CTT310: Digital Image Processing

Introduction to Digital Image Processing

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Outline

- What is Digital Image Processing?
- The origins of Digital Image Processing
- Examples of fields that use Digital Image Processing
- Fundamental steps in Digital Image Processing
- Components of an Image Processing System

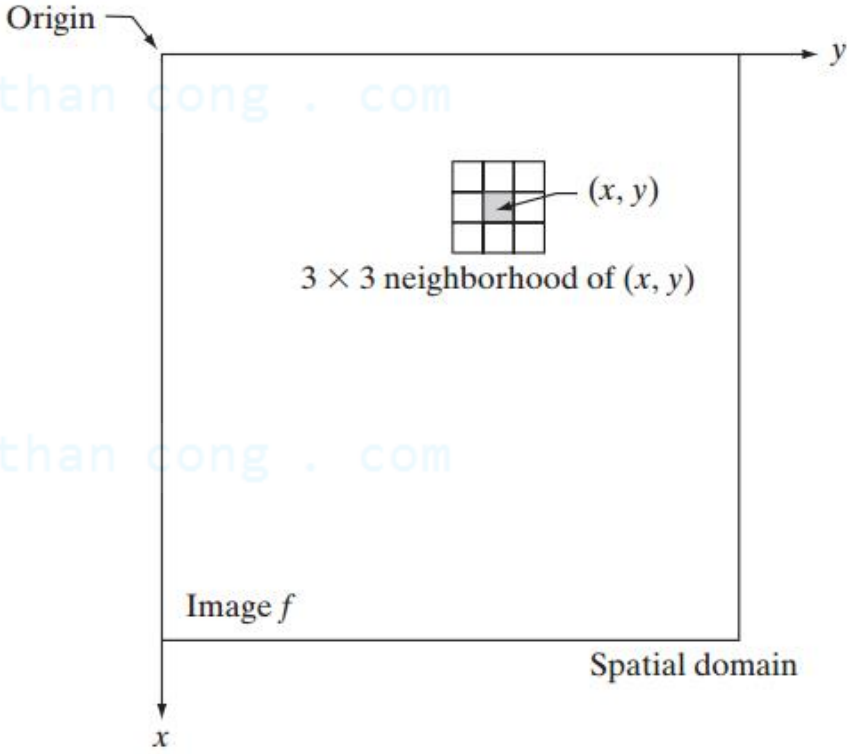
Introduction

Section 1.1

WHAT IS DIGITAL IMAGE PROCESSING?

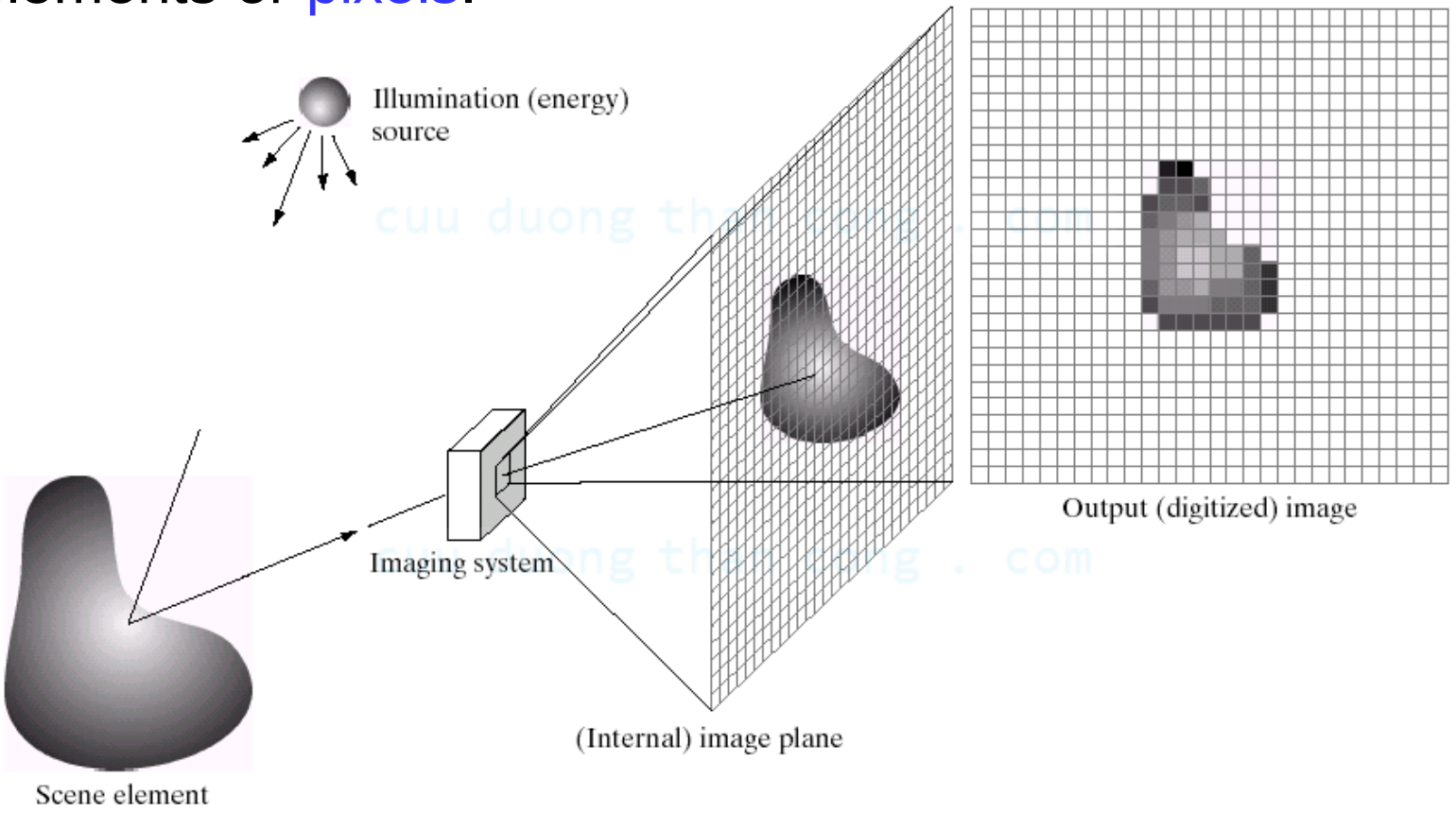
What is an image?

- An **image** is defined as a two-dimensional function, $f(x, y)$.
  - where x and y are spatial (plane) coordinates
- The amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point.



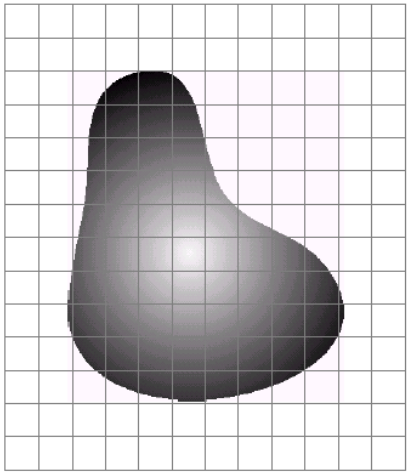
What is a digital image?

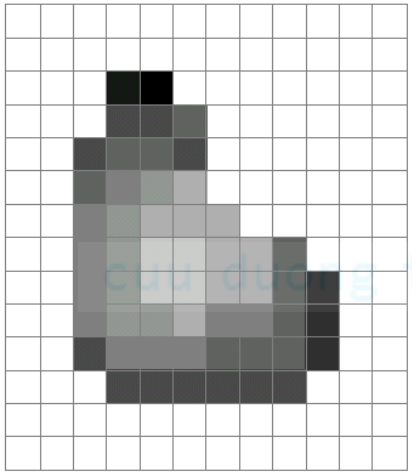
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels.

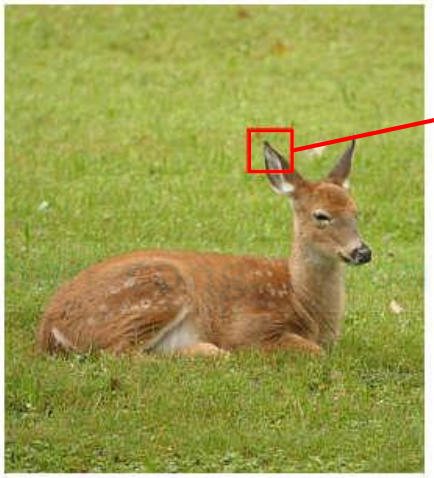


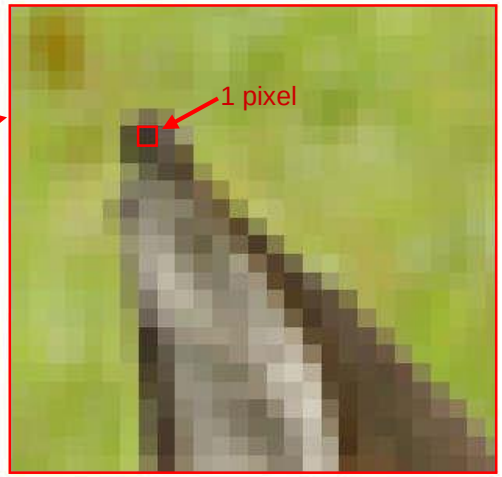
What are pixels?

- Pixel values typically represent gray levels, colours, heights, opacities, etc.
- *Digitization* implies that a digital image is an *approximation* of a real scene.









