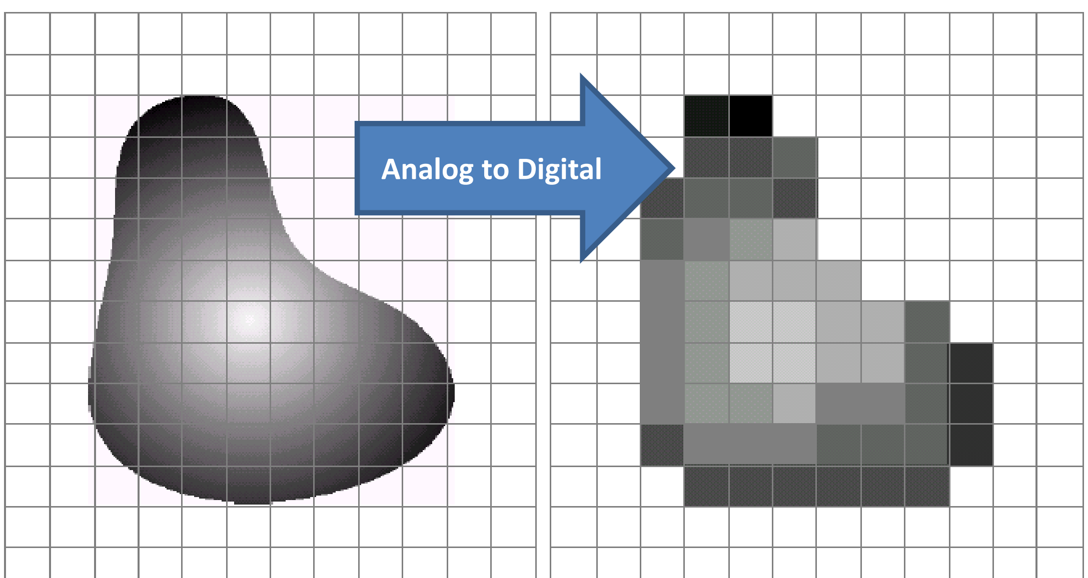
Introduction and Image Acquisition

Today's Contents

- **What is a digital image**
- **How to acquire/represent a digital image**
- **Effects of sampling and quantization**
- **What is image processing**
- **Common IP operations and applications**
- **Course outline**
- ***GP orientation session.***

What is a Digital Image?

- A digital image is a representation of a two-dimensional picture.
- Digitization implies that a the image is an approximation of a real scene. ??

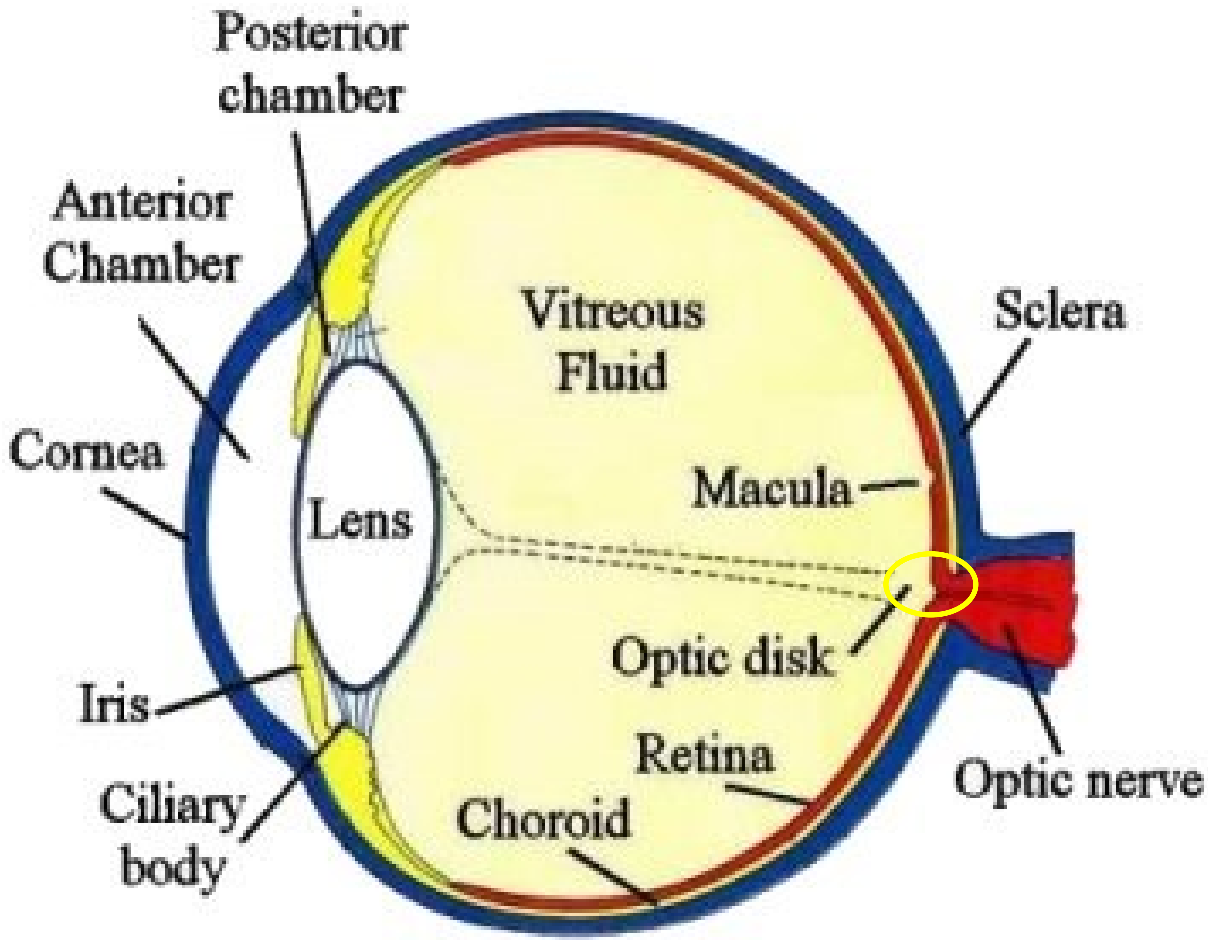


Human Visual Perception

Structure of the Human Eye

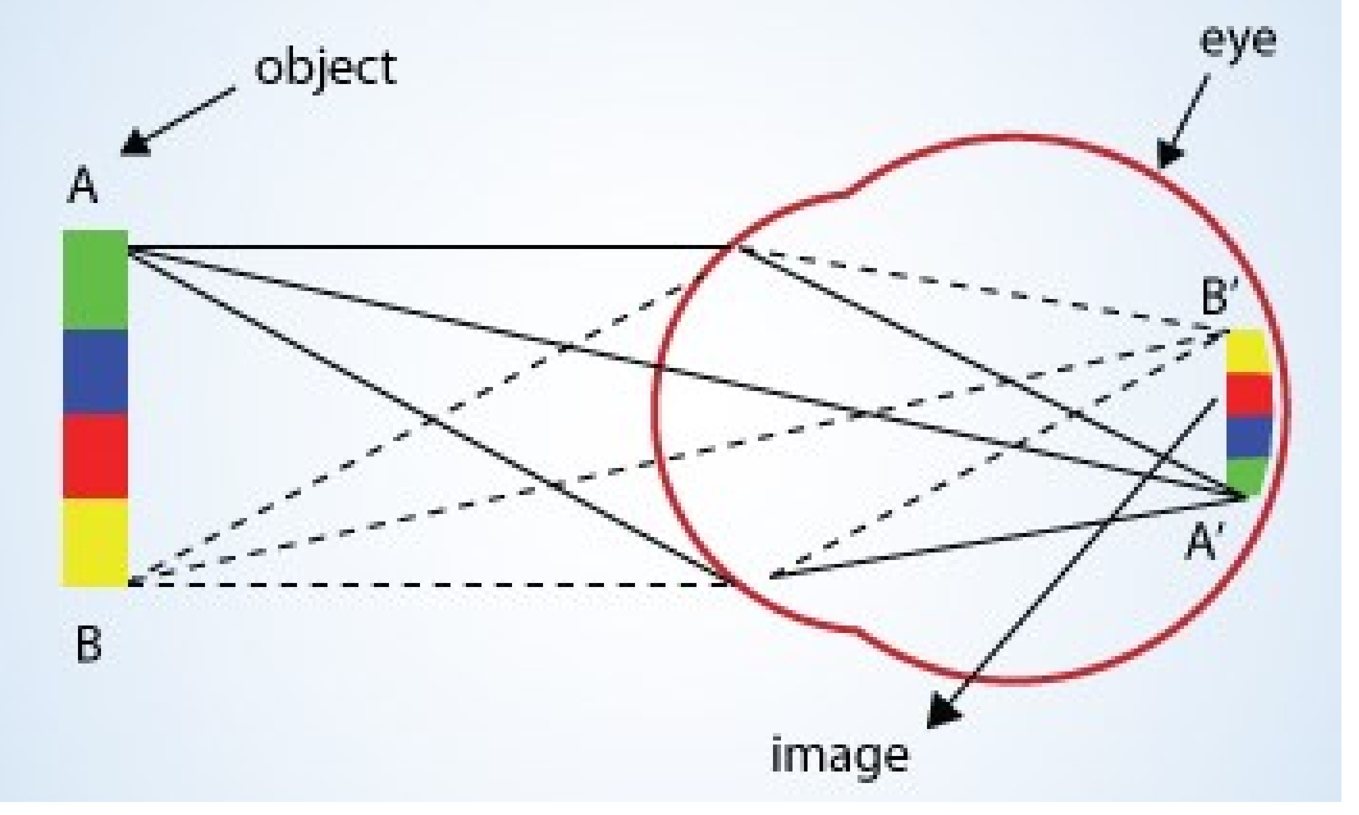
Brightness adaptation and discrimination

Light source

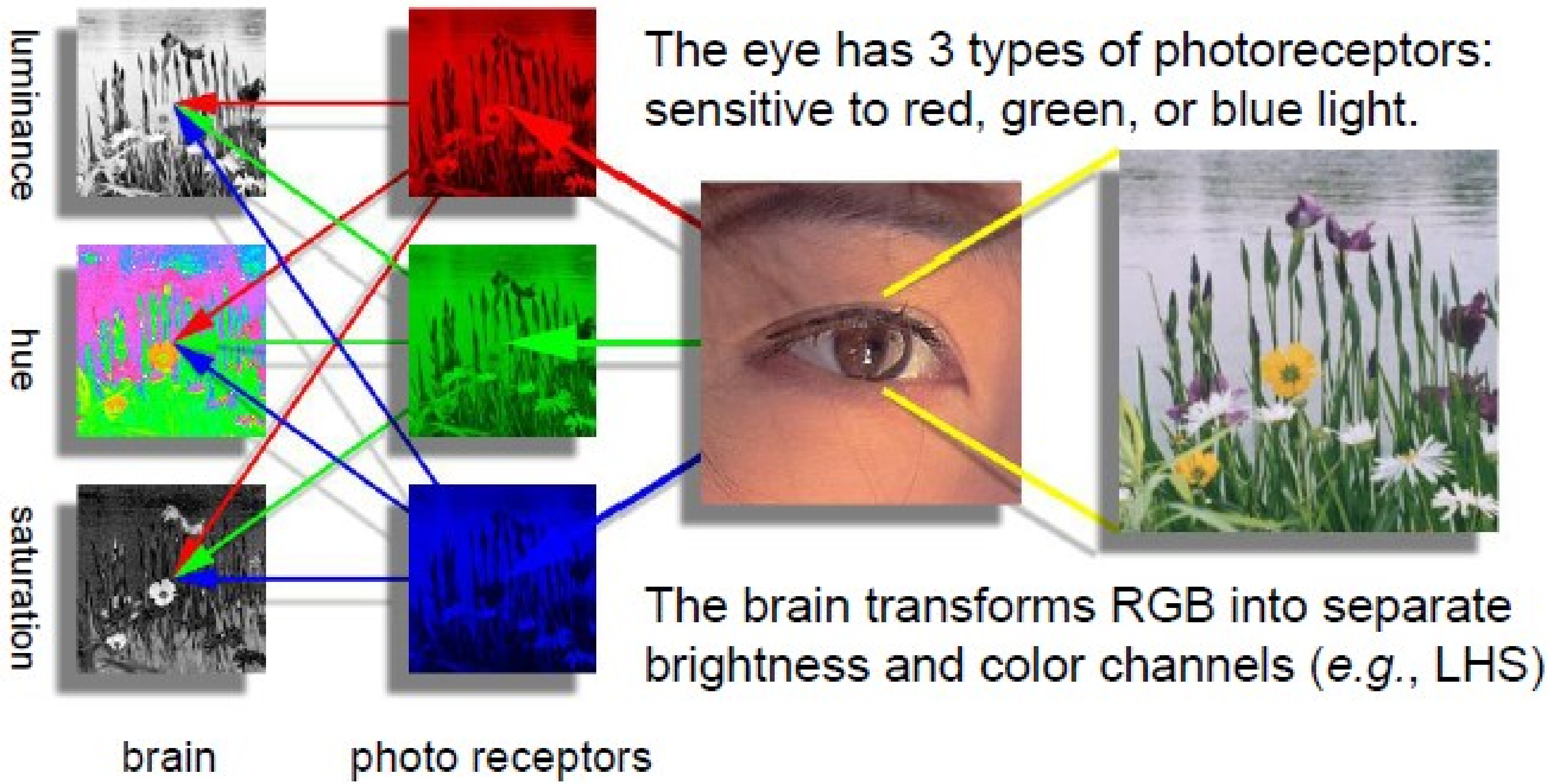


Human Visual Perception – (cont.)

Image Formation in the Eye

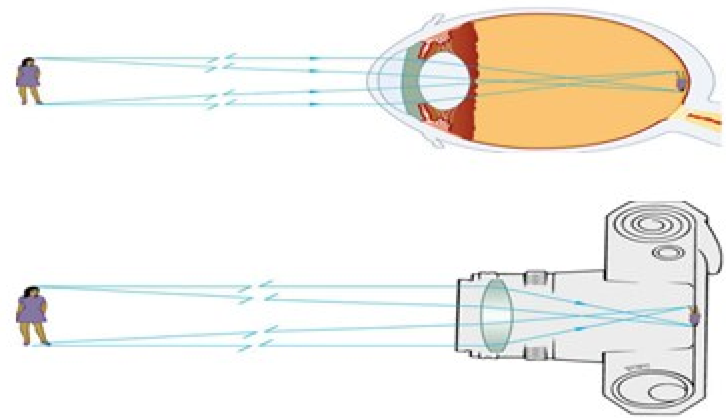


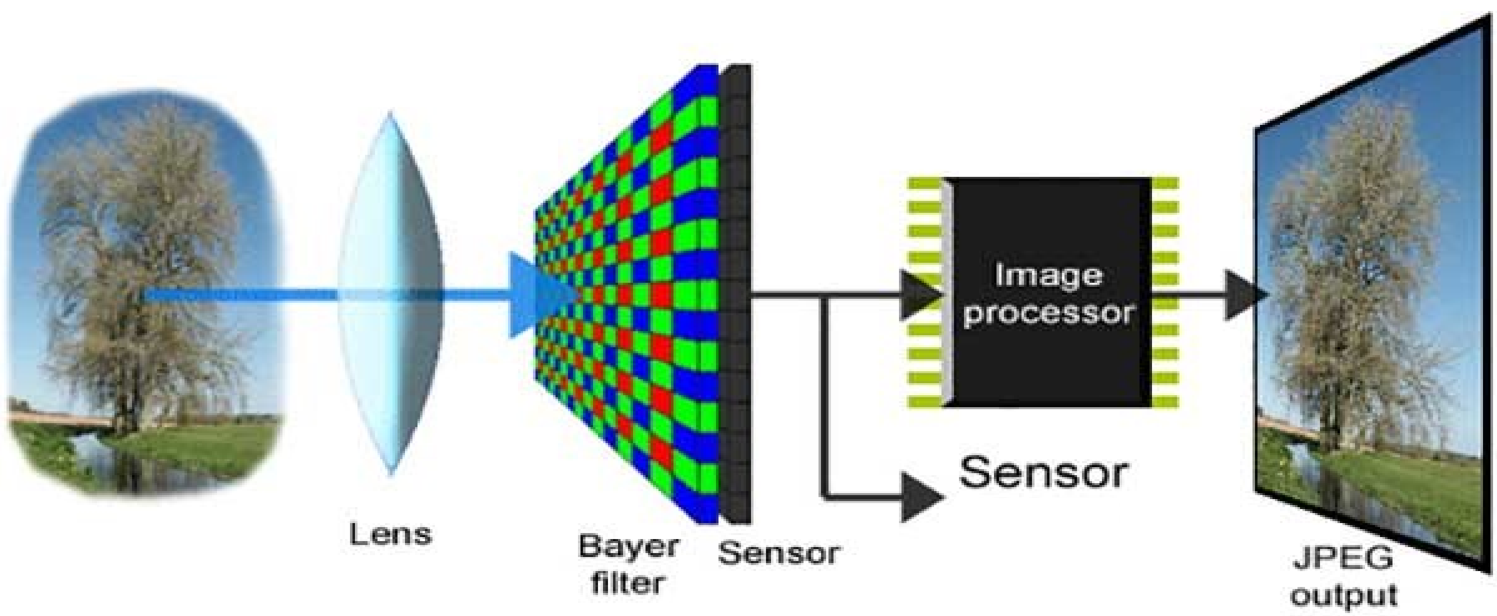
Human Visual Perception – (cont.)



