Digital Image Processing

Lecture No: 02

What is Digital Image Processing?

- An image may be defined as a two-dimensional function *f(x,y)* where x and y are spatial (plane) coordinates.
- Amplitude of *f* at any pair of coordinates is called " **Intensity or gray level of the image"** at that point.
- x,y, and the amplitude values of *f* are all finite, discrete quantities, the image is called as **"Digital Image"**
- Image is composed of a finite number of elements with particular location and value.

What is DIP (Cont'd...)

- These elements are referred to as ***picture elements, image elements, pels, and pixels.***
- Image processing can be defined as a discipline in which both the input and output of a process are ***images.***
- On the other hand, ***computer vision*** – whose ultimate goal is to use computers to emulate human vision, including learning and being able to make inferences and take actions based on visual inputs.

What is DIP (Cont'd...)

Digital image processing focuses on three major tasks

- Improvement of pictorial information for human interpretation.
- Image processing for autonomous machine application
- Processing of image data for storage, transmission and representation

Some argument about where image processing ends and fields such as image analysis and computer vision start

What is DIP (Cont'd...)

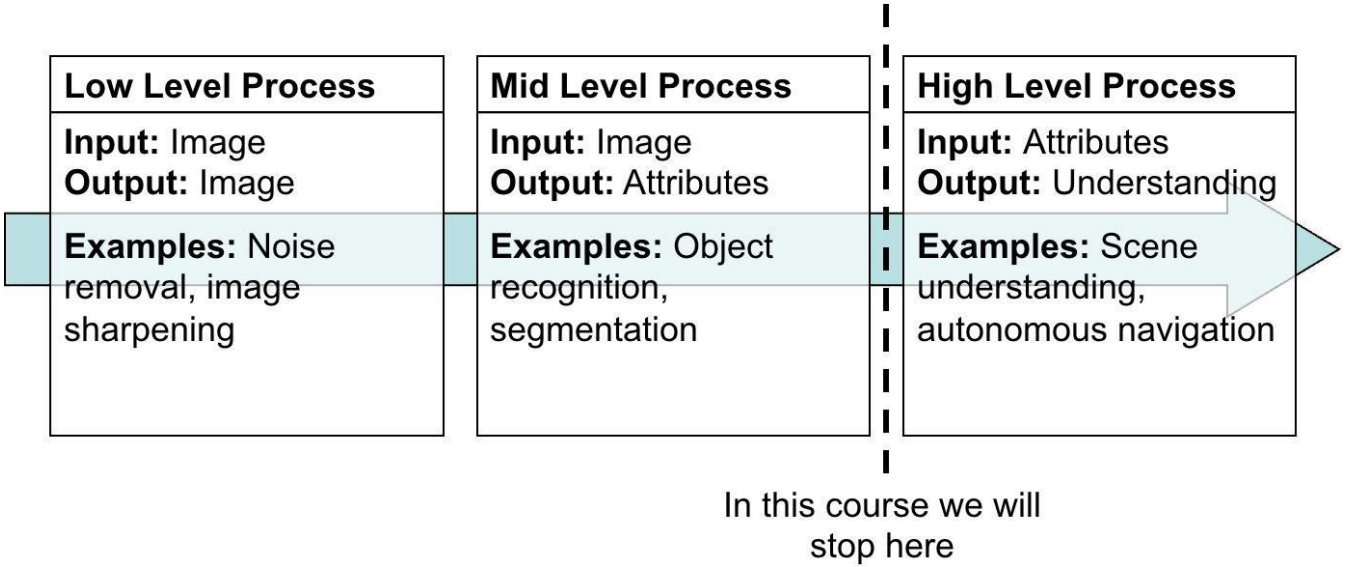
Human Perception

Employ methods able to enhance pictorial information for human interpretation and analysis such as:

- Noise filtering
- Content enhancement
- Contrast enhancement
- Deblurring
- Remote sensing

What is DIP (Cont'd...)

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



History of Digital Image Processing

Early 1920s: One of the first applications of digital imaging was in the newspaper industry

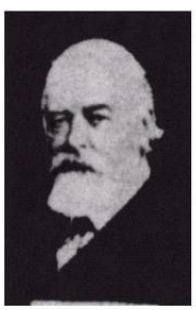
- The Bartlane cable picture transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

Early digital image

History of DIP (Cont'd…)

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



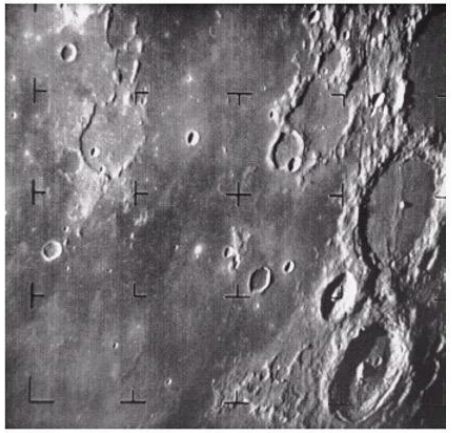
Improved digital image

Early 15 tone digital image

History of DIP (Cont'd…)