Common image formats

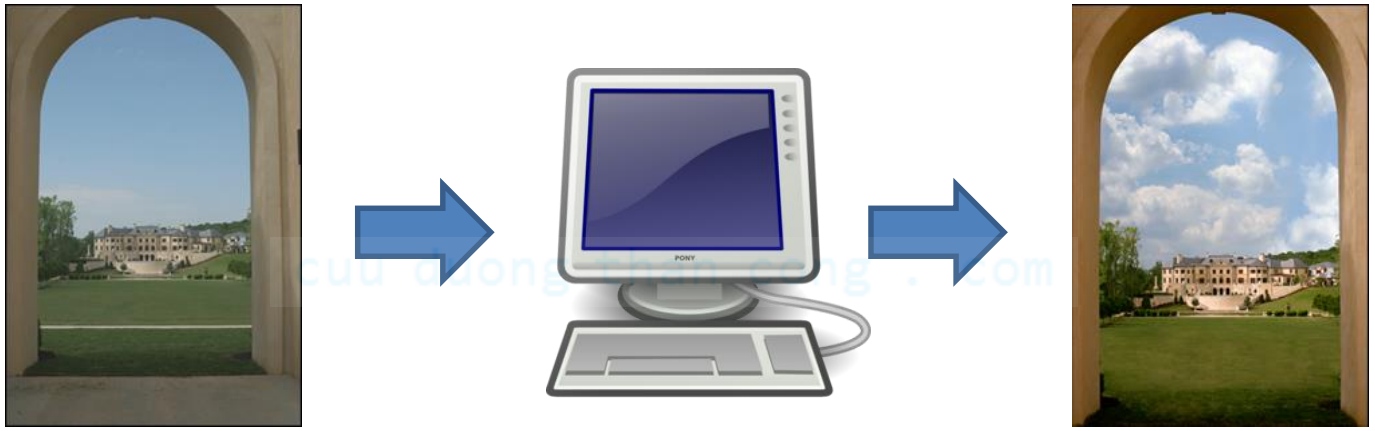
- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)



- *For most of this course we will focus on grey-scale images*

Digital image processing

- **Digital image processing** refers to processing digital images by means of a digital computer.



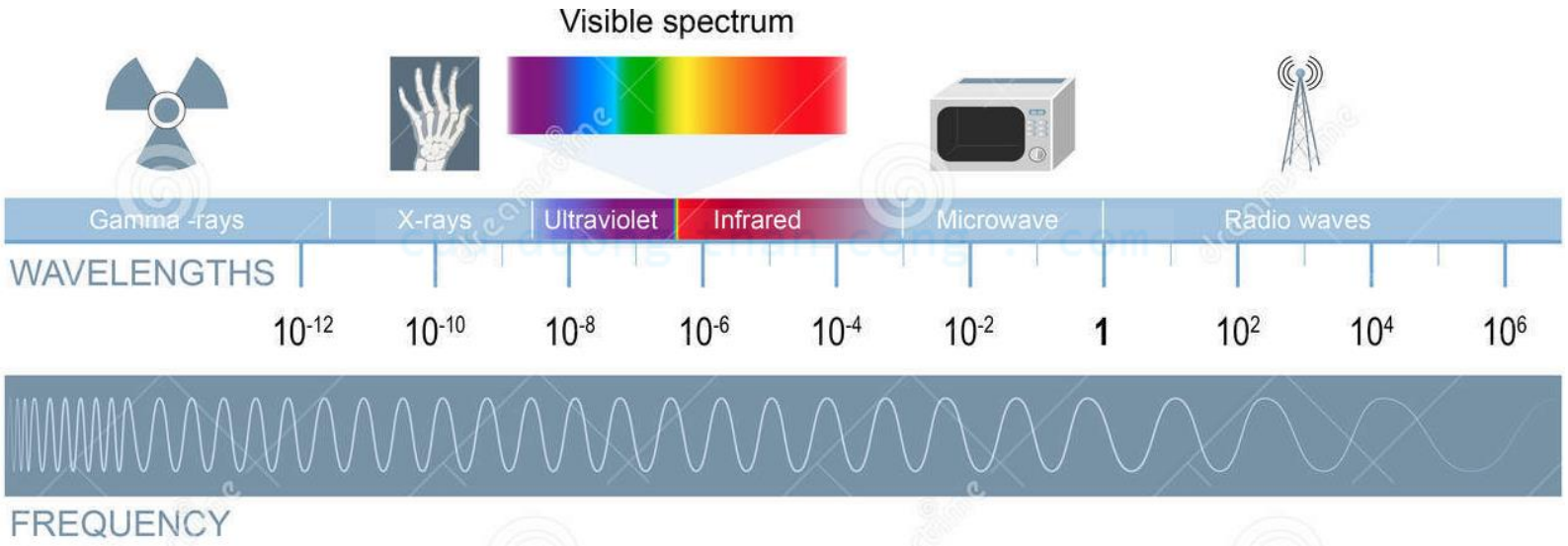
Original image

Contrast-enhanced image

- Two major tasks are focused
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception

Digital image processing

- Digital image processing covers almost the entire electromagnetic spectrum



- It encompasses a wide and varied field of applications.

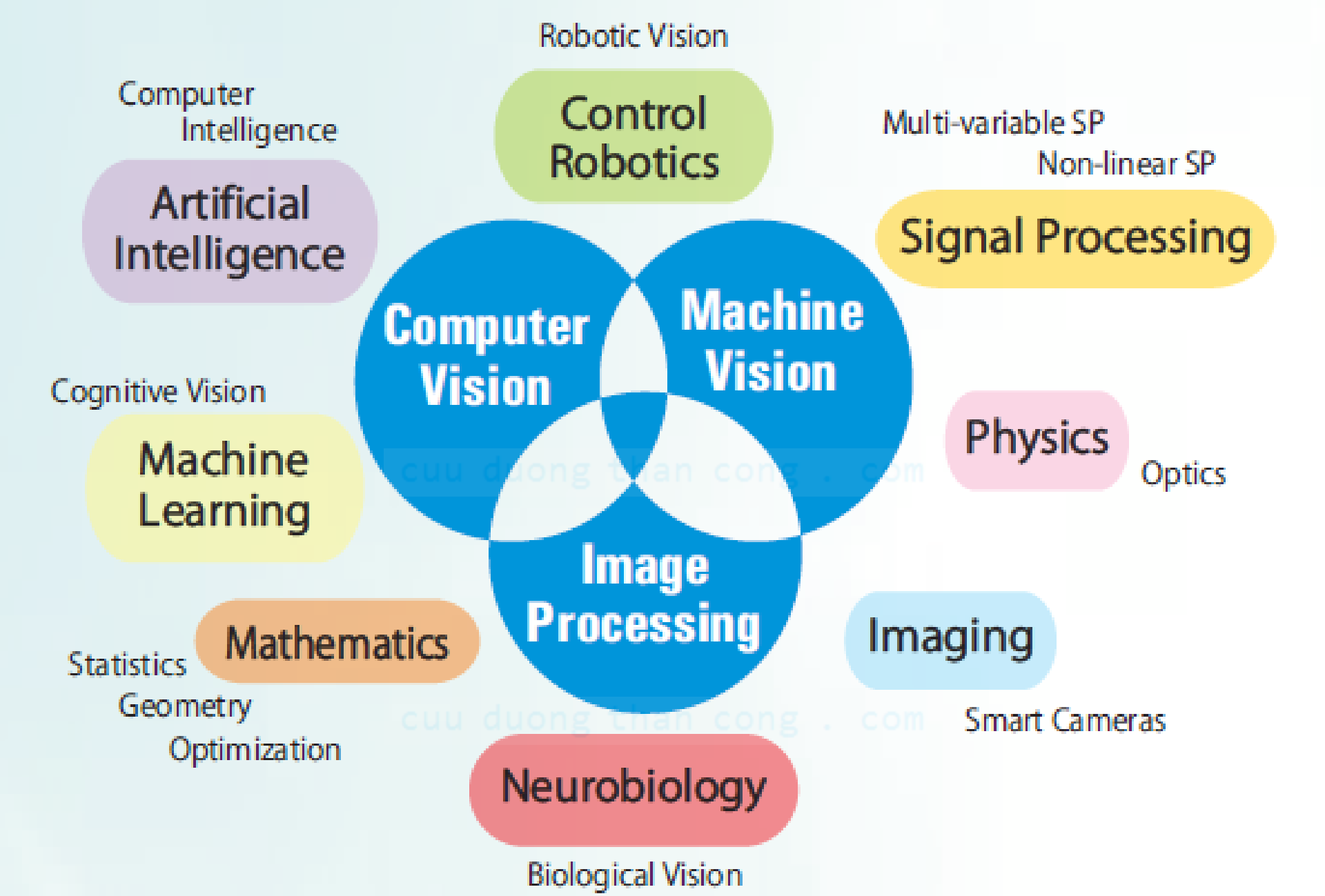
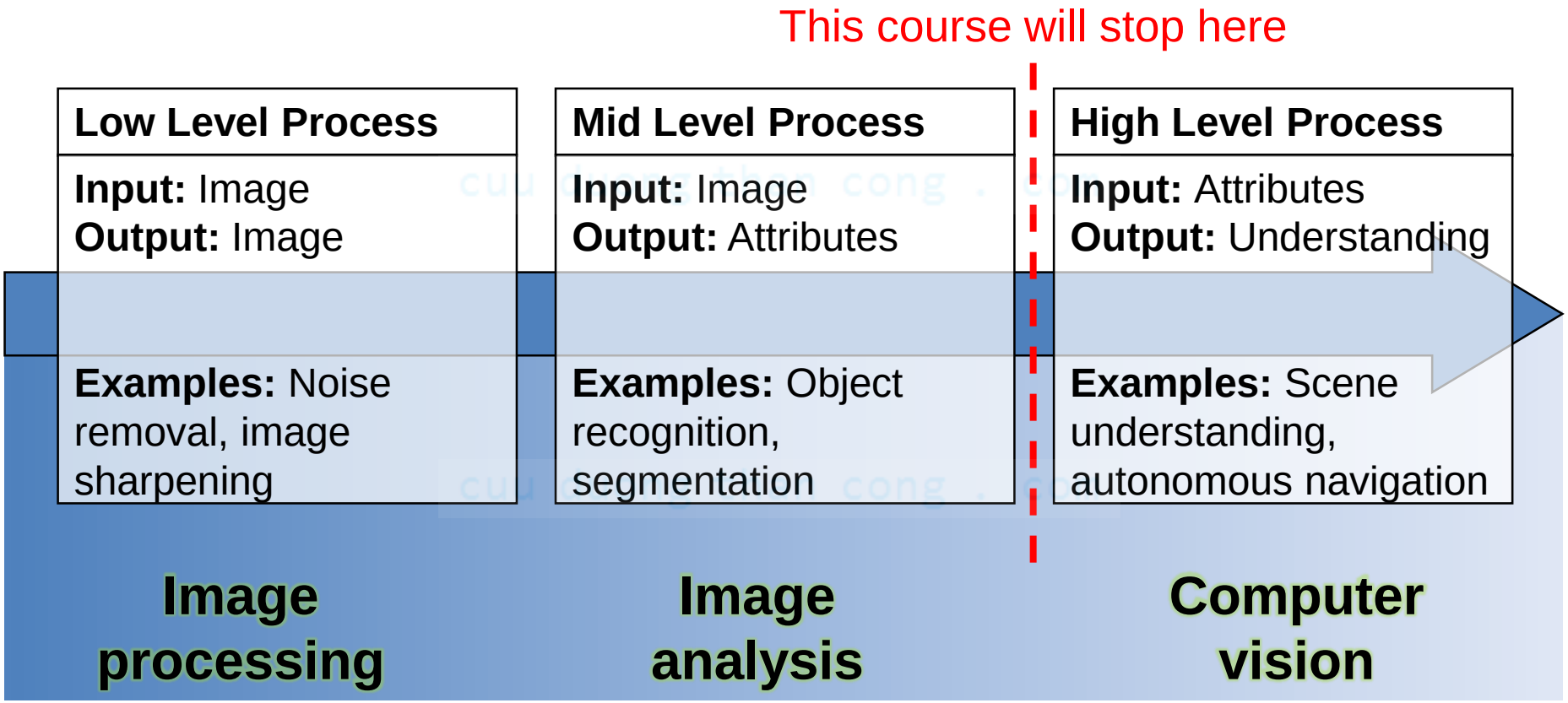