Digital Image Acquisition

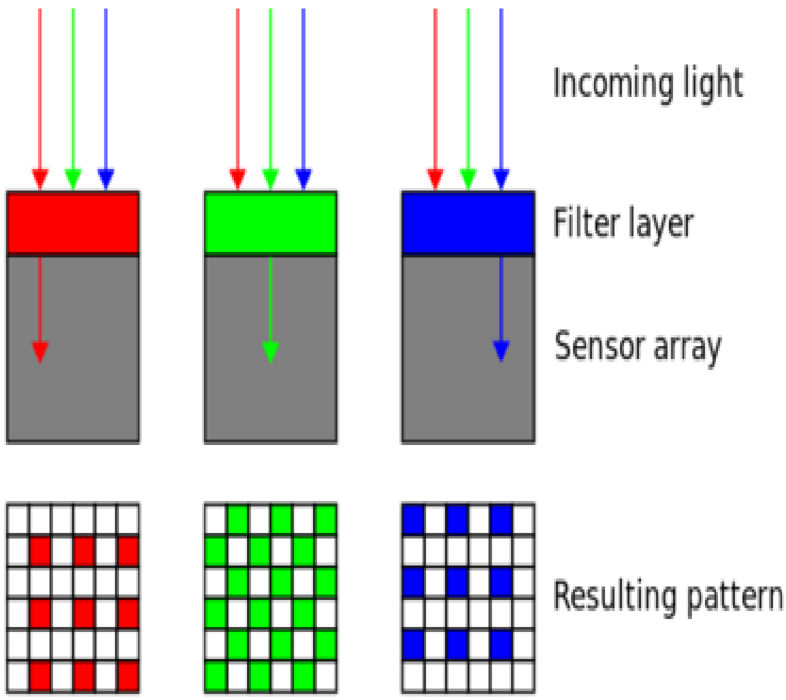
- **Digital Camera**

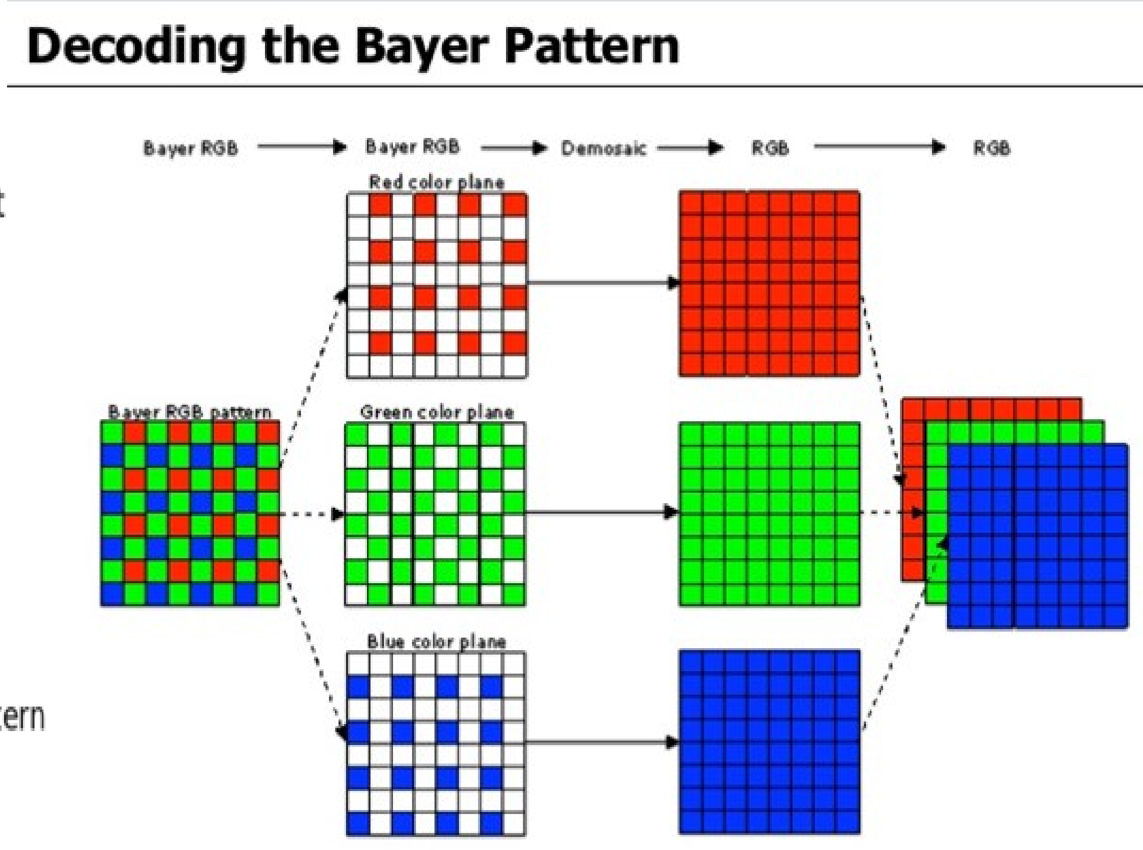




Digital Image Acquisition

- Digital Camera
- Color filter arrays - Bayer

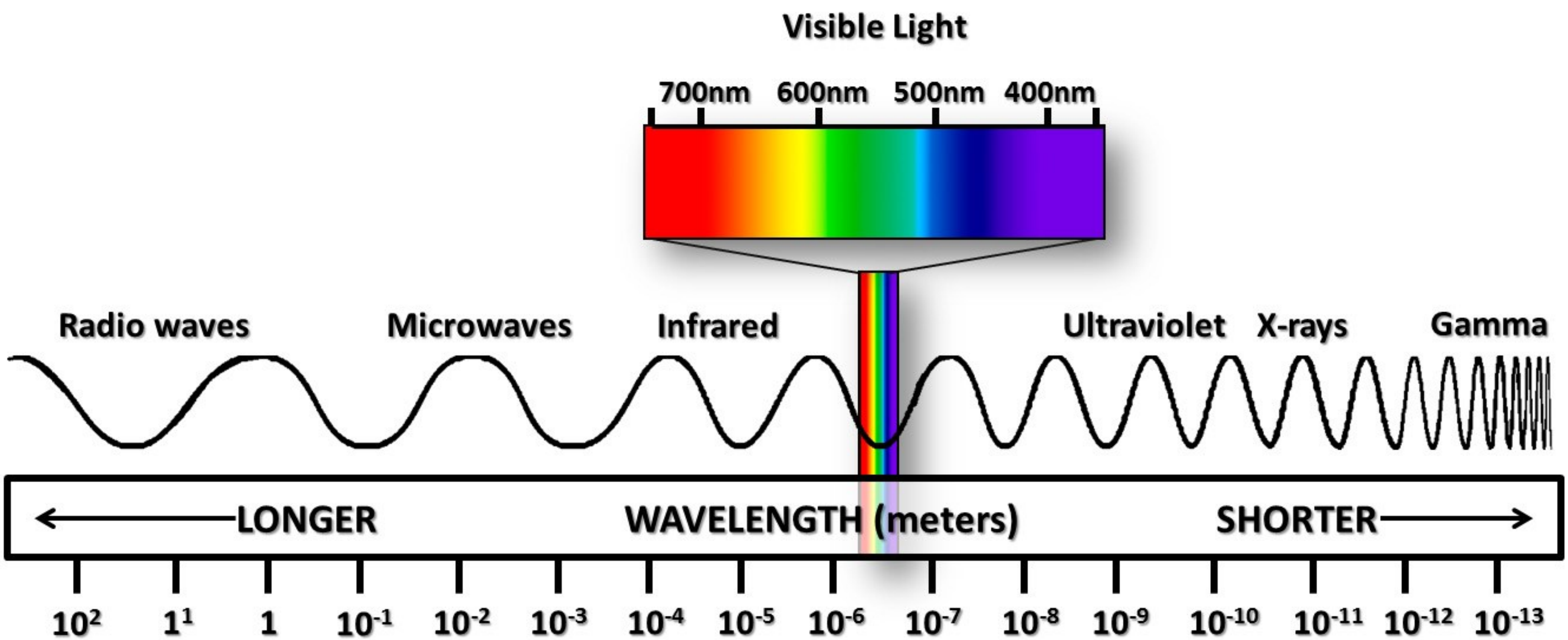




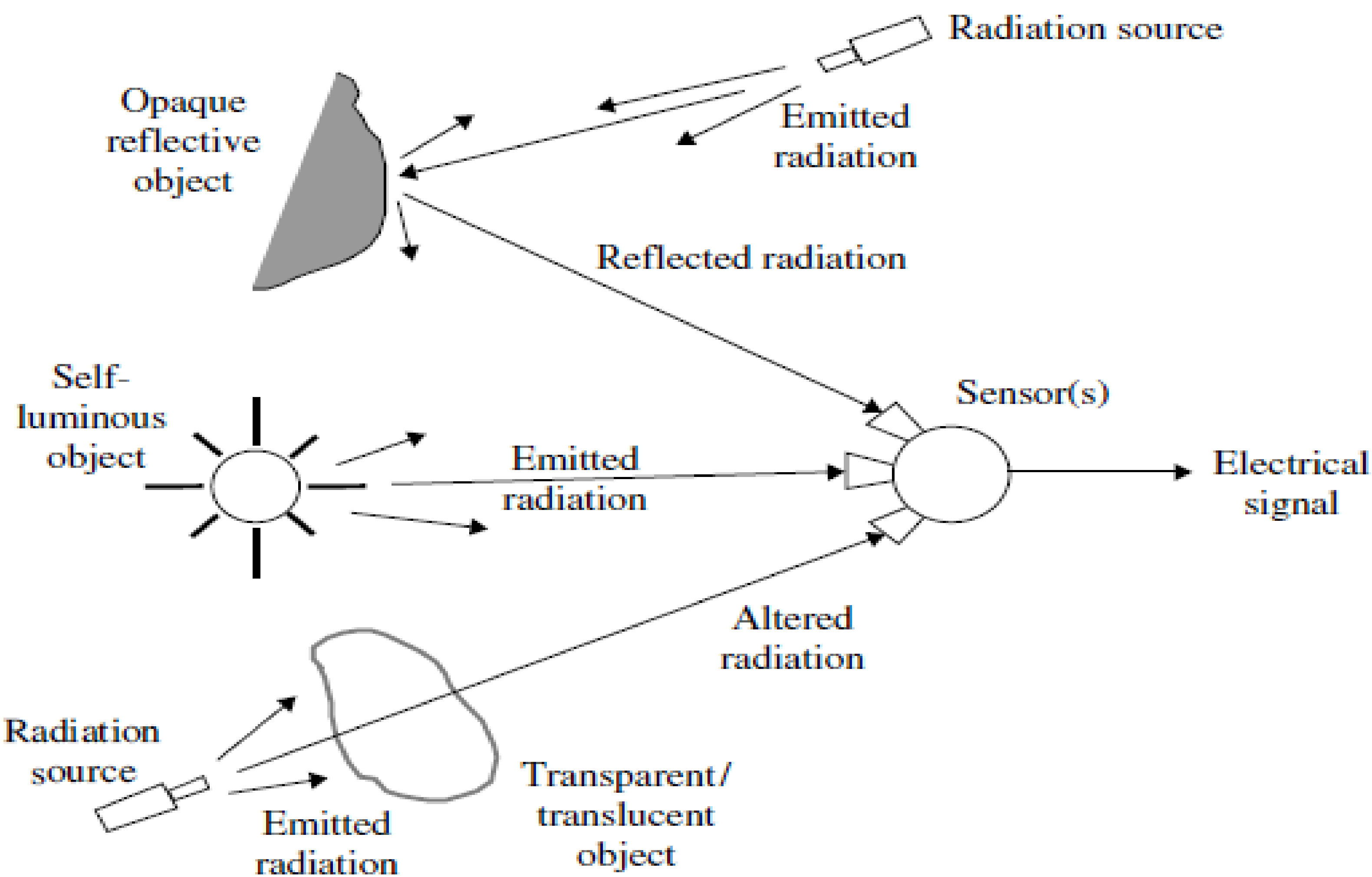
Digital Image Acquisition – (cont.)

The Electromagnetic Spectrum

- **Light is a part of the EM spectrum that can be sensed by the human eye.**

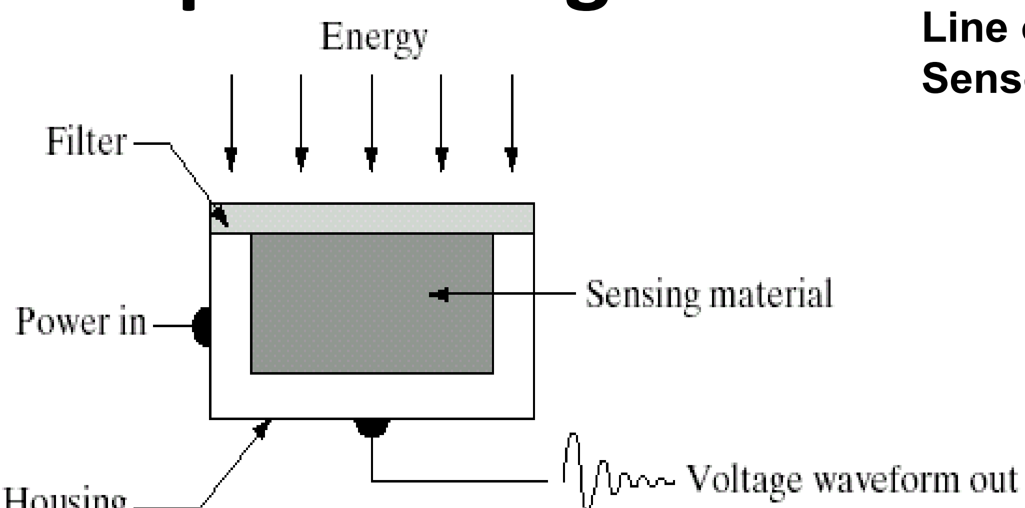


Digital Image Acquisition – (cont.)



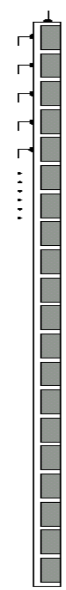
Digital Image Acquisition – (cont.)