Image processing to computer vision

- The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes.



Section 1.2

THE ORIGINS OF DIGITAL IMAGE PROCESSING

History of Digital Image Processing

1920s | 1960s | 1970s | 1980s – now

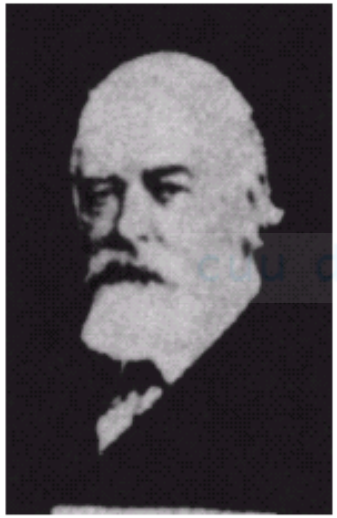
- **Early 1920s:** One of the first applications of digital imaging was in the newspaper industry.
  - The Bartlane cable picture transmission service: Images were transferred by submarine cable between London and New York
  - Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

A digital picture produced in 1921

History of Digital Image Processing

1920s | 1960s | 1970s | 1980s – now

- **Mid to late 1920s:** Improvements to the Bartlane system resulted in higher quality images
  - New reproduction processes based on photographic techniques
  - Increased number of tones in reproduced images



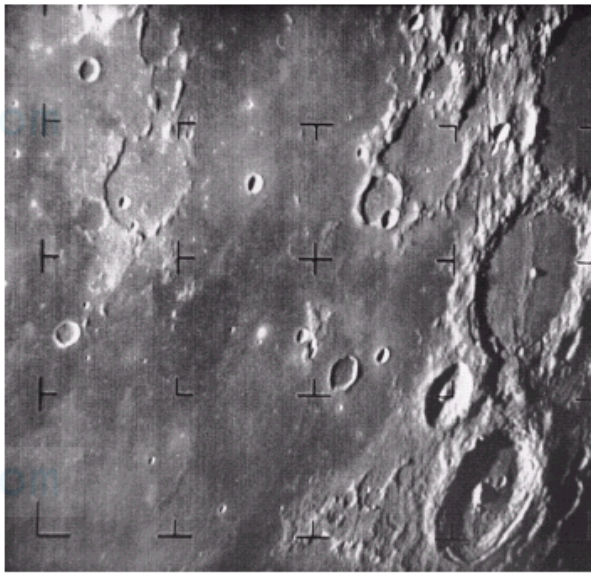
An improved image made in 1922

Early 15-tone digital image

History of Digital Image Processing

1920s | 1960s | 1970s | 1980s – now

- **1960s:** Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing
  - 1964: Computers used to improve the quality of images of the moon taken by the Ranger 7 probe
  - Such techniques were used in other space missions

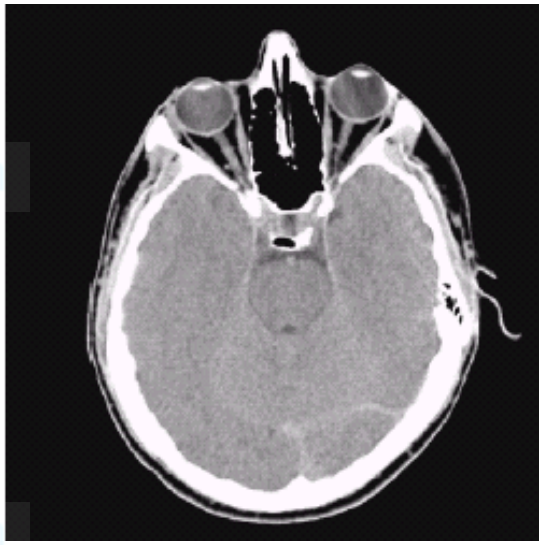


A picture of the moon taken by the Ranger 7 probe minutes before landing

History of Digital Image Processing

1920s | 1960s | 1970s | 1980s – now

- **1970s:** Medical applications of digital image processing arises.
  - 1979: Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans
  - Also used in remote Earth resources observations, and astronomy.



Typical head slice CAT image

History of Digital Image Processing

1920s | 1960s | 1970s | 1980s – now

- **1980s to now:** The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all areas.
  - Image enhancement/restoration
  - Artistic effects
  - Medical visualisation
  - Industrial inspection
  - Law enforcement
  - Human computer interfaces

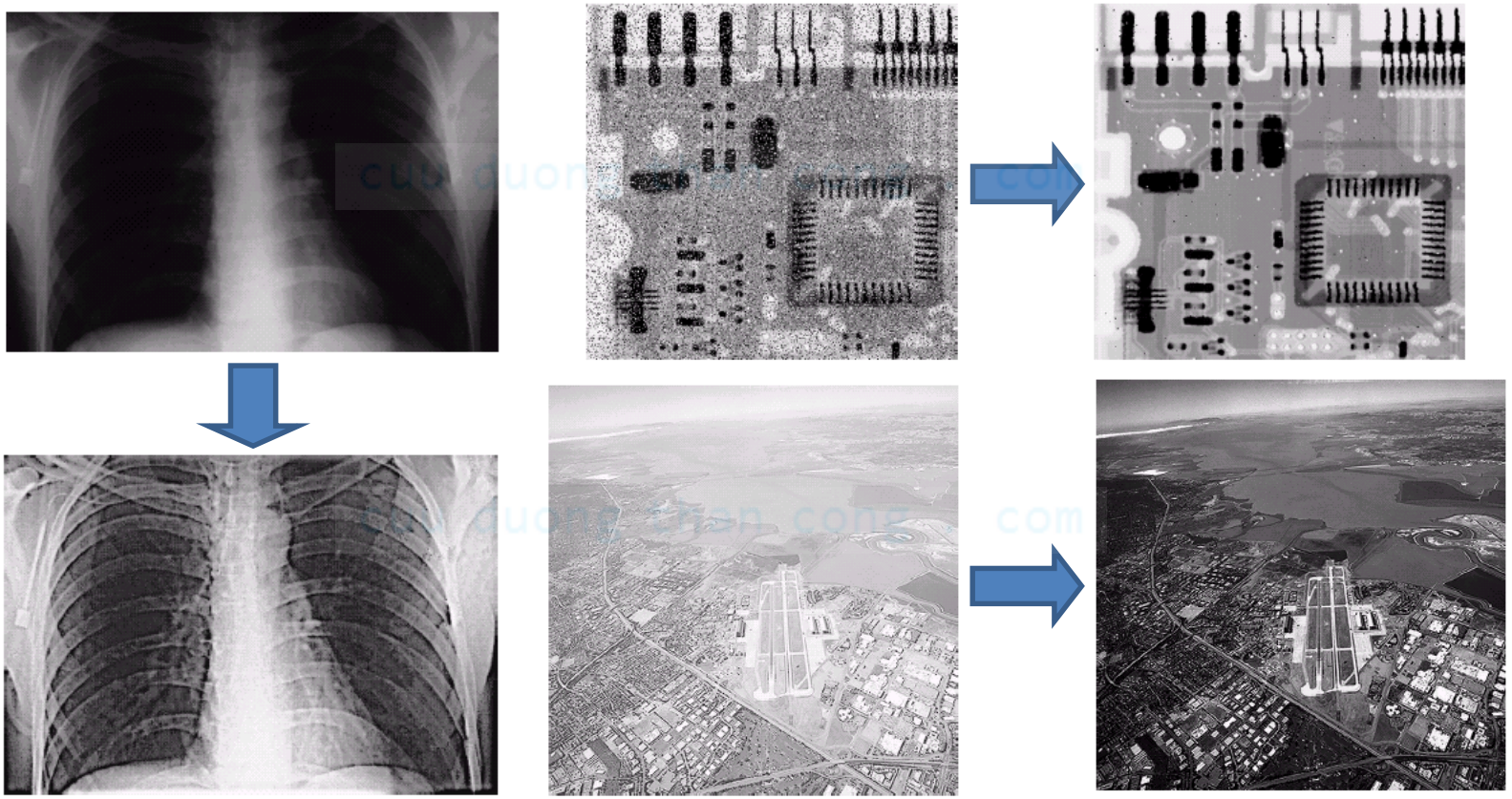
Restoration of historical documents in archeology (EG2014)

Section 1.3

EXAMPLES OF DIGITAL IMAGE PROCESSING APPLICATION

Image enhancement

- One of the most common uses of digital image processing techniques.
- Improve quality, remove noise, etc.

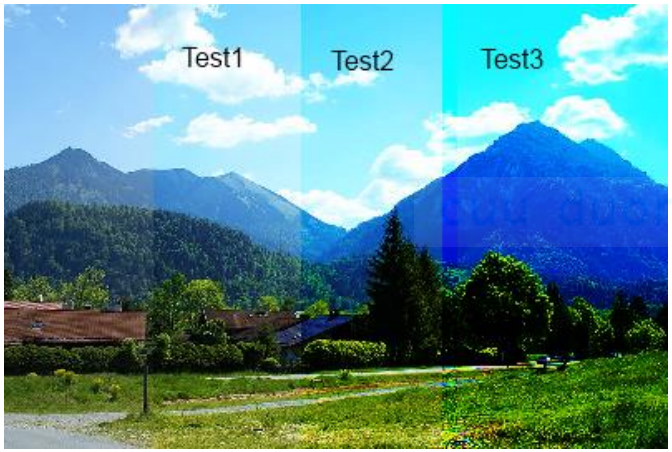


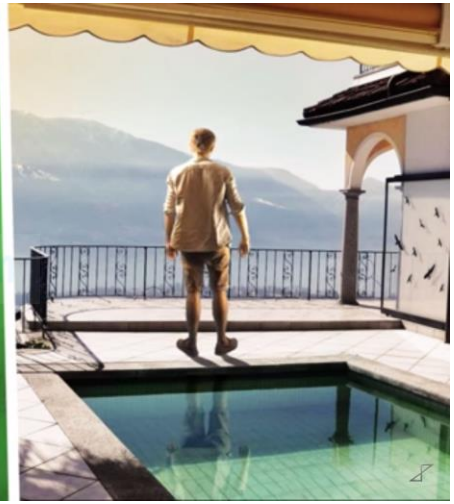
Astronomy: The Hubble Telescope

- Launched in 1990, the Hubble telescope can take images of very distant objects.
- However, many Hubble's images are useless due to an incorrect mirror

Artistic effects

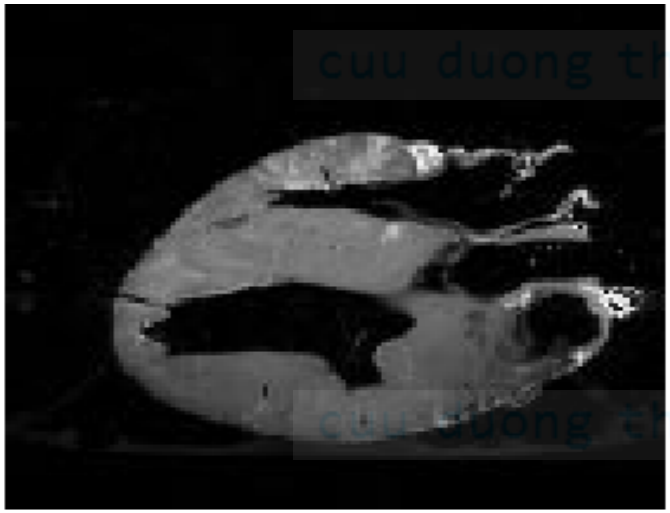
- Images are modified to be more visually appealing.
- Add special effects and make composite image



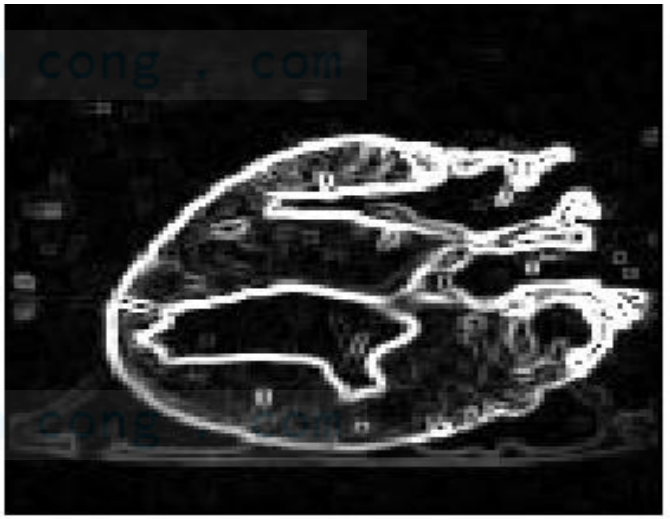


Medicine

- Take slice from MRI scan of canine heart, and find boundaries between types of tissue
  - Image with gray levels representing tissue density
  - Use a suitable filter to highlight edges



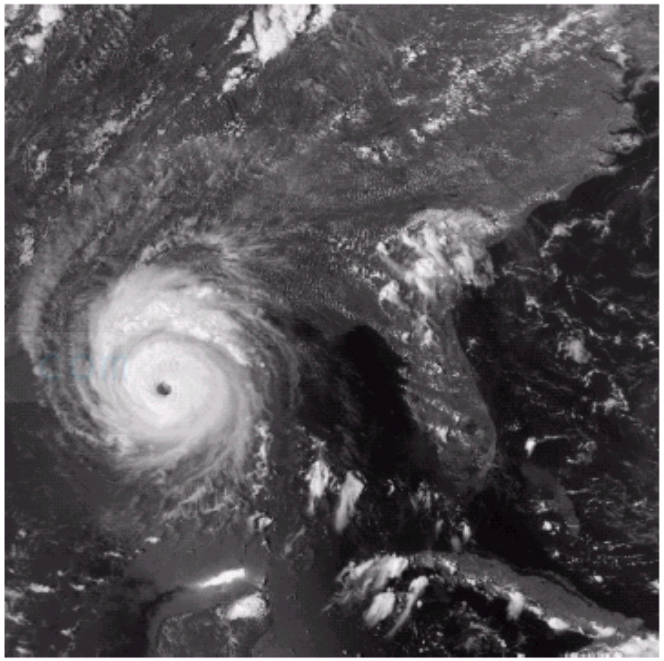
Original MRI image

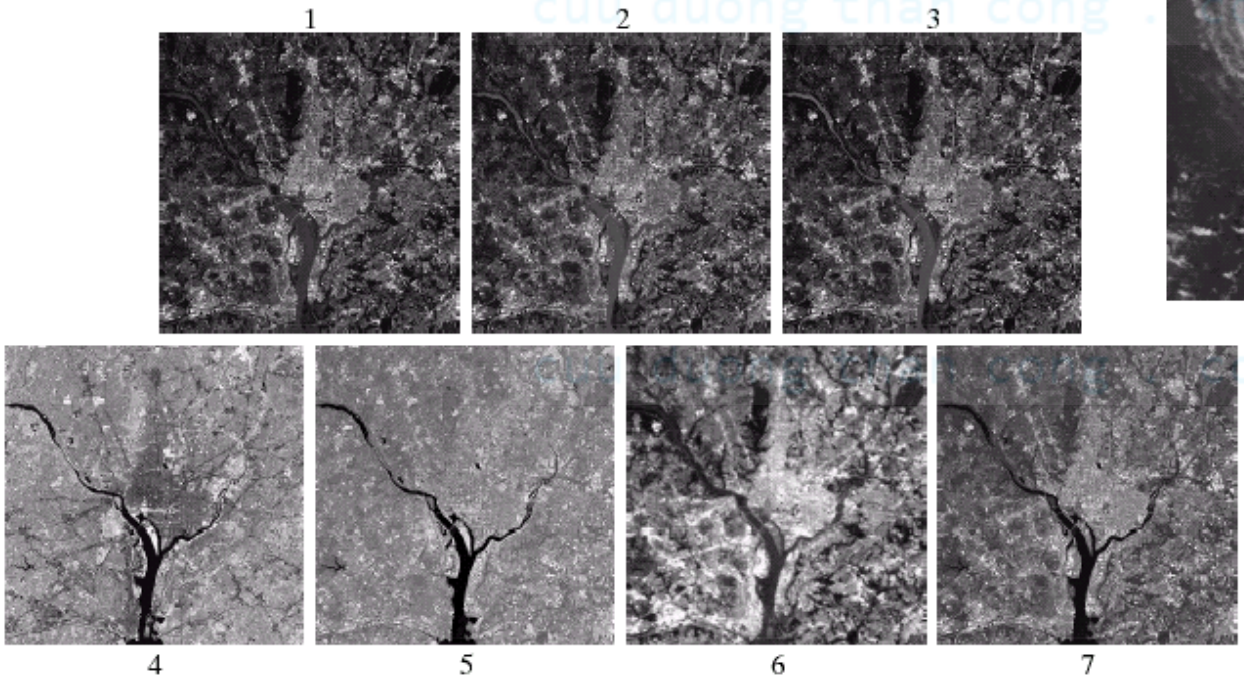


Edge-enhanced image

Geographic Information Systems (GIS)