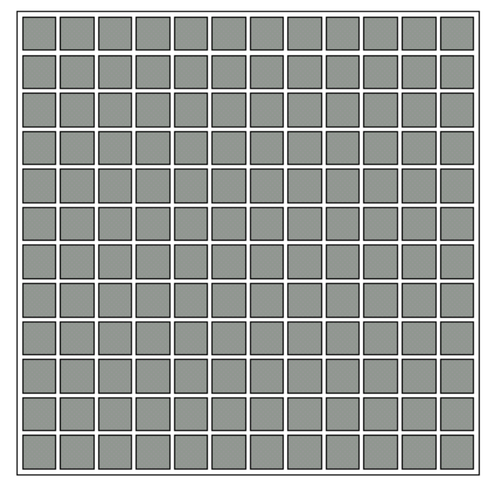
- **Incoming energy lands on a sensor material responsive to that type of energy and this generates a voltage.**
- **Collections of sensors are arranged to capture images.**



Imaging Sensor

Line of Image Sensors

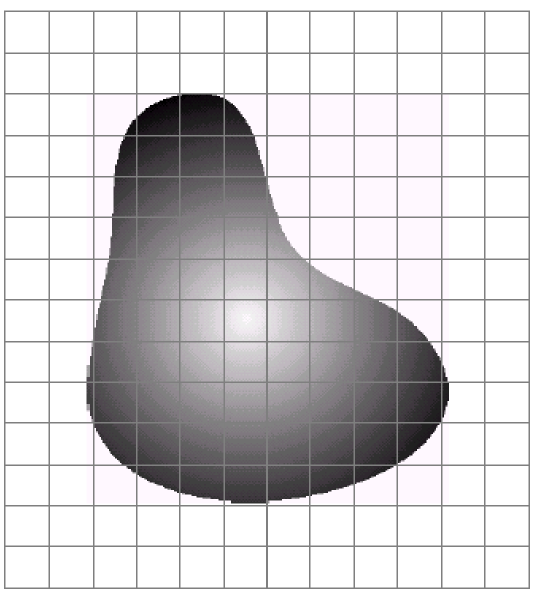


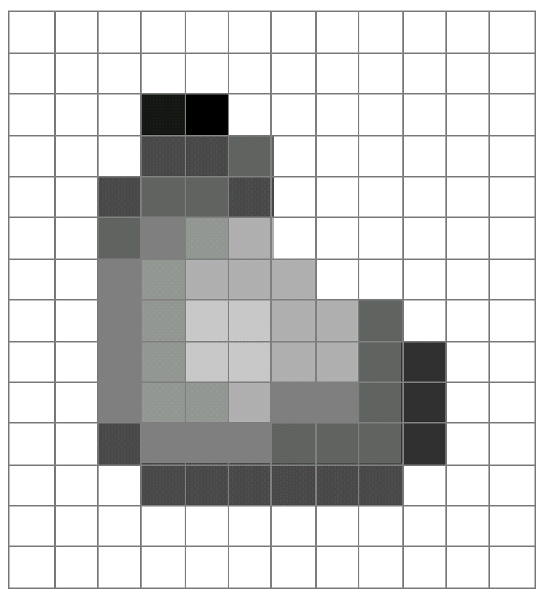


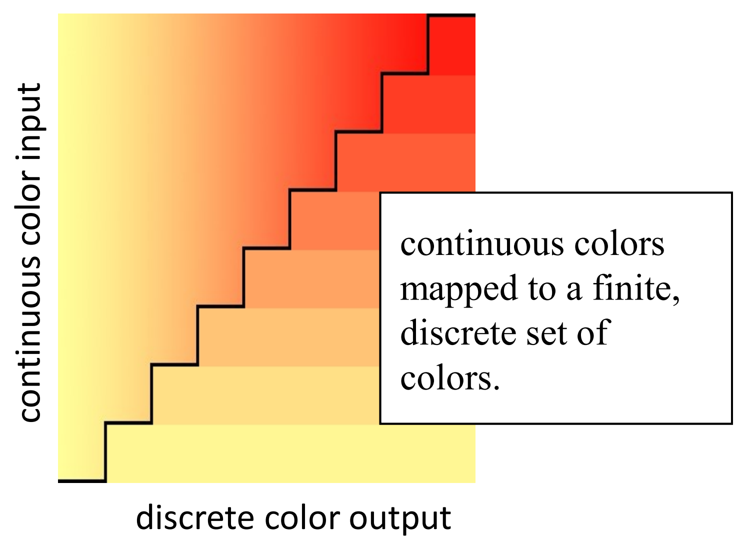
Array of Image Sensors

Digital Image Acquisition – (cont.)

- **Image (as a signal) is continuous in x- and y-coordinates → requires sampling and in amplitude → requires quantization**

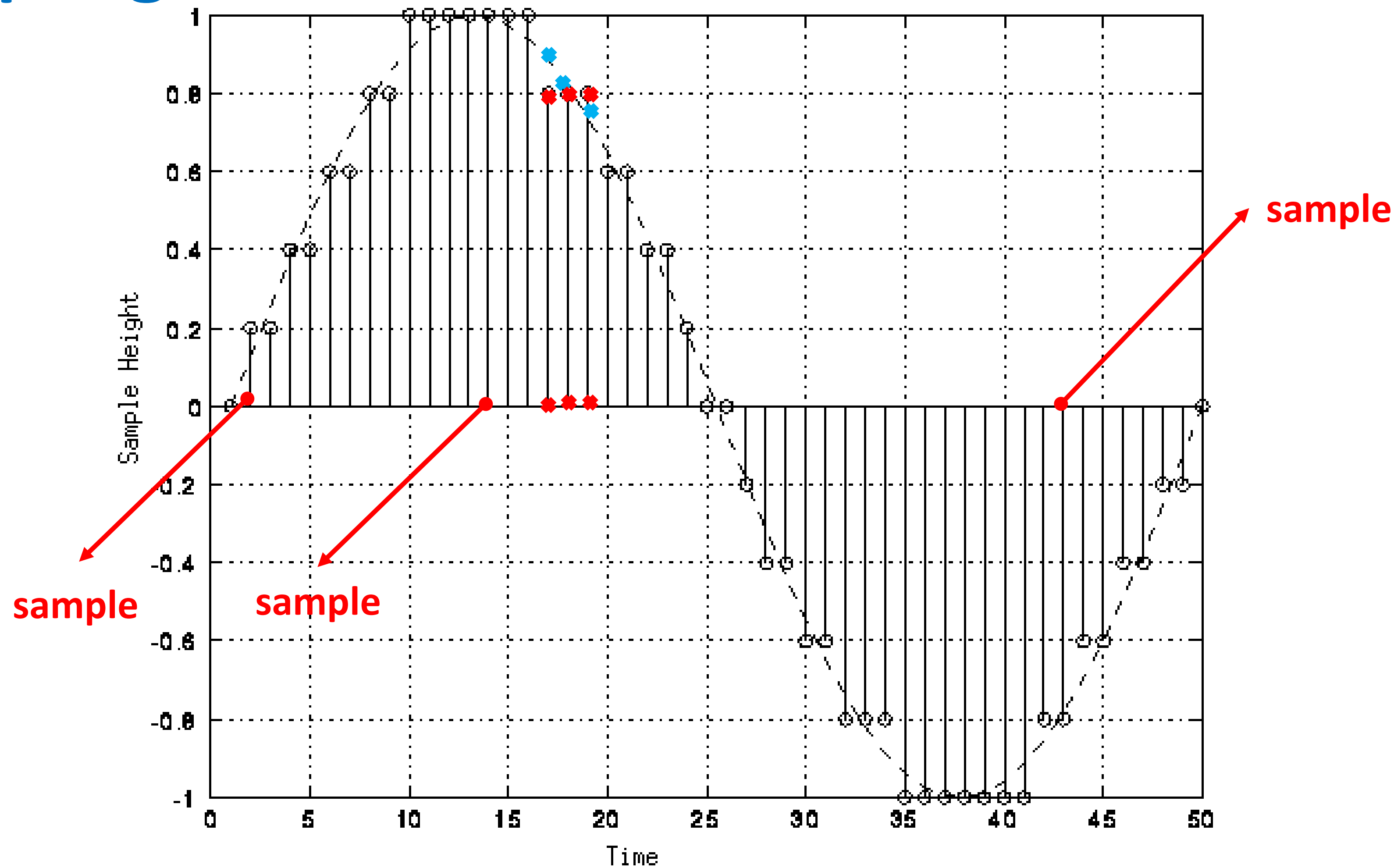






Digital Image Acquisition – (cont.)

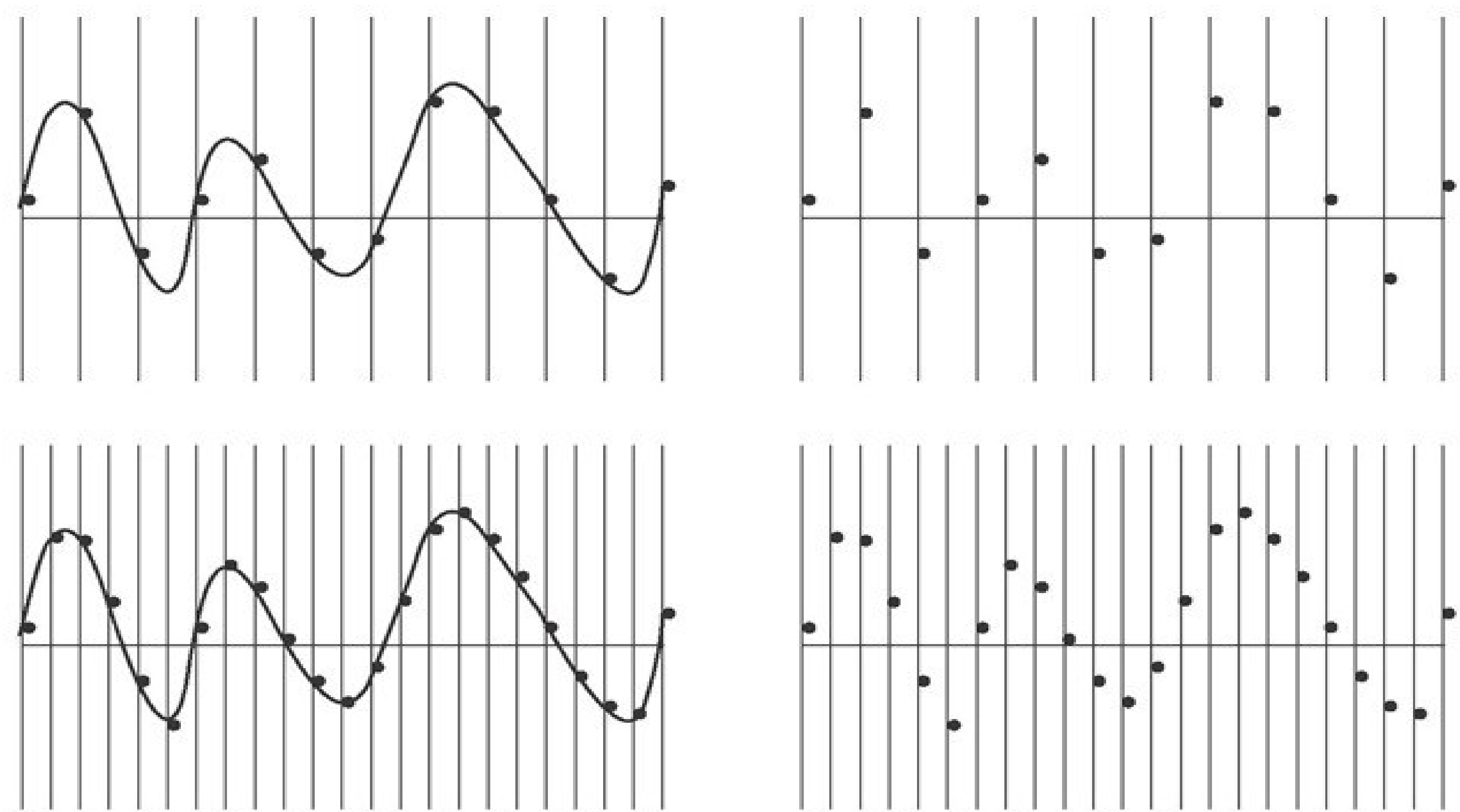
Sampling and Quantization



Digital Image Acquisition – (cont.)

Sampling and Quantization

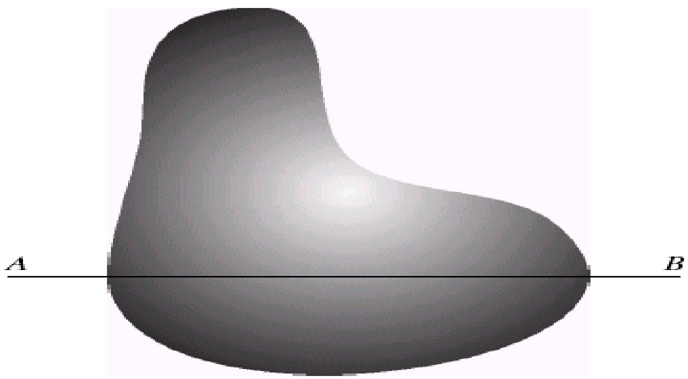
Q. Which?

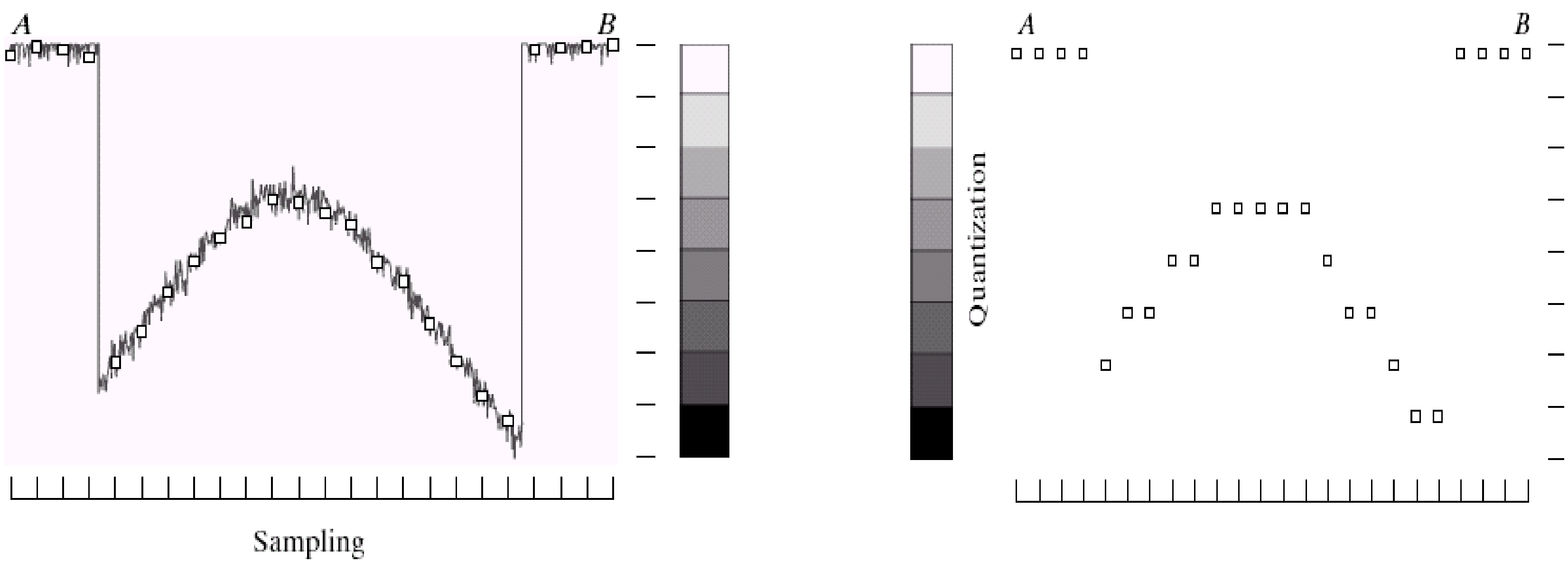


Digital Image Acquisition – (cont.)

Sampling and Quantization Example

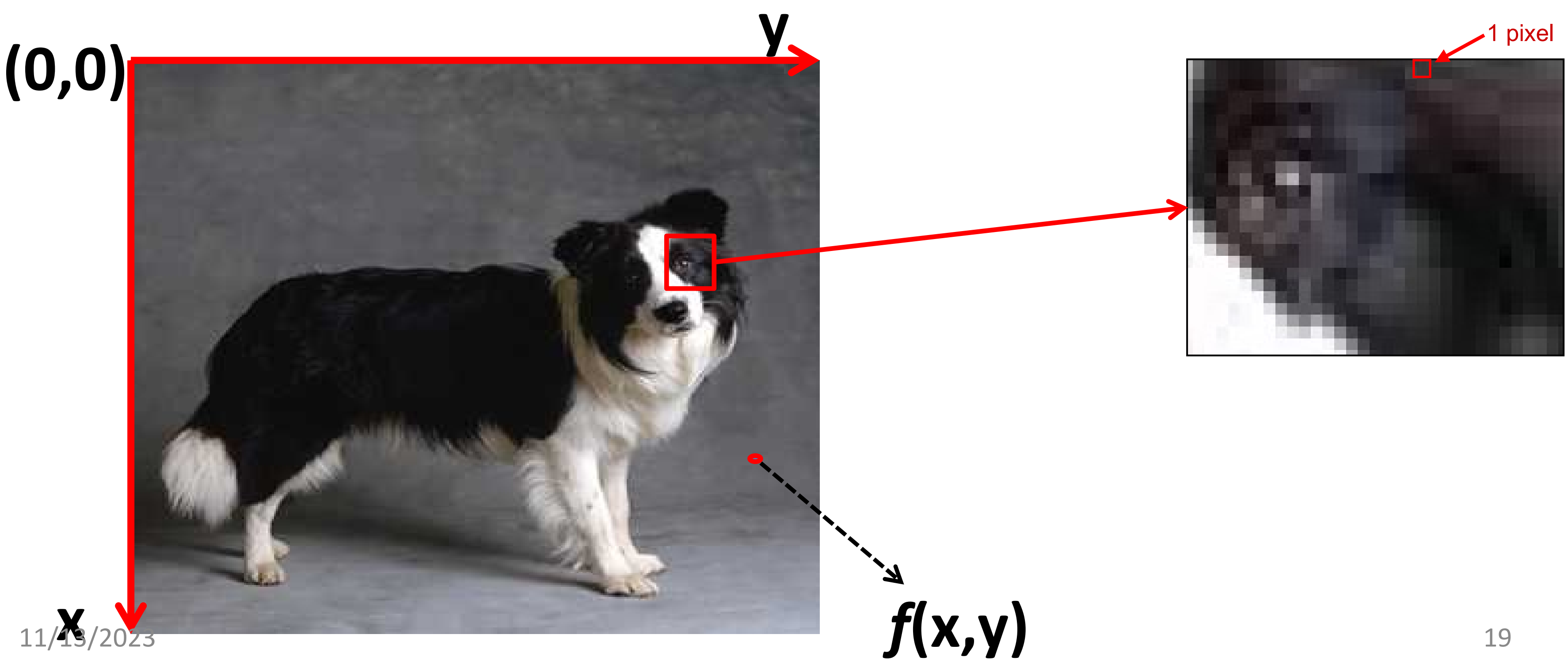
- **Quality depends on the number of samples and discrete intensity levels used in sampling and quantization.**