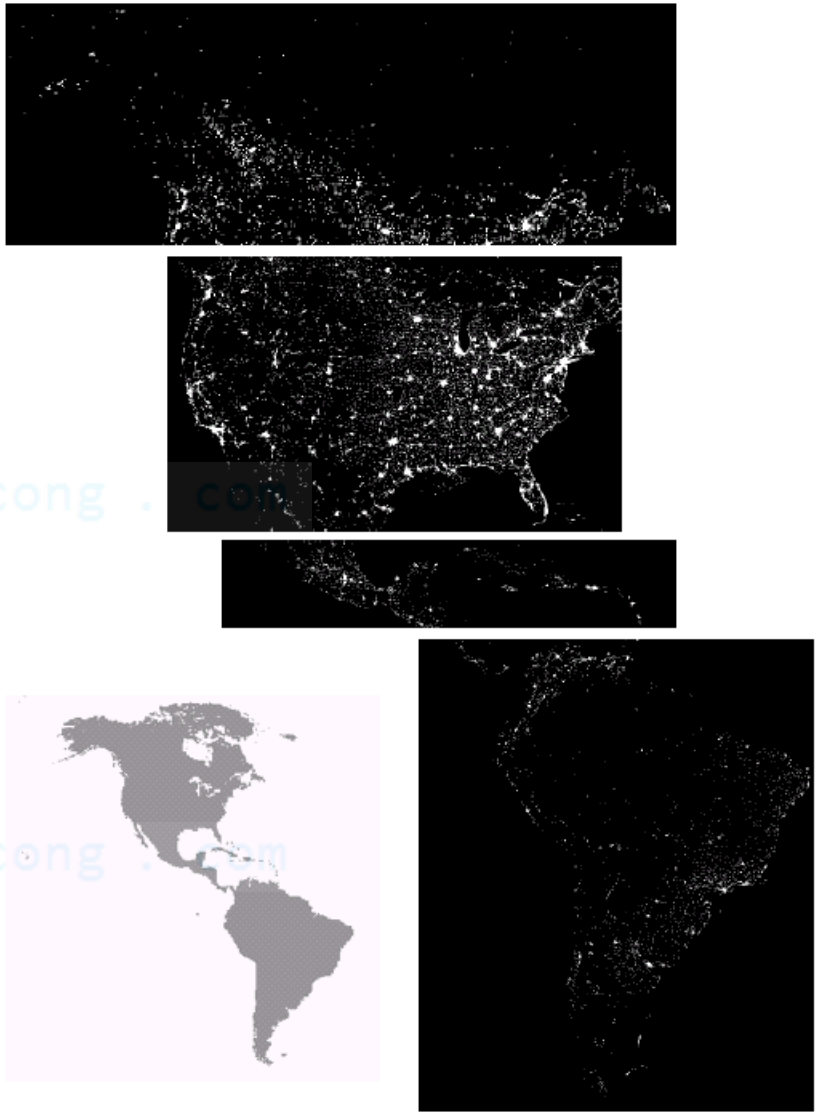
- Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification, meteorology





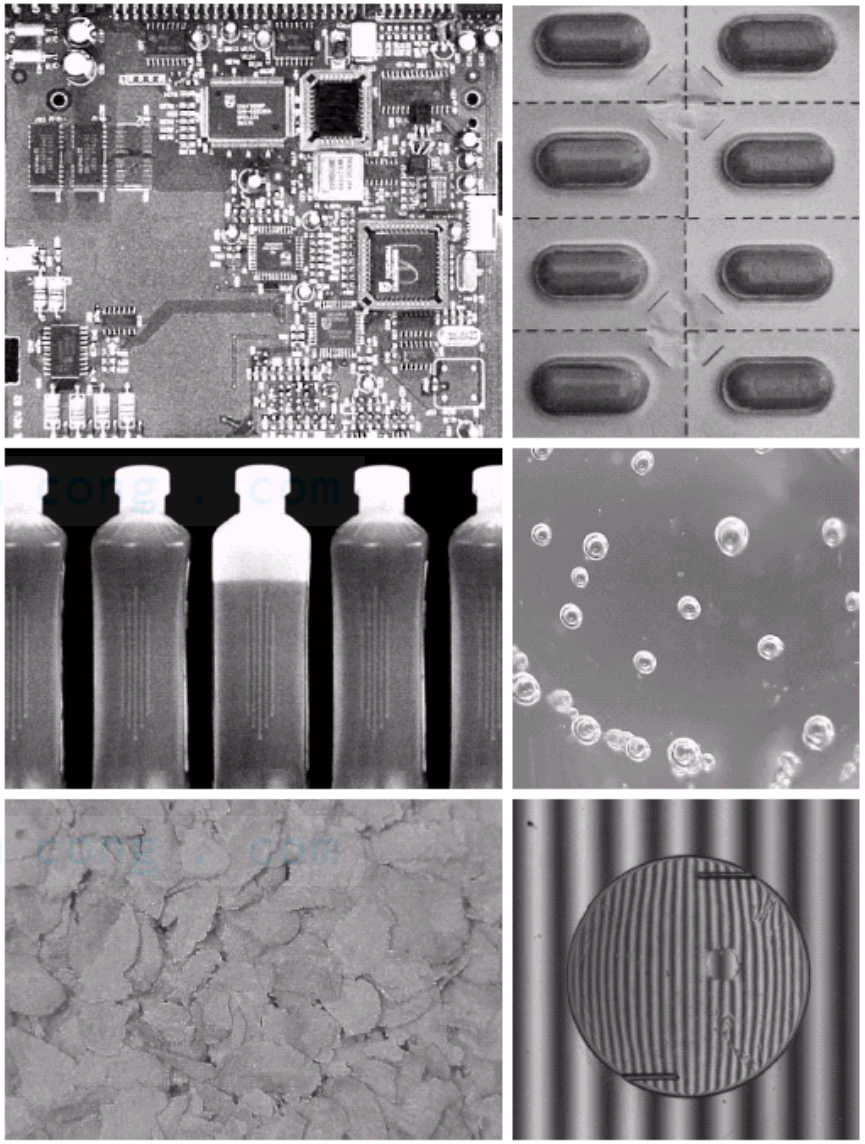
Geographic Information Systems (GIS)

- Night-Time Lights of the World data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data



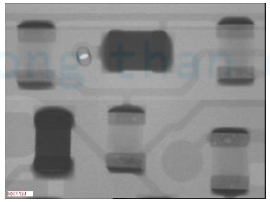
Industrial inspection

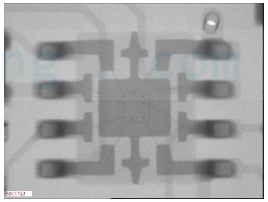
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries
- Can we trust them?

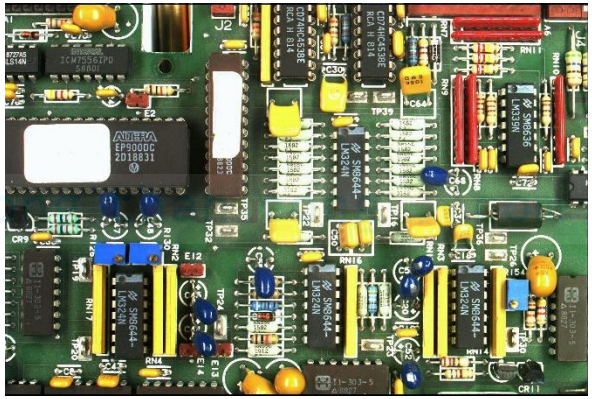


Industrial inspection

- Printed Circuit Board (PCB) inspection
  - Machine inspection is used to determine that all components are present and that all solder joints are acceptable.
  - Both conventional imaging and x-ray imaging are used.

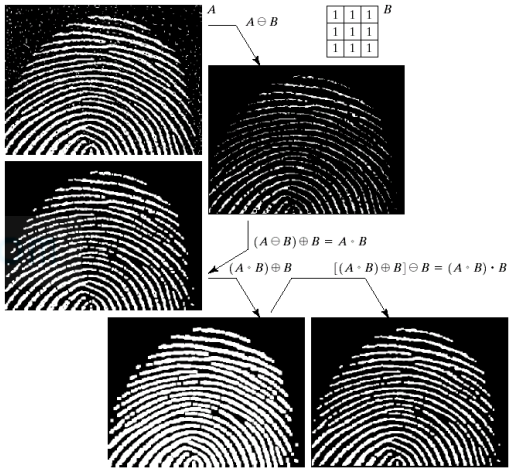






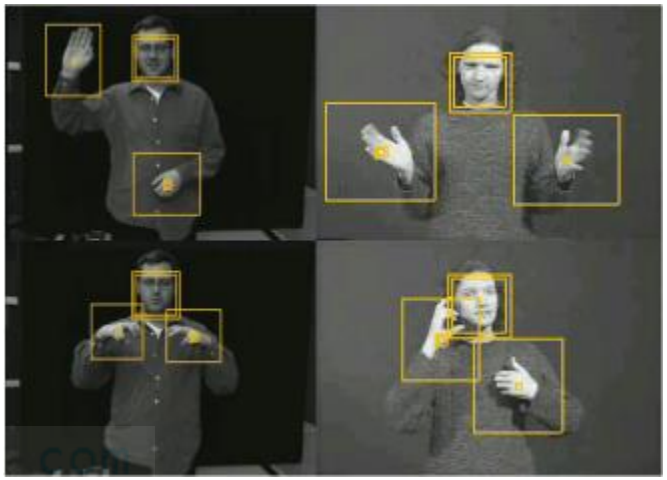
Law enforcement

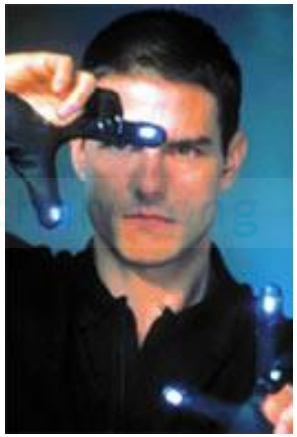
- Used extensively by law enforcers
- Number plate recognition for speed cameras/automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images

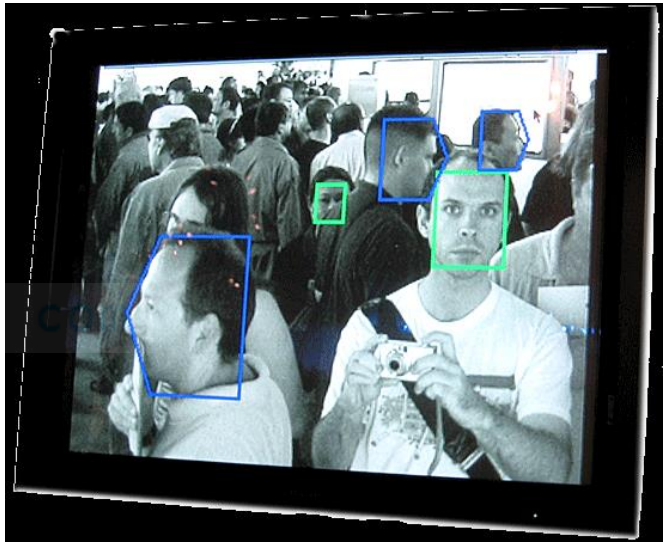


Human – computer interactions (HCI)

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- These tasks can be extremely difficult.

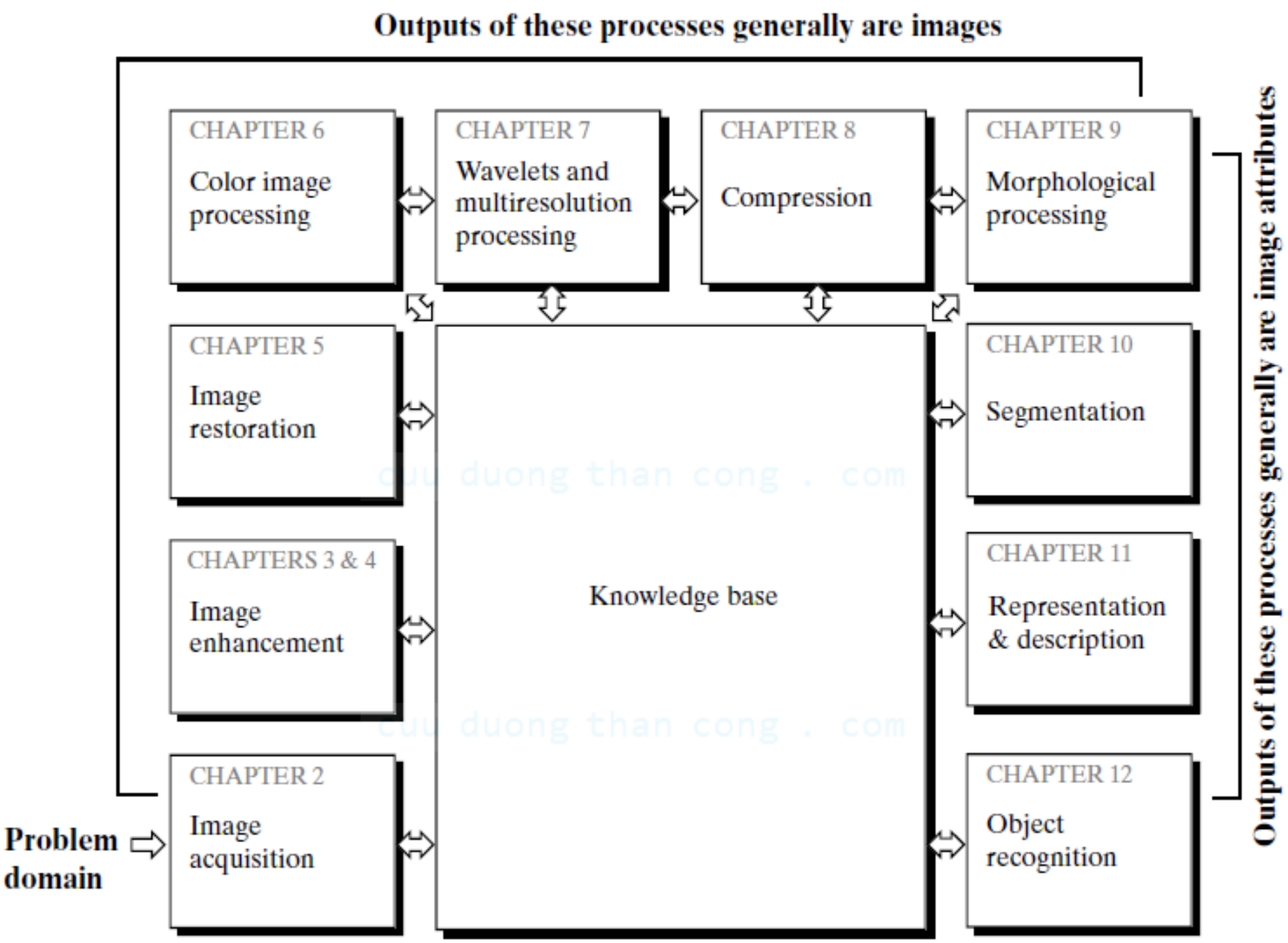






Section 1.4

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING



Outputs of these processes generally are images

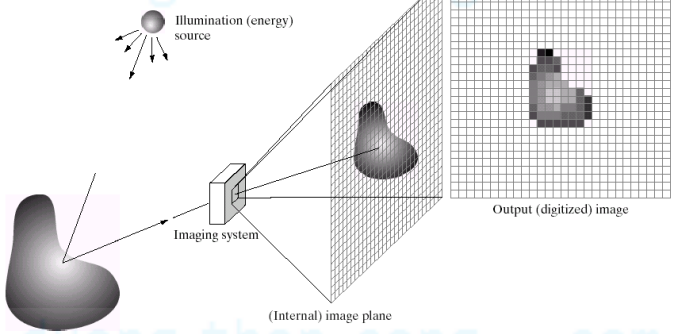
CHAPTER 6
Color image processing

CHAPTER 7
Wavelets and multiresolution processing

CHAPTER 8
Compression

CHAPTER 9
Morphological processing

- A number of basic digital image concepts
- Involve preprocessing, e.g. sampling, quantization, scaling, etc.