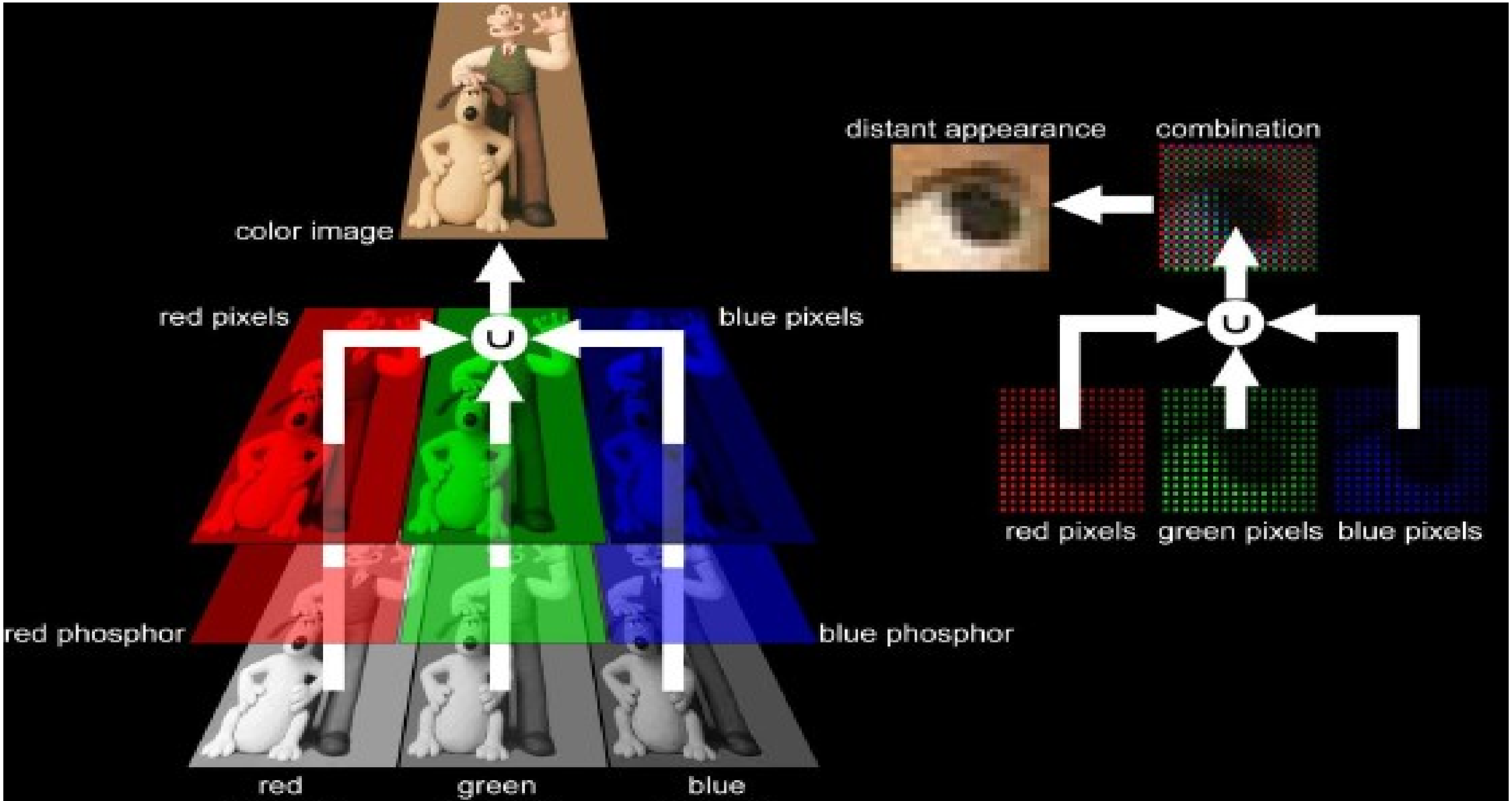
Digital Image Acquisition – (cont.)

- A **digital image** is a representation of a two-dimensional picture as a **finite set** of **digital values**, called **picture elements** or **pixels**.



Digital Image Acquisition – (cont.)

- **Color image**



Digital Image Acquisition – (cont.)

Image Representation

- **The image now is composed of M rows and N columns of pixels each storing a value $f(x,y)$.**
- **In practice, the *grey scale* is shifted to $[0, L\text{-}1]$.**
- **x and y are called *spatial coordinates*.**

Digital Image Acquisition – (cont.)

Image Representation

- **The number L of discrete intensity levels is typically a power of 2.**

$$L = 2^k$$

- **k = bits required to store the image.**
- **k-bit image, e.g. 8-bit image.**

Digital Image Acquisition – (cont.)

Image Representation

- **That representation can take several forms.**
- **This affects the size, quality (resolution), and data structure used to save the image on disk.**
- **This does not necessarily correspond to the file format.**

Digital Image Acquisition – (cont.)

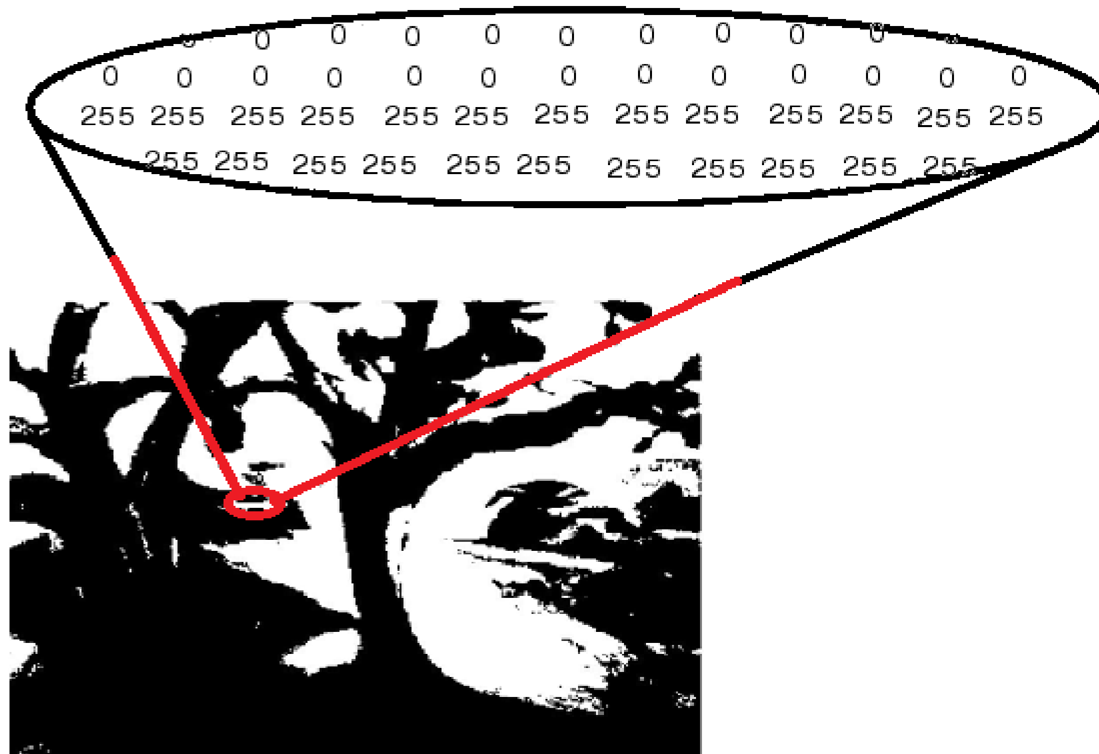
Image Representation - Binary Image

- **2D array of integer numbers where each pixel has two possible values.**

(usually 0 and 1,

or 0 and 255 in an

8-bit image).

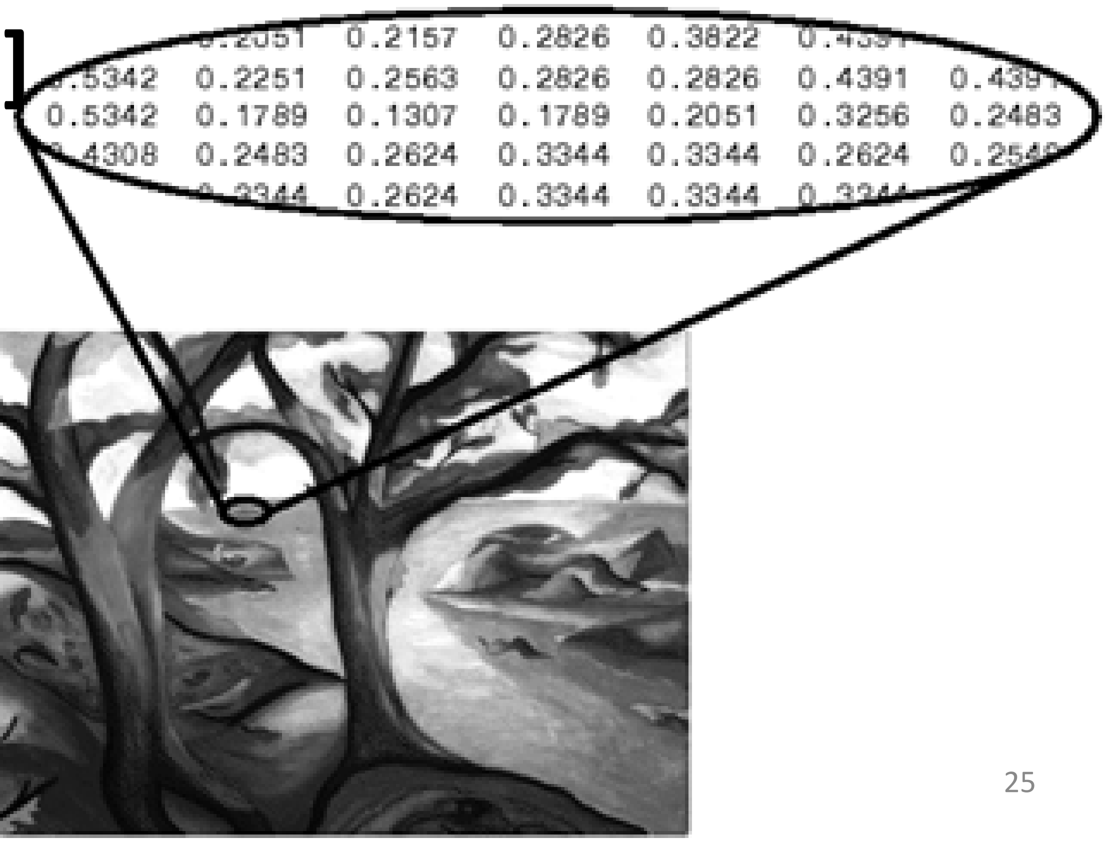


Digital Image Acquisition – (cont.)

Image Representation - Gray-scale (intensity) Image

- **2D array of integer numbers where each pixel has a value in the range [0-1], or most commonly [0-255]**

for an 8-bit image.



Digital Image Acquisition – (cont.)

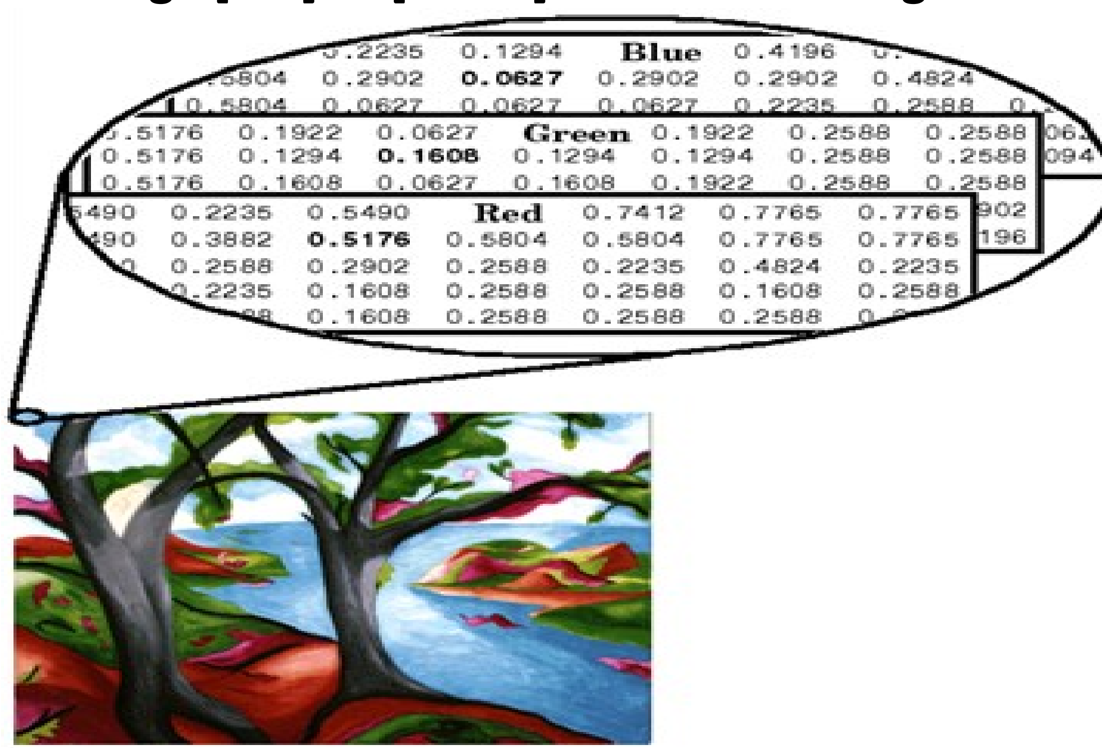
Image Representation - RGB (truecolor) Image

- **3D array that defines red, green, and blue color components for each individual pixel.**
- **Each of the three values is in the range [0-1] or [0-255] for an 8-bit image.**

Black = (0, 0, 0)

White = (1, 1, 1)

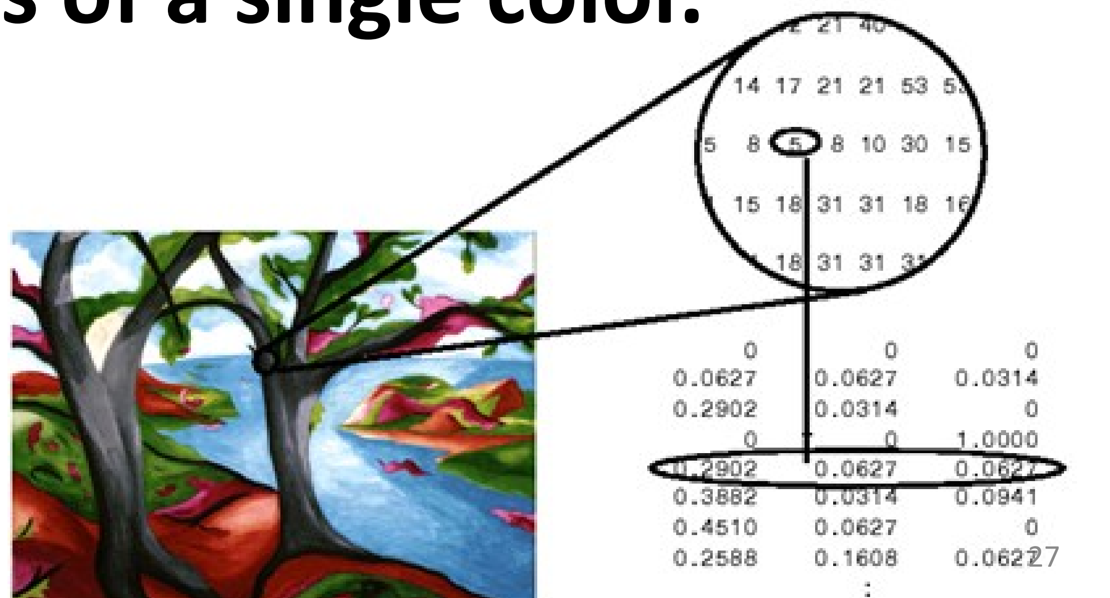
or = (255, 255, 255)



Digital Image Acquisition – (cont.)

Image Representation - Indexed Image

- **2D array of integer numbers (indexes) representing a row in a color map.**
- **Each row of map specifies the red, green, and blue components of a single color.**



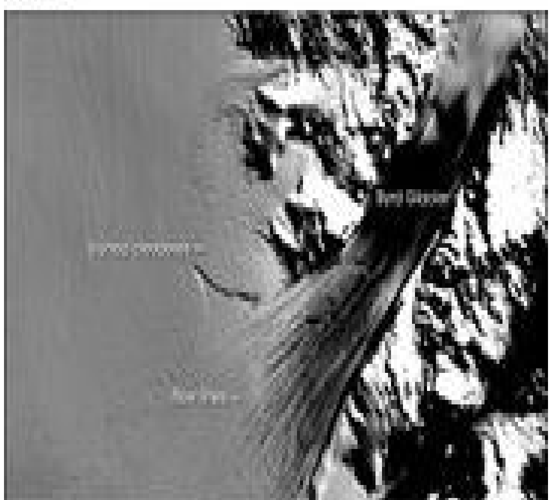
Digital Image Acquisition – (cont.)

- **An 8-bit image has a its *grey scale* $[0, 255]$, however, not all images use the whole range.**
- **The actual range used by an image is called the dynamic range.**
- **Dynamic range affects contrast and the contrast ratio.**

Digital Image Acquisition – (cont.)

Contrast Examples

low contrast



high contrast

Digital Image Acquisition – (cont.)

Most Popular Image File Formats

Compressed Vs. raw

Effects of Sampling & Quantization – (cont.)

Image Resolution

- **A measure of quality of the image.**
- **How close the lines can be to each other and still be visibly resolved.**
- **Depends strongly on the number of**
  - **Samples → Pixel**
  - **Device → Spatial Resolution**
  - **Gray levels → Intensity Resolution**

Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution

- **Refers to the pixel count of the image.**
- **Conventions:**

The number of pixel columns (width) times the number of pixel rows (height), e.g. as *640 by 480*.

The total number of pixels in the image, typically given as number of megapixels.

Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution – Example 1

1024

512

256

128

64

32

Effects of Sampling & Quantization – (cont.)

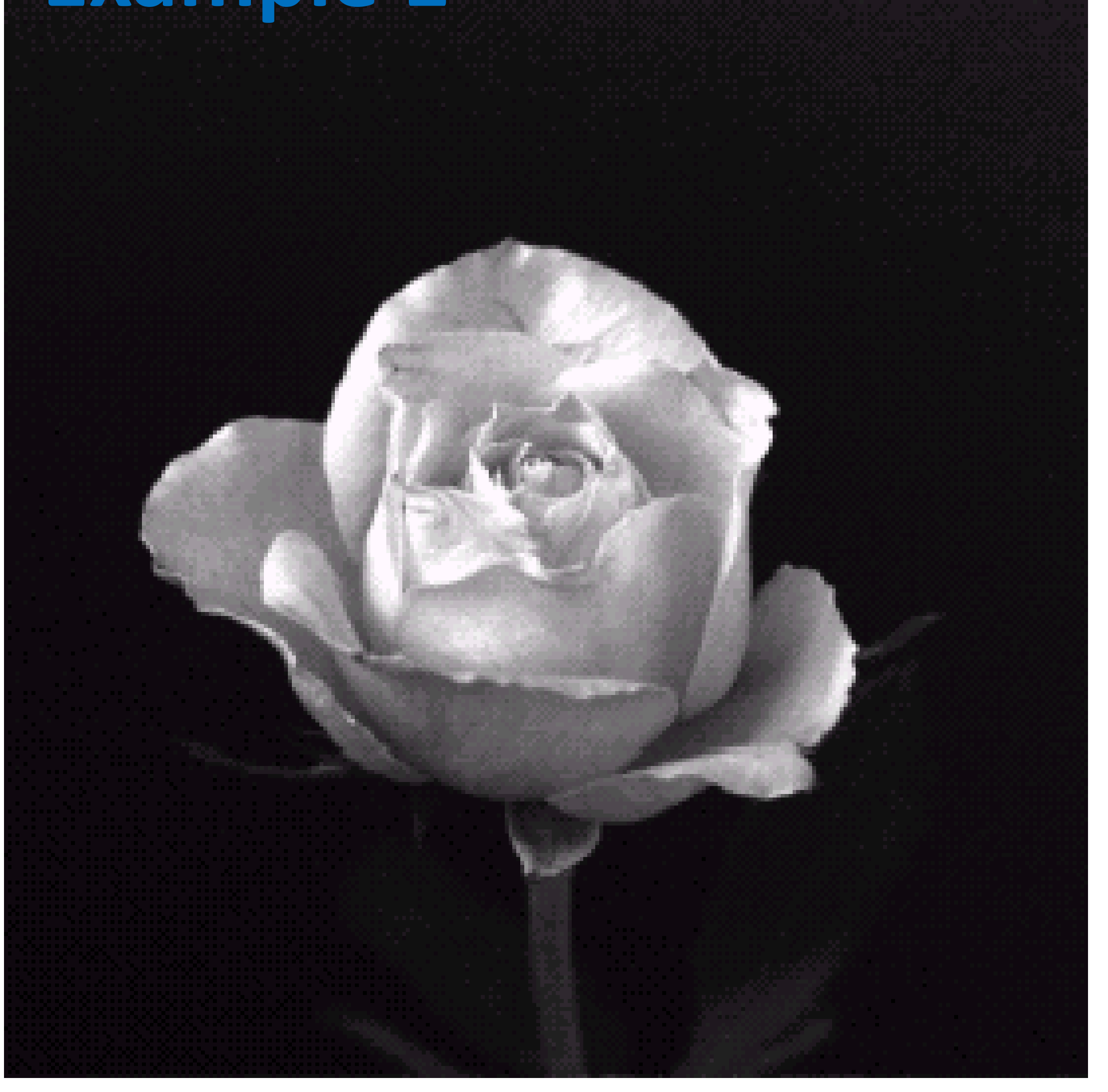
1- Pixel Resolution – Example 1

1024×1024

Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution – Example 1

512×512



Effects of Sampling & Quantization – (cont.)

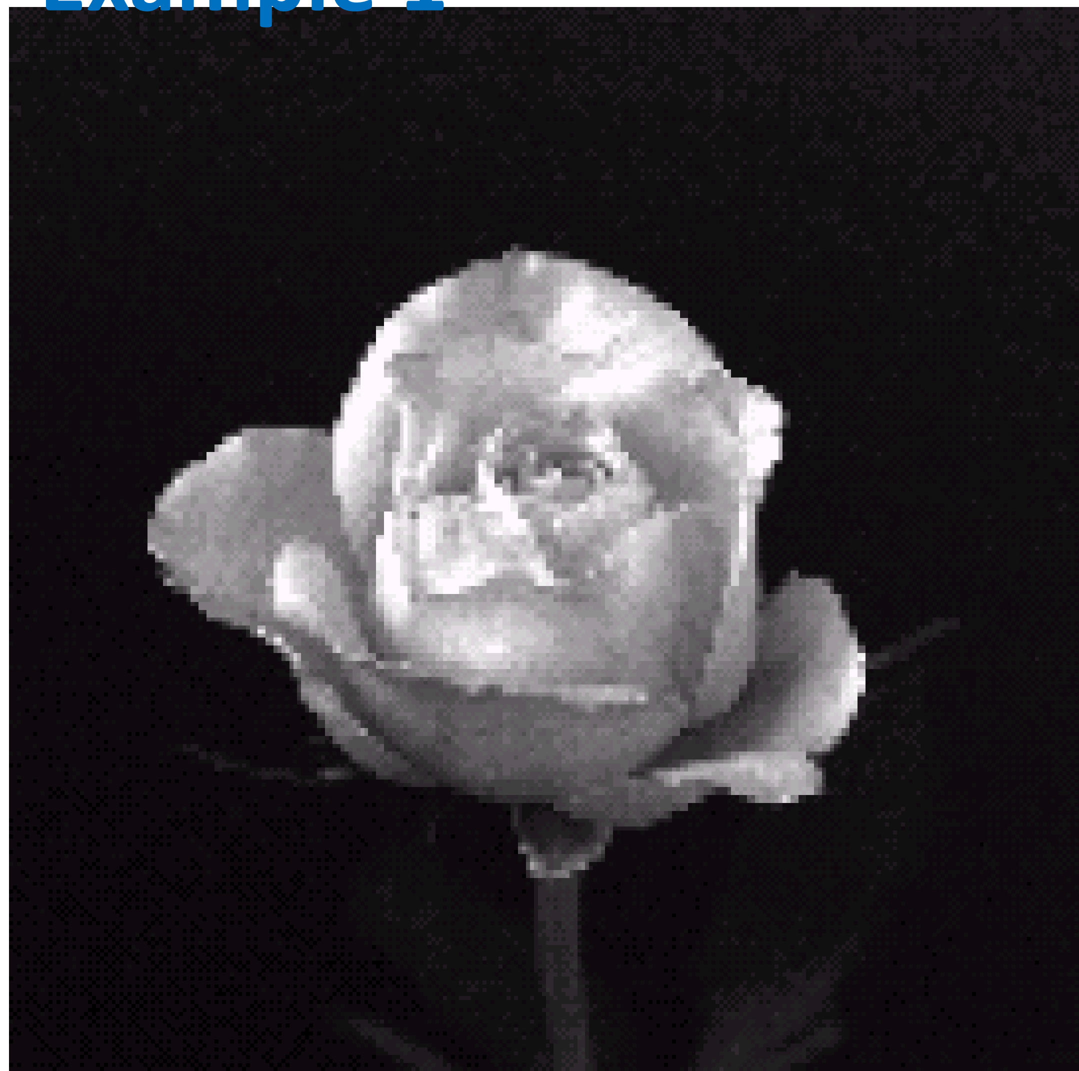
1- Pixel Resolution – Example 1

256×256

Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution – Example 1

128×128



Effects of Sampling & Quantization – (cont.)

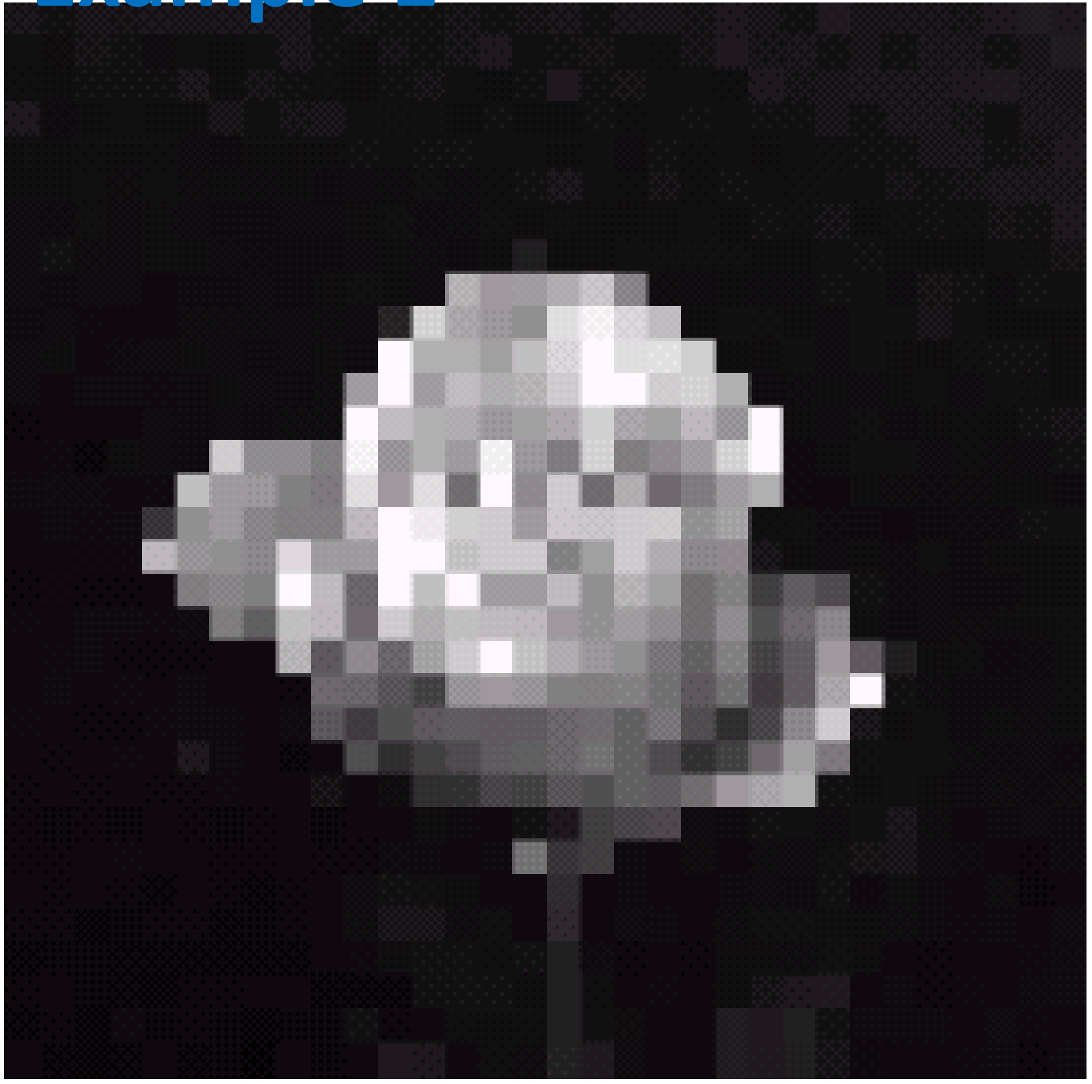
1- Pixel Resolution – Example 1

64×64

Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution – Example 1

32×32



Effects of Sampling & Quantization – (cont.)

1- Pixel Resolution – Example 2

Effects of Sampling & Quantization – (cont.)

3- Intensity Resolution

- *R*efers to the number of intensity levels used to represent the image.
  - More intensity levels = finer discernable detail.
  - In terms of number of bits used to store each intensity level.

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

Effects of Sampling & Quantization – (cont.)

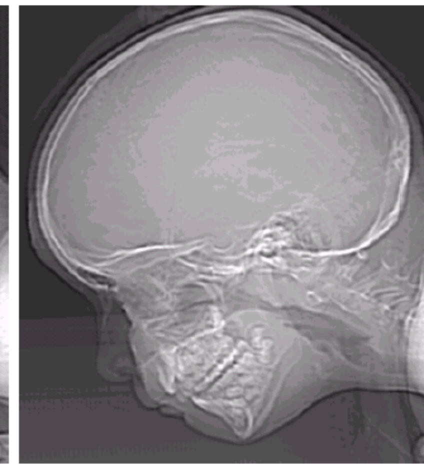
3- Intensity Resolution

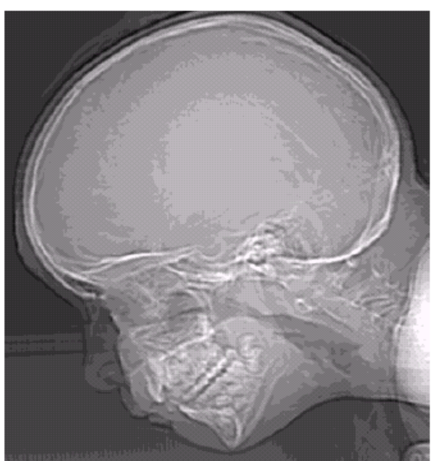
256 grey levels (8 bits per pixel)

128 grey levels (7 bpp)

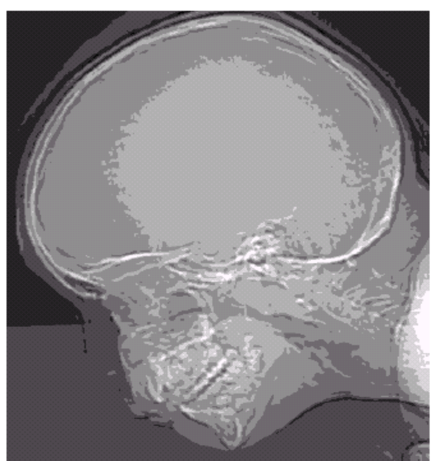
64 grey levels (6 bpp)

32 grey levels (5 bpp)

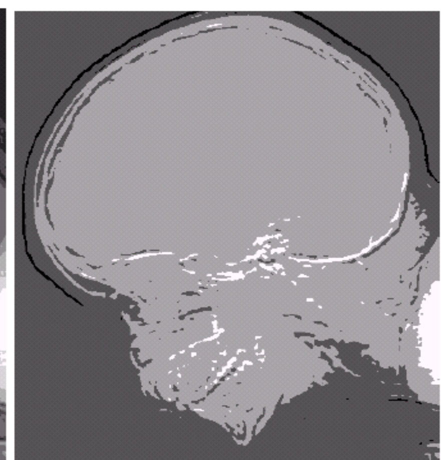




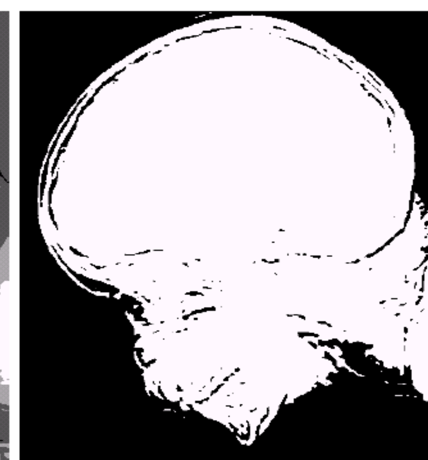
16 grey levels (4 bpp)



8 grey levels (3 bpp)



4 grey levels (2 bpp)



2 grey levels (1 bpp)

Effects of Sampling & Quantization – (cont.)