CHAPTERS 3 & 4
Image enhancement

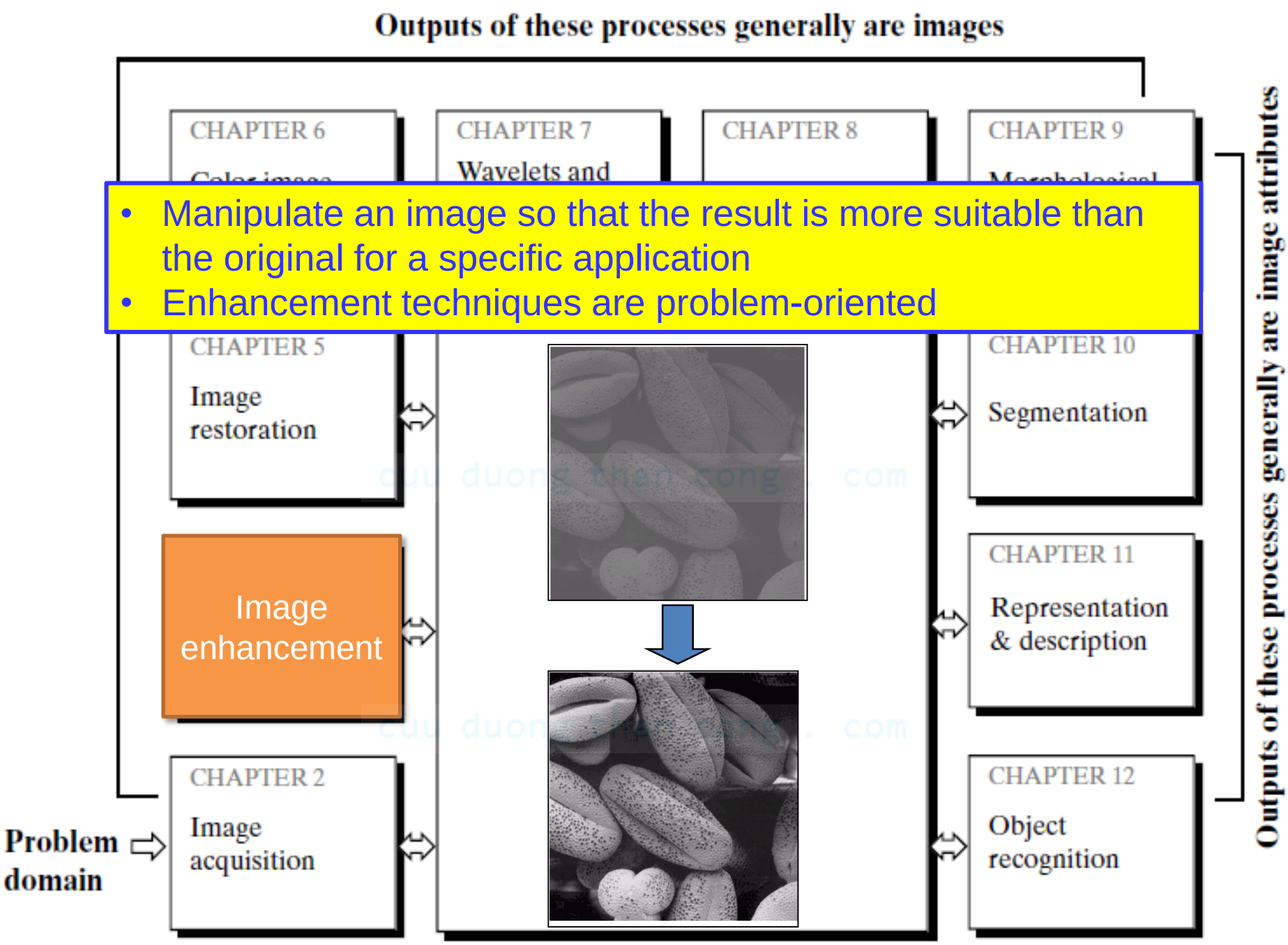
CHAPTER 11
Representation & description

Problem domain

Image acquisition

CHAPTER 12
Object recognition

Outputs of these processes generally are image attributes

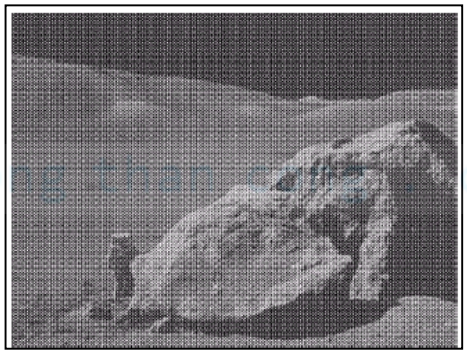

Outputs of these processes generally are images
CHAPTER 6
CHAPTER 7
Wavelets and
CHAPTER 8
CHAPTER 9
• Manipulate an image so that the result is more suitable than the original for a specific application
• Enhancement techniques are problem-oriented
CHAPTER 5
Image restoration
CHAPTER 10
Segmentation
Image enhancement
CHAPTER 11
Representation & description
CHAPTER 2
Image acquisition
CHAPTER 12
Object recognition
Problem domain
Outputs of these processes generally are image attributes

Outputs of these processes generally are images

CHAPTER 6 | CHAPTER 7 | CHAPTER 8 | CHAPTER 9

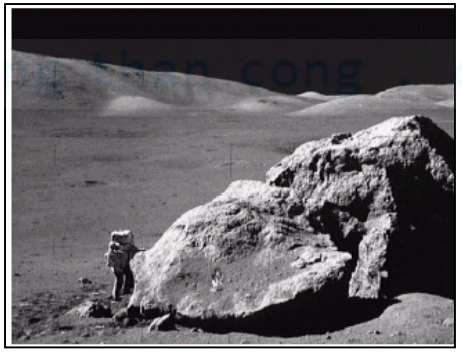
- Improve the appearance of an image
- Objective, techniques based on mathematical or probabilistic models of image degradation

Image restoration



CHAPTER 10
Segmentation

CHAPTERS 3 & 4
Image enhancement



CHAPTER 11
Representation & description

Problem domain

CHAPTER 2
Image acquisition

CHAPTER 12
Object recognition

Outputs of these processes generally are image attributes

Outputs of these processes generally are images

Color image restoration

CHAPTER 7
Wavelets and multiresolution processing

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Compression

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Morphological processing

CHAPTER 5
Image restoration

CHAPTER 10
Segmentation

CHAPTERS 3 & 4
Image enhancement

CHAPTER 11
Representation & description

Problem domain

Outputs of these processes generally are image attributes

- Fundamental concepts in color models and basic color processing in a digital domain
- Also be the basis for extracting features of interest in an image

Outputs of these processes generally are images

CHAPTER 6
Color image processing

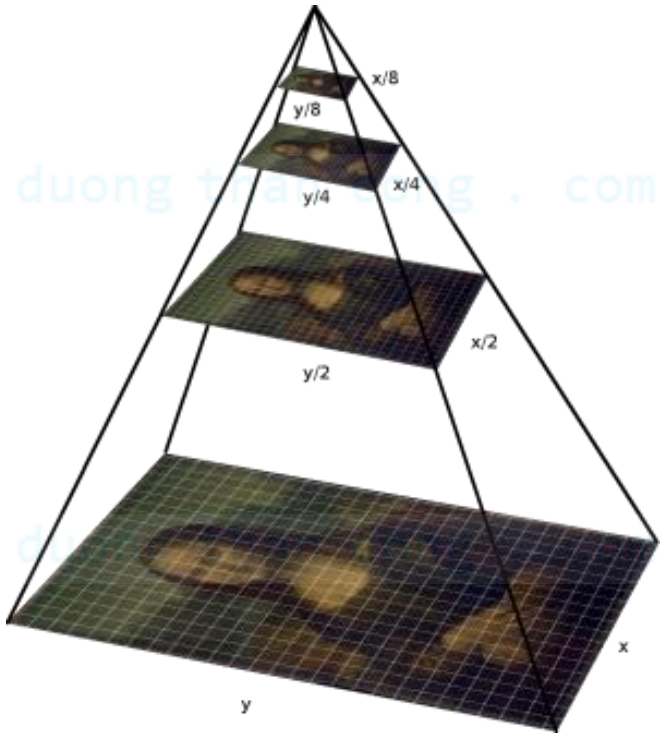
Wavelet and multiresolution processing

CHAPTER 8

CHAPTER 9

- Represent images in various degrees of resolution
- Pyramidal representation

CHAPTER 5
Image restoration



CHAPTER 10
Segmentation

CHAPTERS 3 & 4
Image enhancement

CHAPTER 11
Representation & description

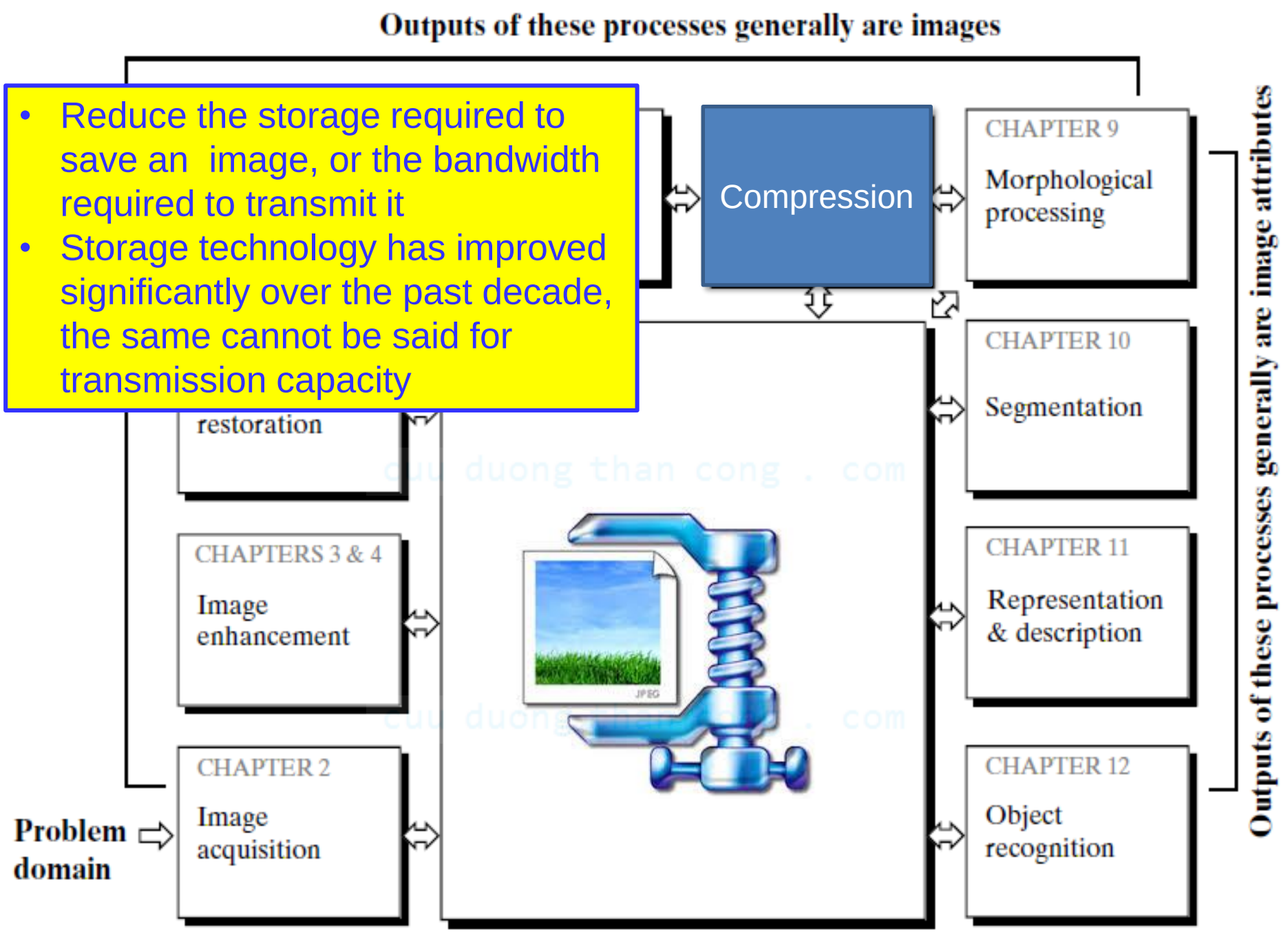
Problem domain

CHAPTER 2
Image acquisition

CHAPTER 12
Object recognition

Outputs of these processes generally are image attributes

- Reduce the storage required to save an image, or the bandwidth required to transmit it
- Storage technology has improved significantly over the past decade, the same cannot be said for transmission capacity



Outputs of these processes generally are images

- Extracting image components that are useful in the representation and description of shape.

CHAPTER 6

CHAPTER 7

CHAPTER 8

Morphological processing

CHAPTER 5

Image restoration

CHAPTER 10

Segmentation

CHAPTERS 3 & 4

Image enhancement

CHAPTER 11

Representation & description

CHAPTER 2

Image acquisition

CHAPTER 12

Object recognition

Problem domain

Outputs of these processes generally are image attributes

Outputs of these processes generally are images

CHAPTER 6
Color proces

CHAPTER 7

CHAPTER 8

CHAPTER 9

- Partition an image into its constituent parts or objects
- Autonomous segmentation is one of the most difficult tasks in digital image processing.