- Resolution: How much is enough?

- **This all depends on what is in the image and what you would like to do with it**
- **Key questions include**

- Does the image look aesthetically pleasing?

- Can you see what you need to see within the image?

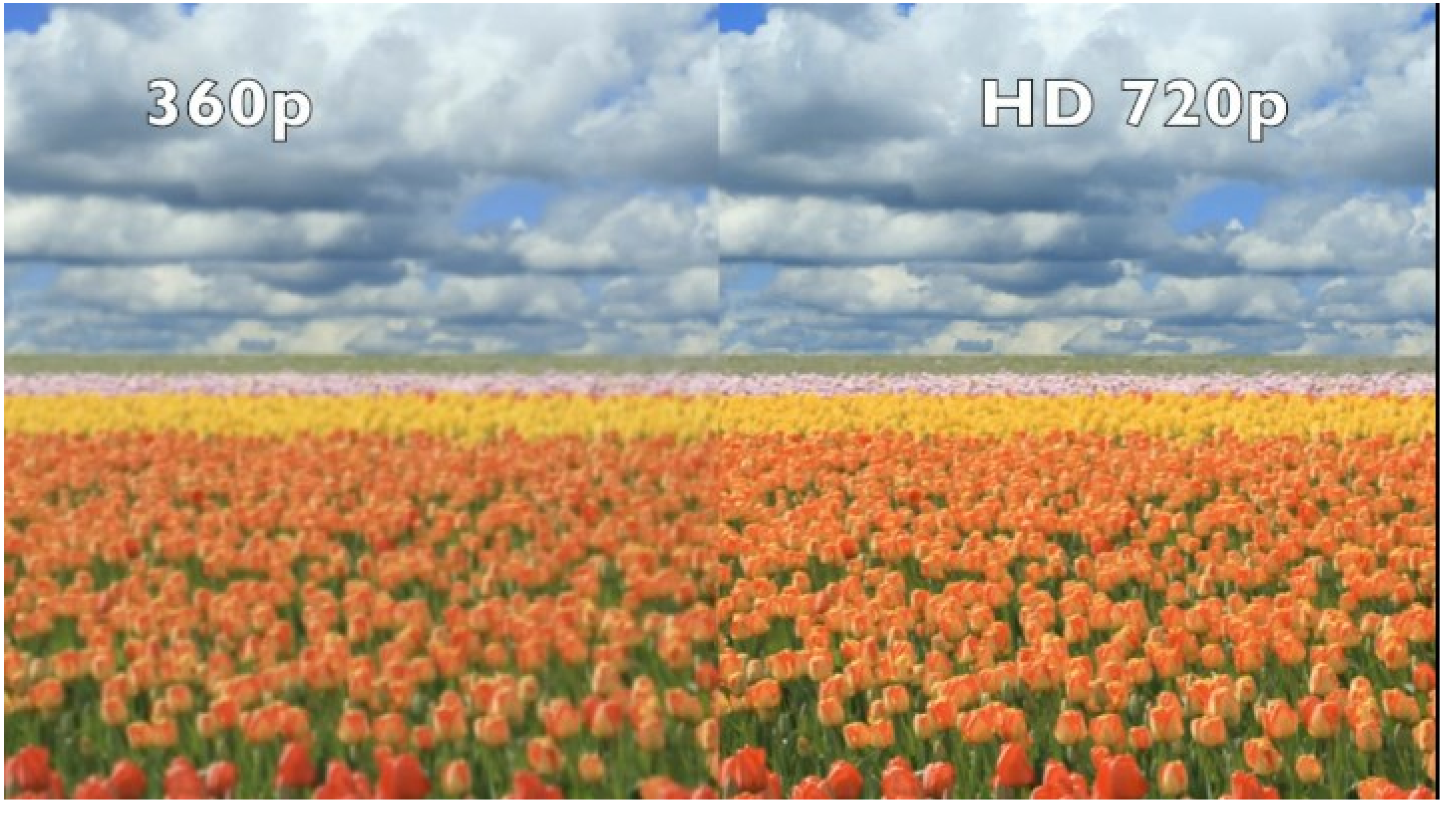
Effects of Sampling & Quantization – (cont.)

- Resolution: How much is enough?

The picture on the right is fine for counting the number of cars, but not for reading the plate number.

Note on Video

- **Sequence of images (frames) with specific frame rate→ definitely needs compression→ affects quality.**

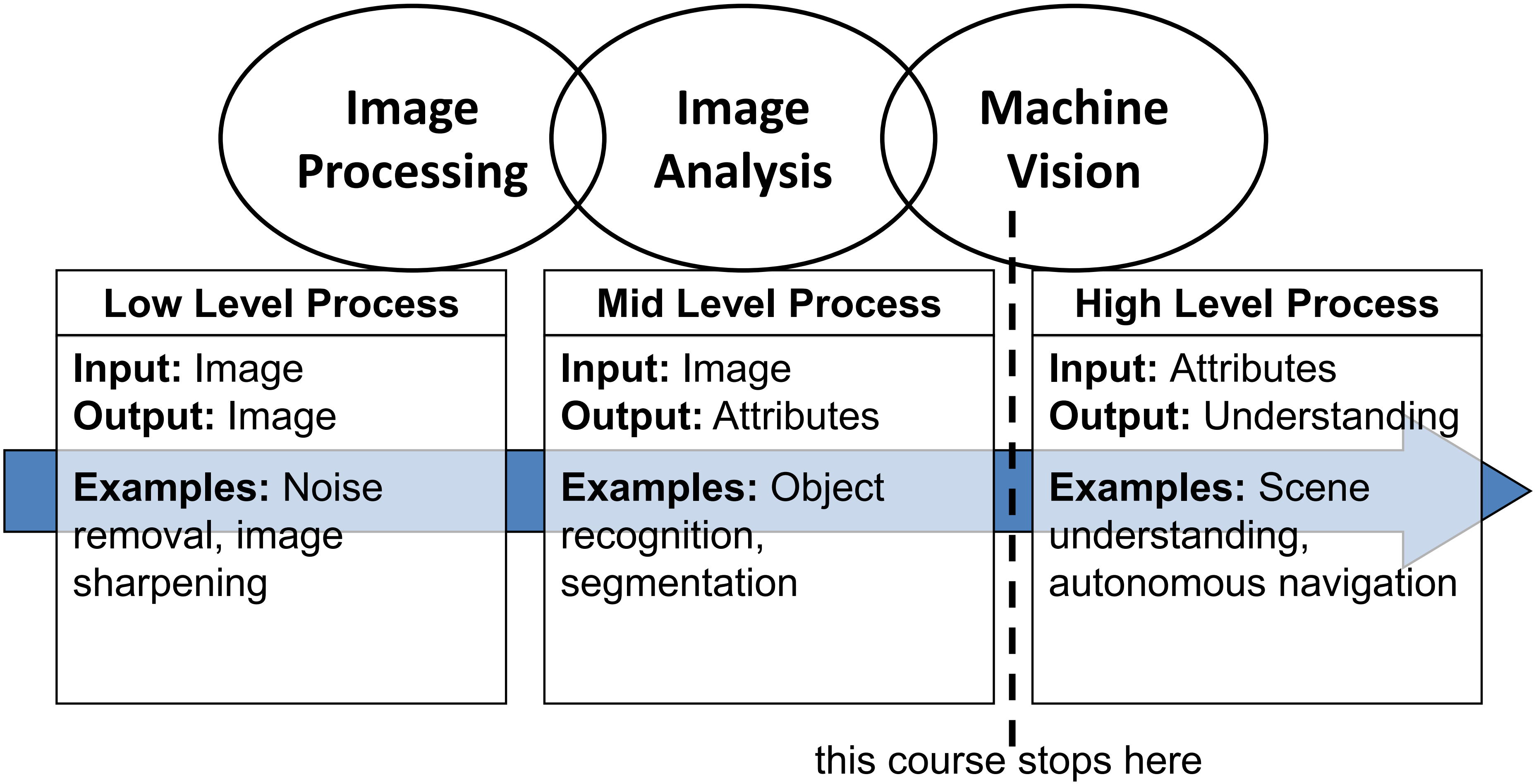


Digital Image Processing

- **DIP: Processing of a digital image by means of a computer.**

- **Why?**
  - **Improvement of pictorial information for human interpretation (low-level).**
  - **Processing of scene data for autonomous machine perception (computer vision).**

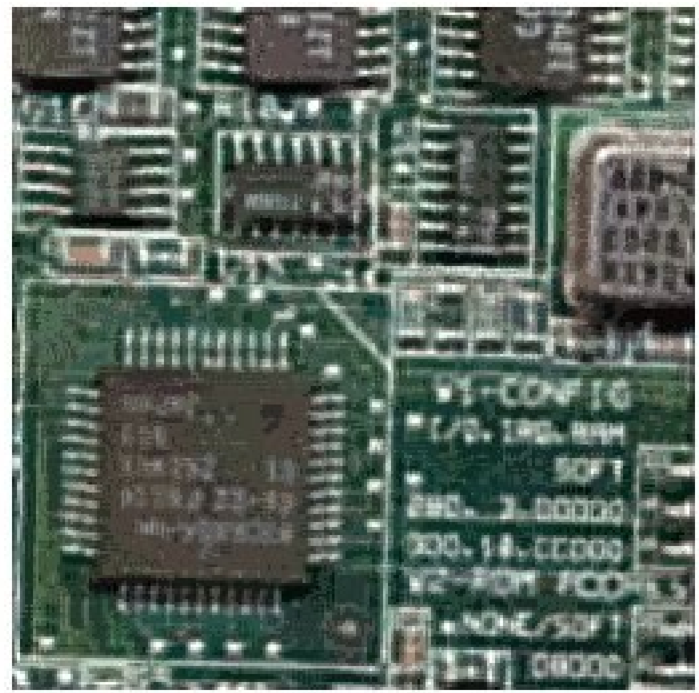
Digital Image Processing



Example Applications

- **Image Enhancement/restoration**: One of the most common uses of DIP techniques: improve quality, remove noise, etc.

Blurred & noisy image



Restored image

Example Applications – (cont.)

- **Image Enhancement/restoration**: One of the most common uses of DIP techniques: improve quality, remove noise, etc.

Wide Field Planetary Camera 1 Wide Field Planetary Camera 2

Example Applications – (cont.)

- Medical Visualization:

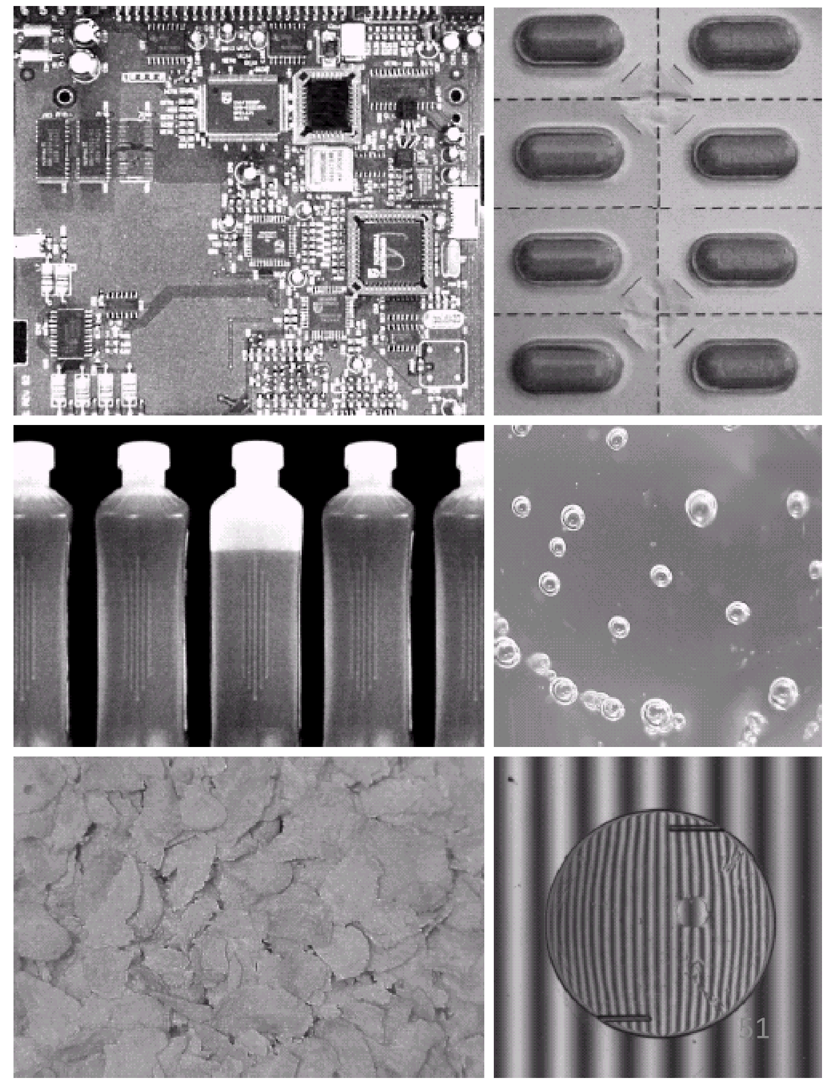
Computerized Axial Tomography (CAT) scans.

Magnetic Resonance Imaging (MRI).

Example Applications – (cont.)

- Industrial Inspection:

detecting anomalies.



Example Applications – (cont.)

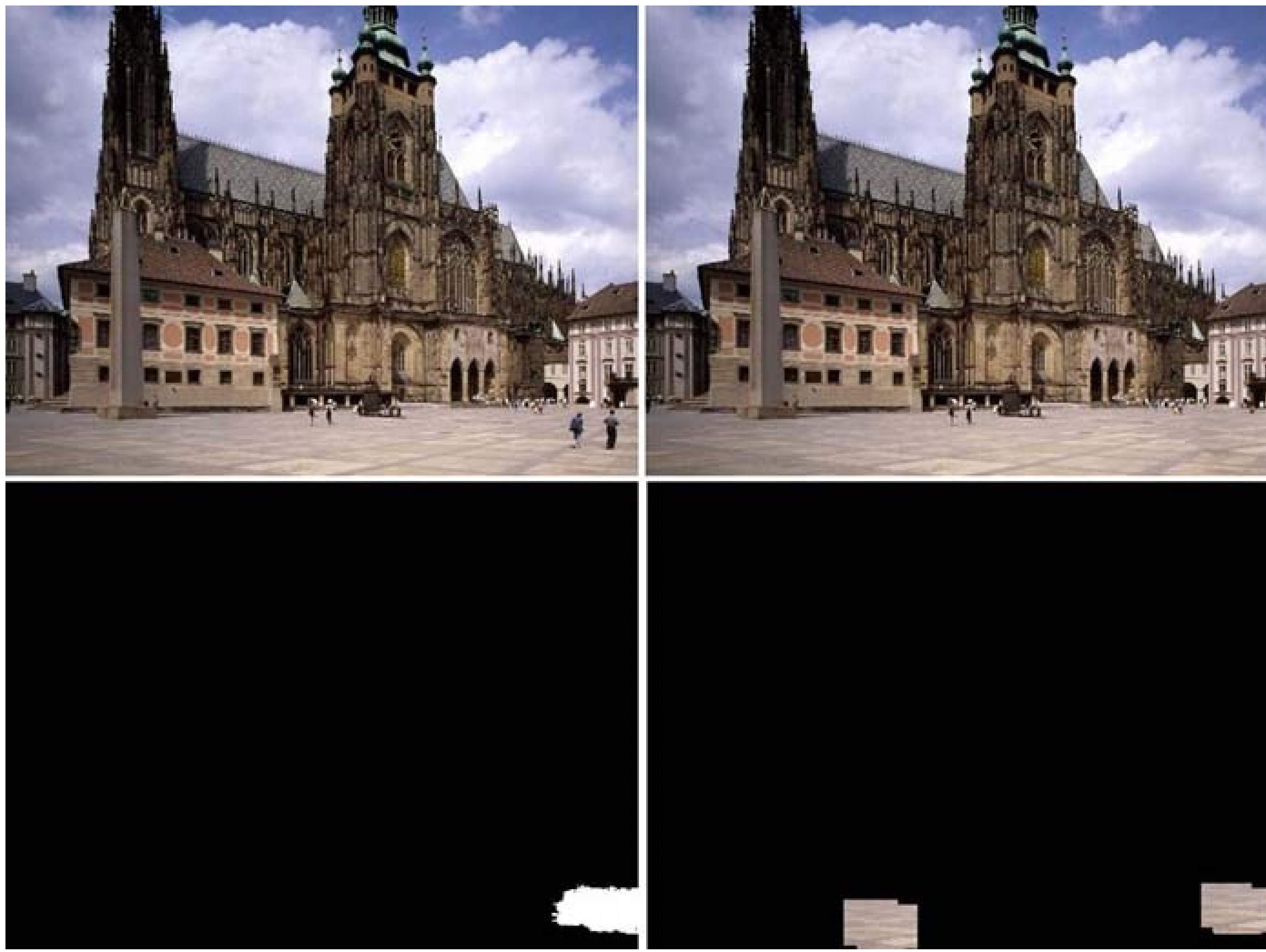
- **Special Effects**: make images more visually appealing, or make composites.

Example Applications – (cont.)

- **Image Forensics**: authentication and forgery detection.

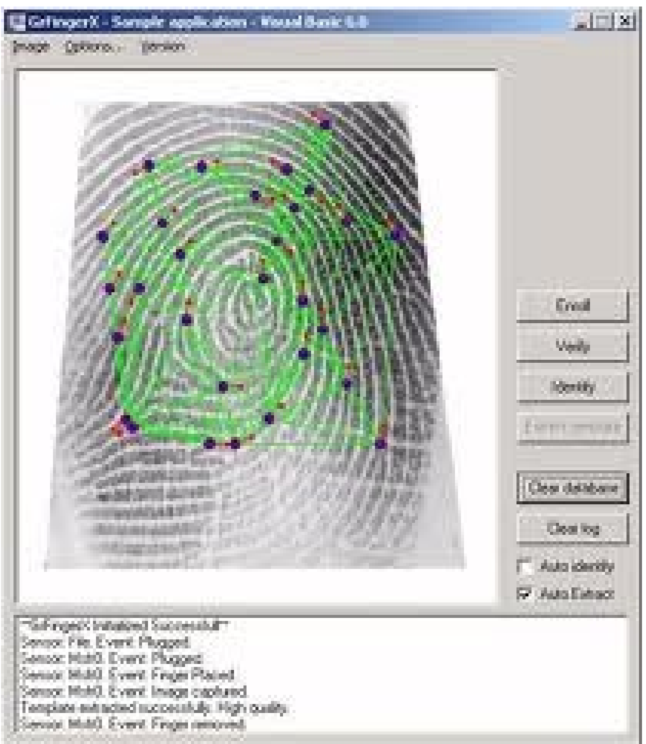
Example Applications – (cont.)

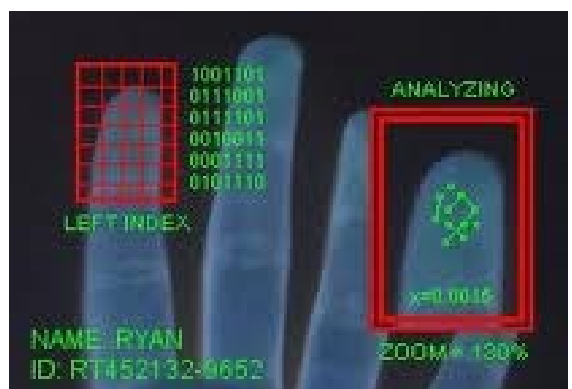
- **Image Forensics**: authentication and forgery detection.



Example Applications – (cont.)

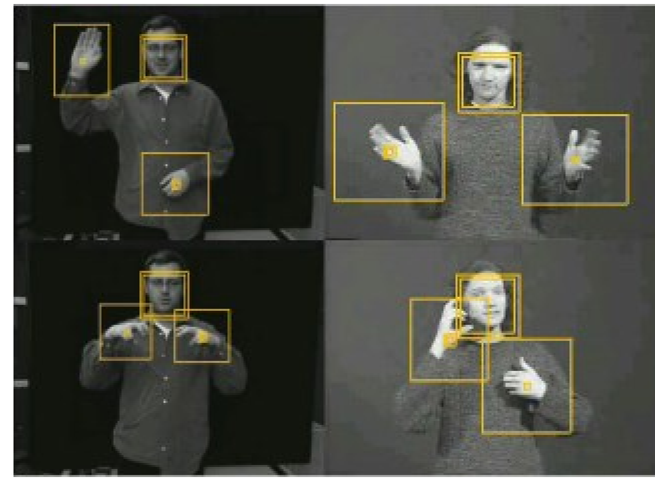
- **Law Enforcement**: automated detection, tracking, and identification.





Example Applications – (cont.)

- **HCI**: Try to make human computer interfaces more natural
  - **Face recognition**
  - **Gesture recognition**
  - **Computer Graphics**



Most Common Topics in DIP

1. Image formation
2. Sampling and quantization
3. Point processing and equalization
4. Re-sampling and geometric transformations
5. Convolution and spatial filtering
7. Fourier transform and frequency filtering
8. Restoration and noise reduction
9. Morphology
10. Segmentation

Fundamental Steps of DIP

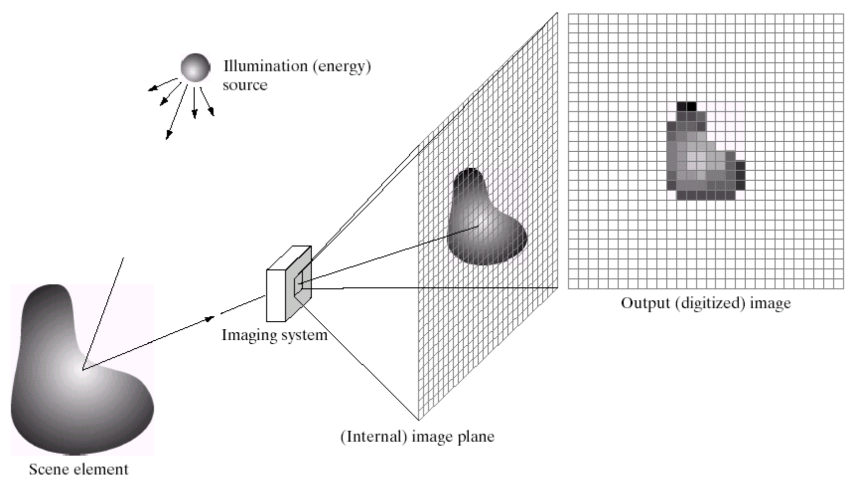
Image Restoration

Morphological Processing

Image Enhancement

Segmentation

Image Acquisition



Object Recognition

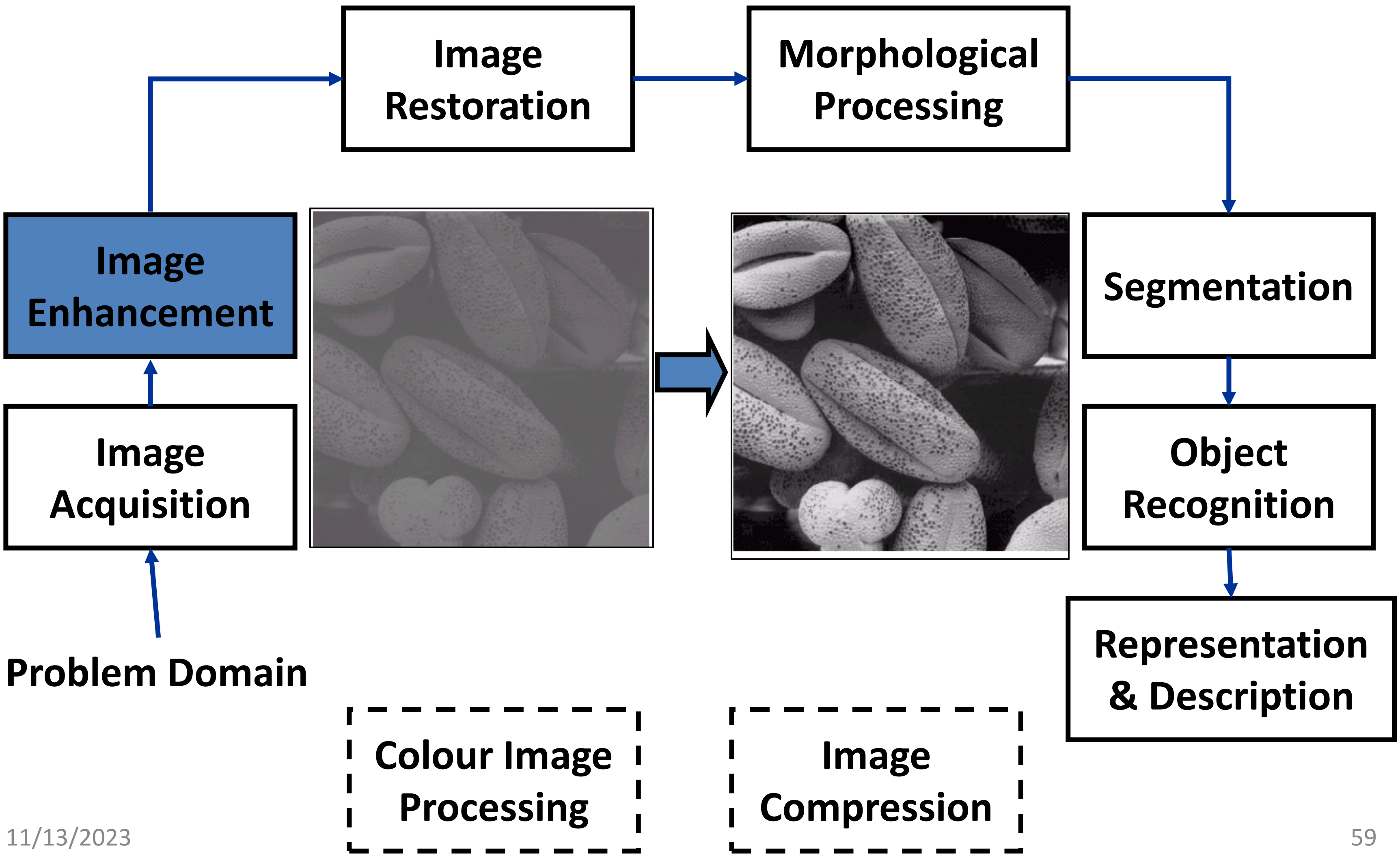
Problem Domain

Representation & Description

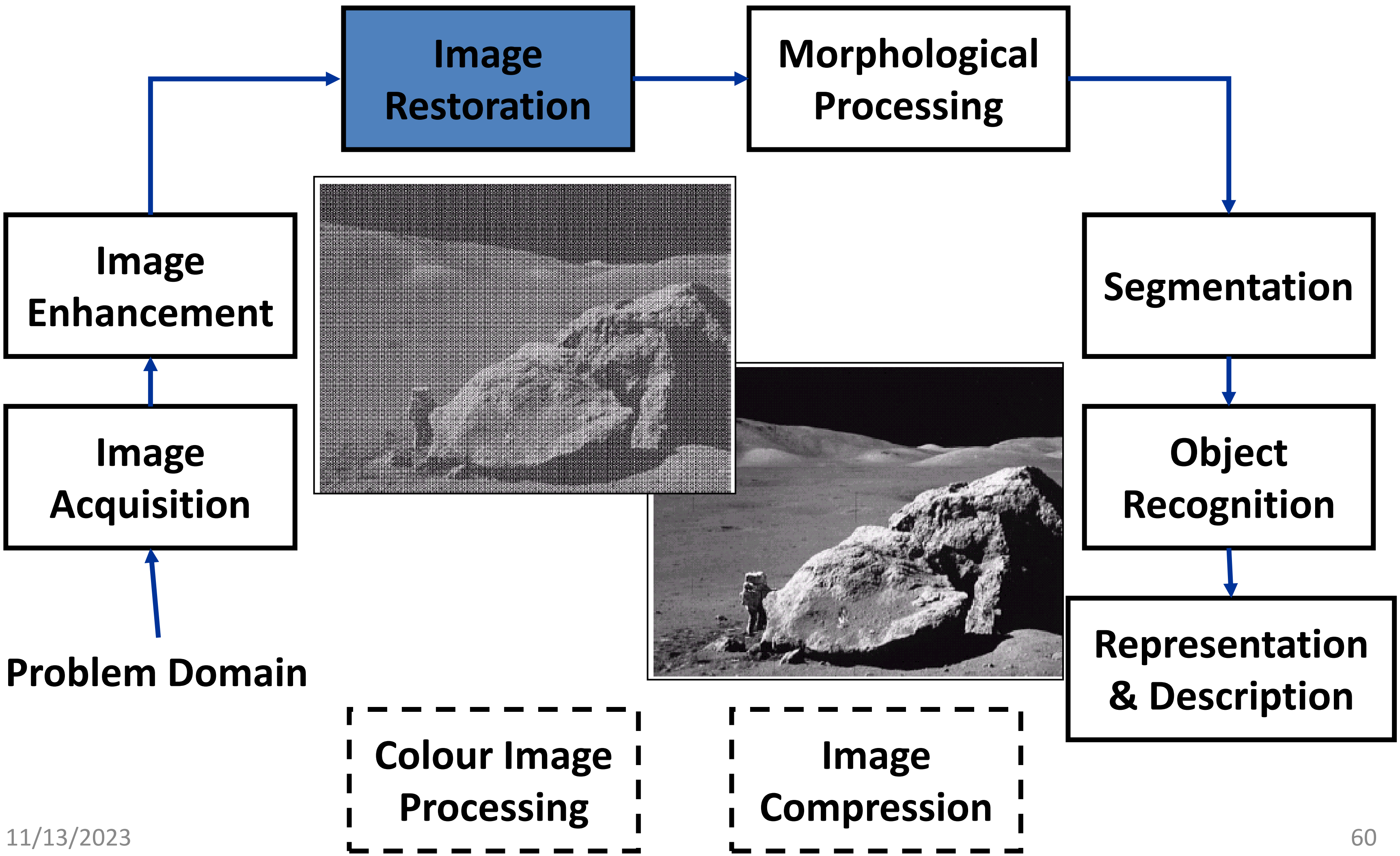
Colour Image Processing

Image Compression

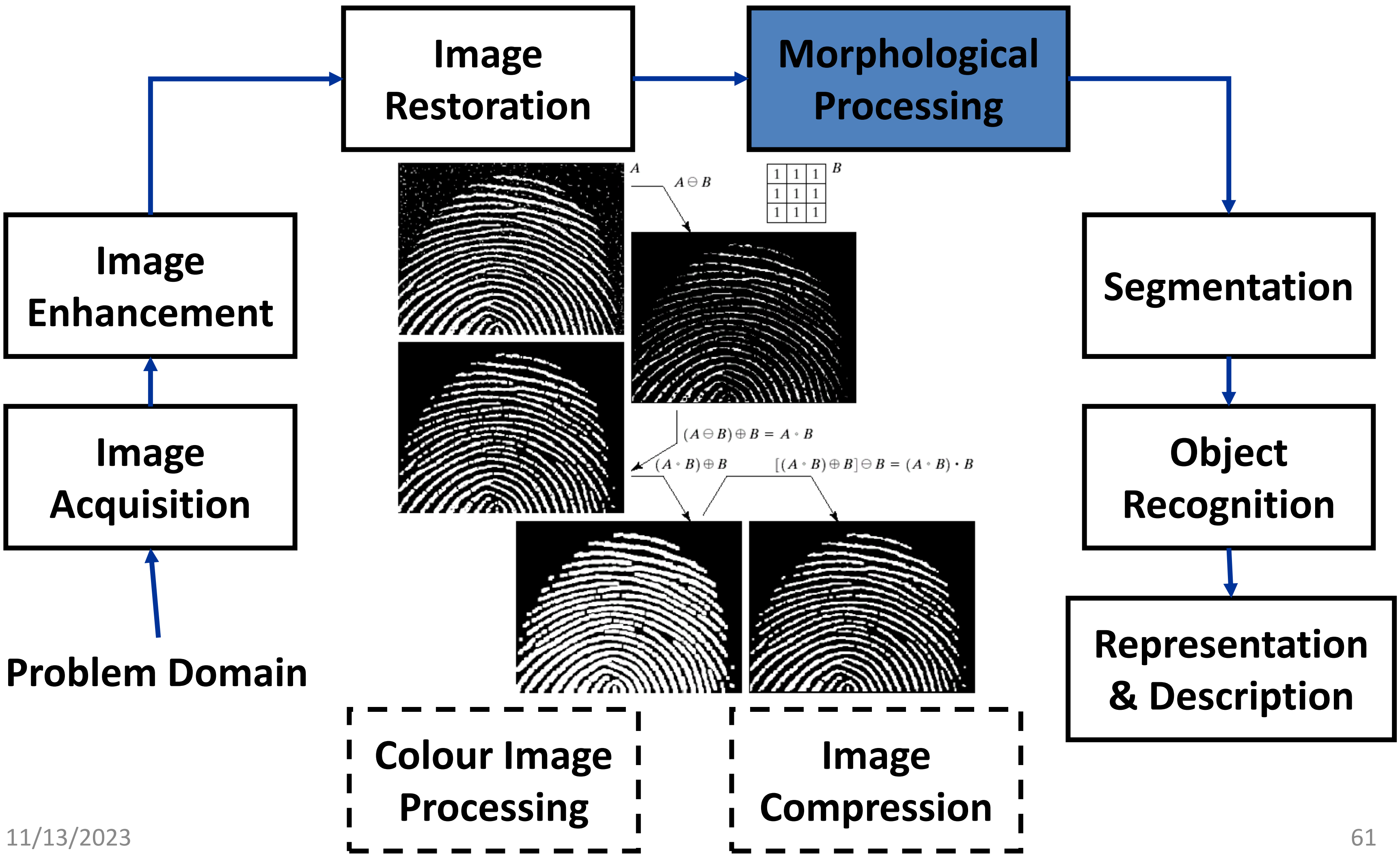
Fundamental Steps of DIP – (cont.)