CHAPTER 5
Image restoration

Segmentation

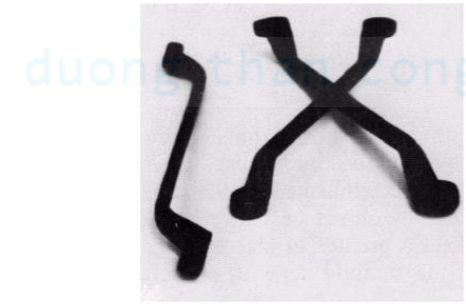
CHAPTERS 3 & 4
Image enhancement

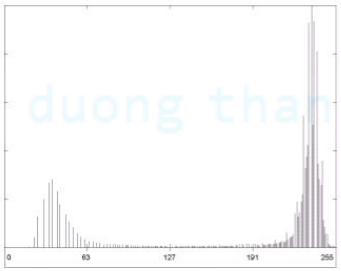
CHAPTER 11
Representation & description

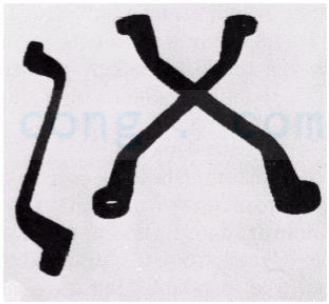
Problem domain

CHAPTER 2
Image acquisition

CHAPTER 12
Object recognition







Outputs of these processes generally are image attributes

- Representation: whether the data should be represented as a boundary or as a complete region
- Descriptions: attributes are extracted, resulting in some quantitative information of interest
- Almost always follow the output of a segmentation stage

Outputs of these processes generally are images

CHAPTER 6
Color image processing

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Wavelets and multiresolution processing

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Compression

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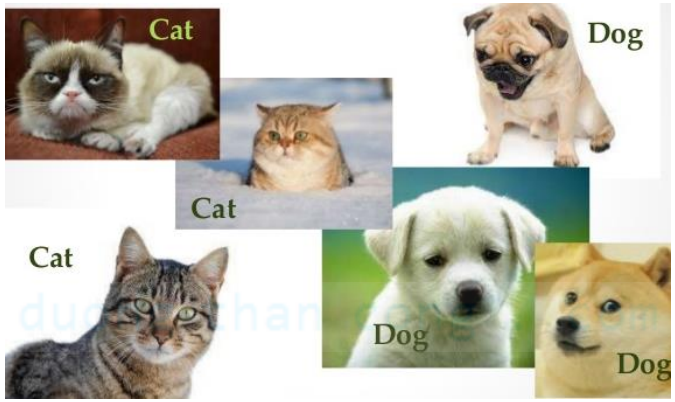
Morphological processing

CHAPTER 5
Image restoration

CHAPTER 10
Segmentation

- Assigns a label (e.g., “vehicle”) to an object based on its descriptors.

CHAPTERS 3 & 4
Image enhancement



CHAPTER 11
Representation & description

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Outputs of these processes generally are image attributes

Section 1.5

COMPONENTS OF AN IMAGE PROCESSING SYSTEM

General-purpose image processing system

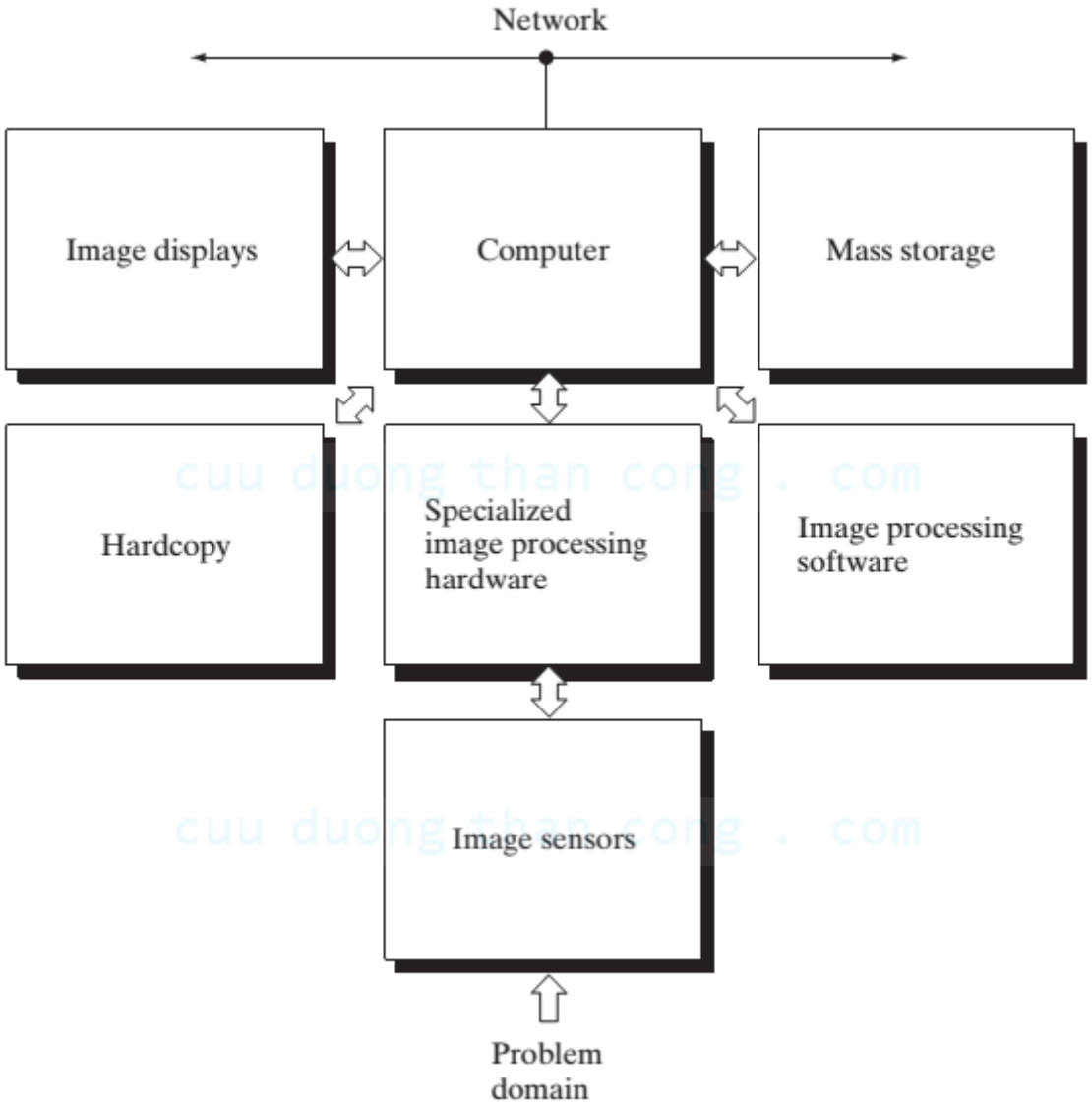
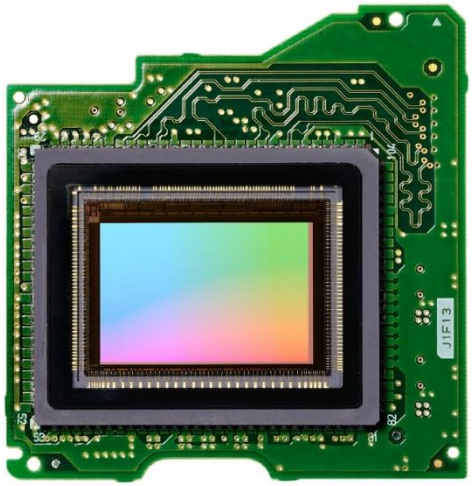


Image sensors

- One of the two elements required to acquire digital images
  - Sensor: a physical device that is sensitive to the energy radiated by the object we wish to image.
  - Digitizer: a device for converting the output of the physical sensing device into digital form.
- For instance, in a digital video camera:
  - Sensors produce an electrical output proportional to light intensity
  - Digitizer converts these outputs to digital data



Specialized image processing hardware

- Usually consists of the digitizer, plus hardware that performs other primitive operations.
  - E.g. arithmetic logic unit (ALU), performing arithmetic and logical operations in parallel on entire images.
- Front-end subsystem
- The most distinguishing characteristic is **speed**.
  - This unit performs functions that require fast data throughputs (e.g., digitizing and averaging video images at 30 frames/s)
  - Typical main computers cannot handle

Computer and software

- A general-purpose computer may range from a PC to a supercomputer.
- Software for image processing consists of specialized modules that perform specific tasks.

Mass storage

- A must in image processing applications
- Digital storage for image processing applications falls into three principal categories:
  - Short-term storage for use during processing
    - Computer memory, frame buffers
  - On-line storage for relatively fast recall
    - Magnetic disks or optical-media storage
  - Archival storage, characterized by infrequent access

Image displays

- Mainly color (preferably flat screen) TV monitors
- Stereo displays: head-gear containing two small displays embedded in goggles worn by the user

Hardcopy devices

- Laser printers, film cameras, heat-sensitive devices, inkjet units, and digital units, such as optical and CD-ROM disks
- Film provides the highest possible resolution, but paper is the obvious medium of choice for written material.
- For presentations, images are displayed on film transparencies or in a digital medium.

Networking

- A default function in any computer system in use today
- The key consideration in image transmission is bandwidth.
  - Large amount of data inherent in image processing applications
  - Communications with remote sites via the Internet are not always as efficient.
    - Optical fiber and other broadband technologies.

Reference

- Rafael C. Gonzalez, Richard E. Woods, “Digital Image Processing”, 3rd edition, 2008. Chapter 1.
- Dr. Brian Mac Namee’s lecture:

  http://www.comp.dit.ie/bmacnamee/materials/dip/lectures/ImageProcessing1-Introduction.ppt

- Images are obtained from the above materials and Google