Fundamental Steps of DIP – (cont.)



Fundamental Steps of DIP – (cont.)



Fundamental Steps of DIP – (cont.)

Image Restoration

Morphological Processing

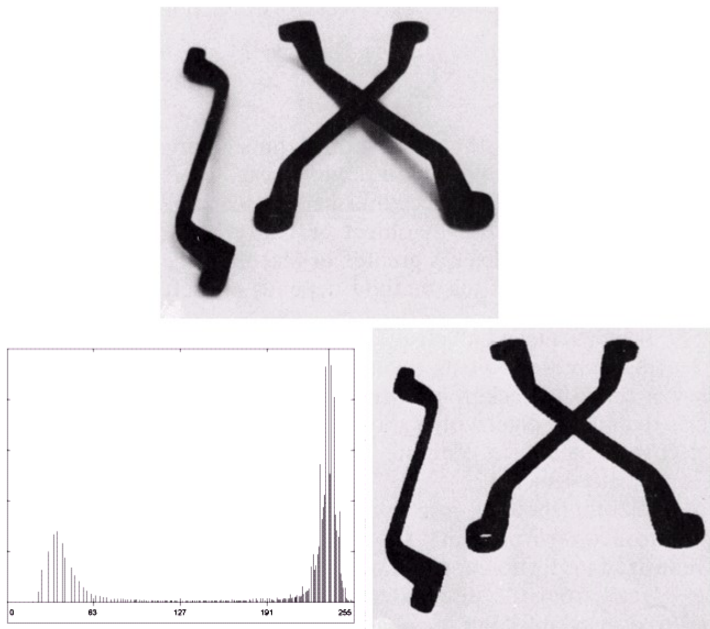
Image Enhancement

Segmentation

Image Acquisition

Object Recognition

Problem Domain

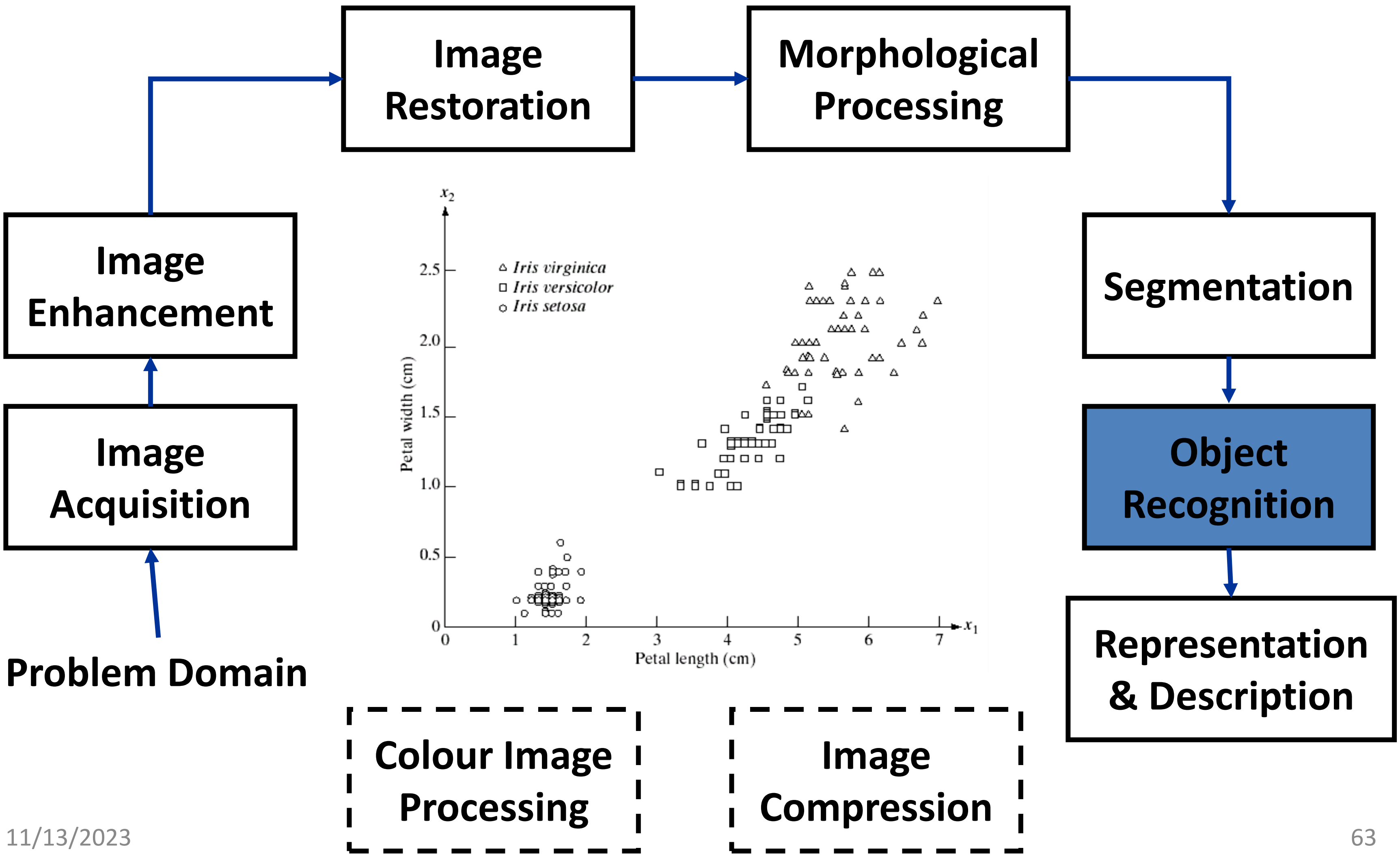


Representation & Description

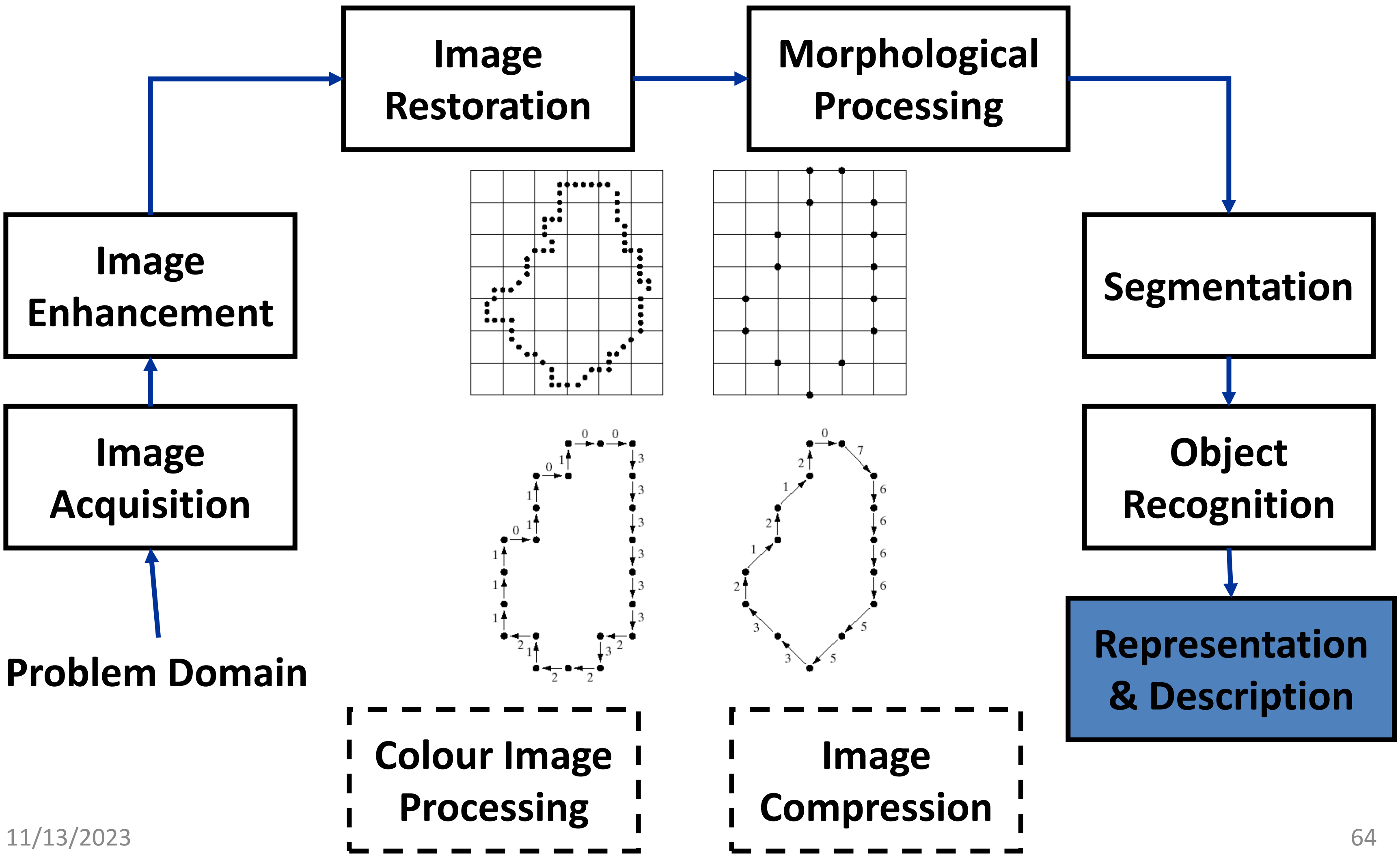
Colour Image Processing

Image Compression

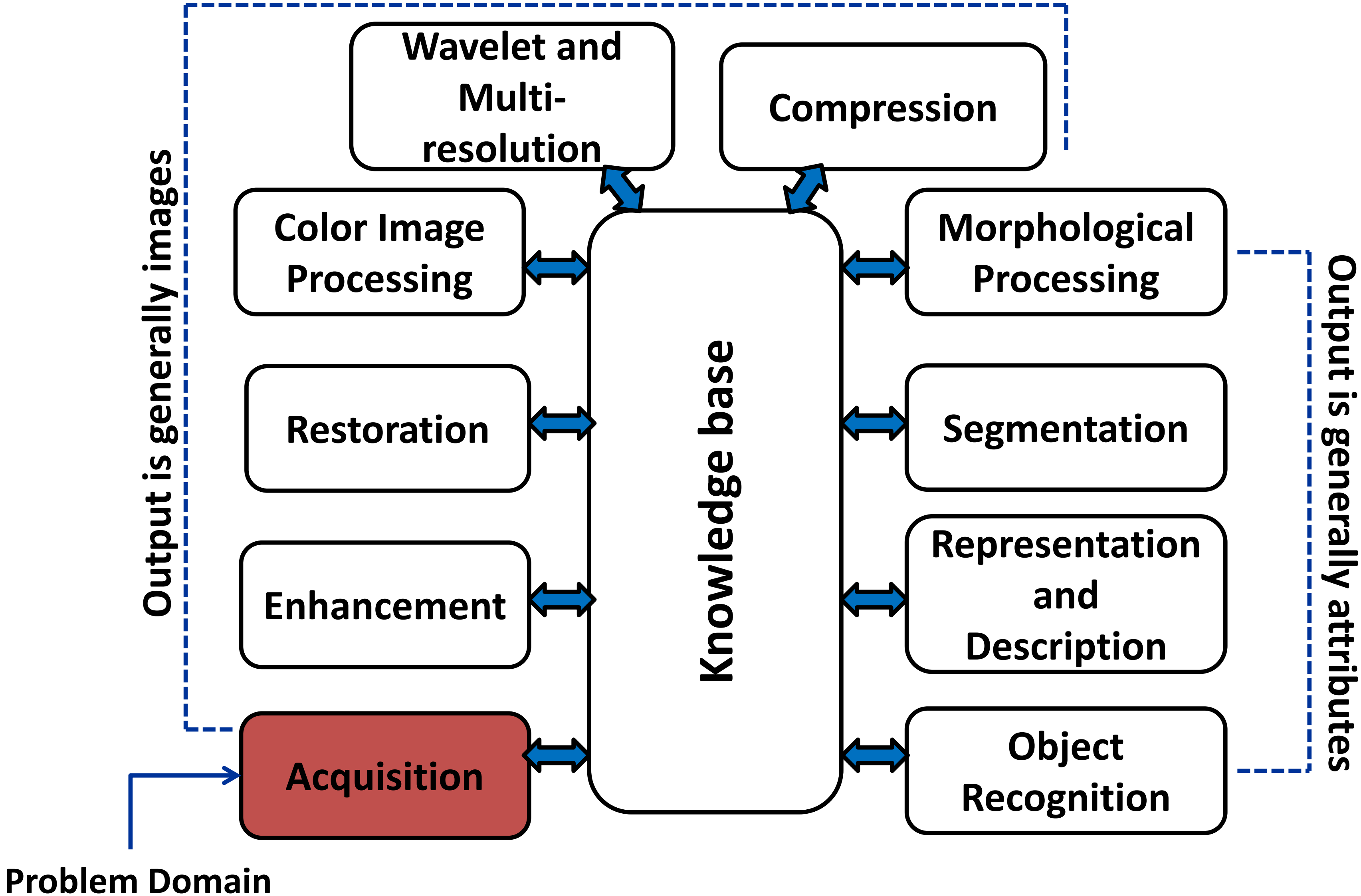
Fundamental Steps of DIP – (cont.)



Fundamental Steps of DIP – (cont.)



Course Outline



Winner

- Diagnose the image(s).
- Develop a solution/process.
- Describe the why.
- Know the how.
- Write about it.

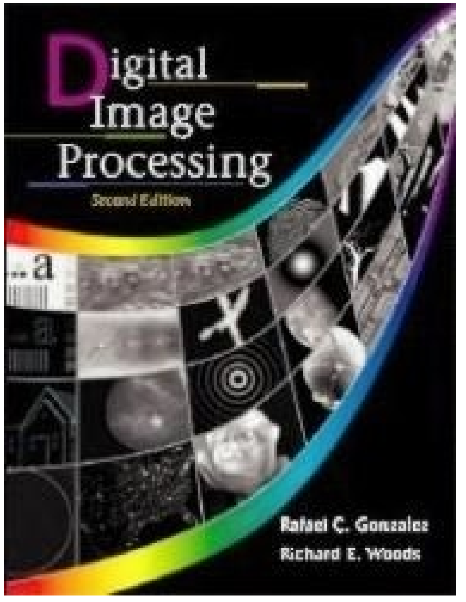
Assessment

Final Test	50 %
Midterm	15%
Quiz	5%
Practical	20 %
Yearwork	**10%**

Textbook

- **Digital Image Processing,** 3rd edition, Rafael C. Gonzalez and Richard E. Woods, Prentice Hall, 2008.

http://www.imageprocessingplace.com



Next Lecture

Image Enhancement in the Spatial Domain

Assignment

- **Textbook Chapter 1**

  Chapter 2: 1, 2, 3, 4, 4.1, 4.2, 4.3

- **Check associated problems:**

Chapter 2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 22, 23

Choose your lab partners (teams of five).

References

- Gonzalez and Woods, Digital Image Processing.

- Peters, Richard Alan, II, “Intro", Lectures on Image Processing, Vanderbilt University, Nashville, TN, April 2008, Available on the web at the Internet Archive, http://www.archive.org/details/Lectures_on_Image_Processing.

- Image Processing, Analysis and Machine Vision, Milan Sonka, Vaclav Hlavac, Roger Boyle, Thomson, 2008.

- Matlab Image Processing Toolbox.

-http://www.scantips.com/basics09.html

-http://vimeo.com/videoschool/lesson/186/the-basics-of-image-resolution

-http://en.wikipedia.org/wiki/Display_resolution

-http://animoto.com/blog/news/hd-video-creation-sharing/