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 including the Apollo landings



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

History of DIP (Cont'd…)

1970s: Digital image processing begins to be used in medical applications

- **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

Typical head slice CAT image

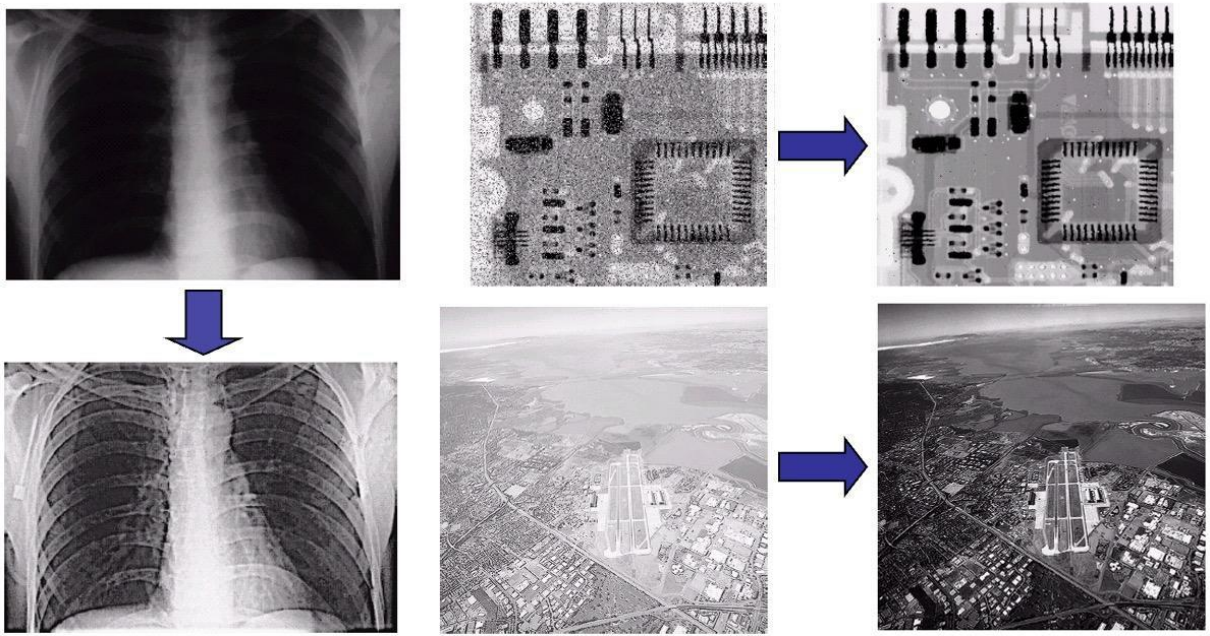
History of DIP (Cont'd...)

1980s - Today: The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas

- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

Examples: Image Enhancement

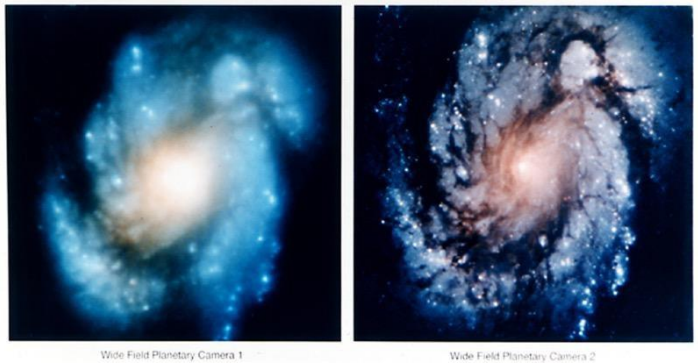
One of the most common uses of DIP techniques: improve quality, remove noise etc



Examples: The Hubble Telescope

Launched in 1990 the Hubble telescope can take images of very distant objects

- However, an incorrect mirror made many of Hubble's images useless
- Image processing techniques were used to fix this



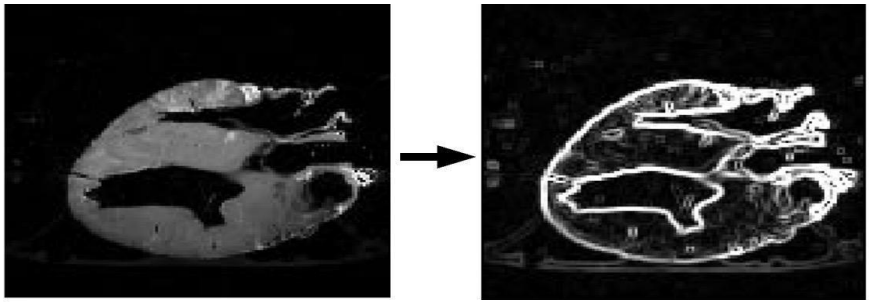
Examples: Artistic Effects

Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

Examples: 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



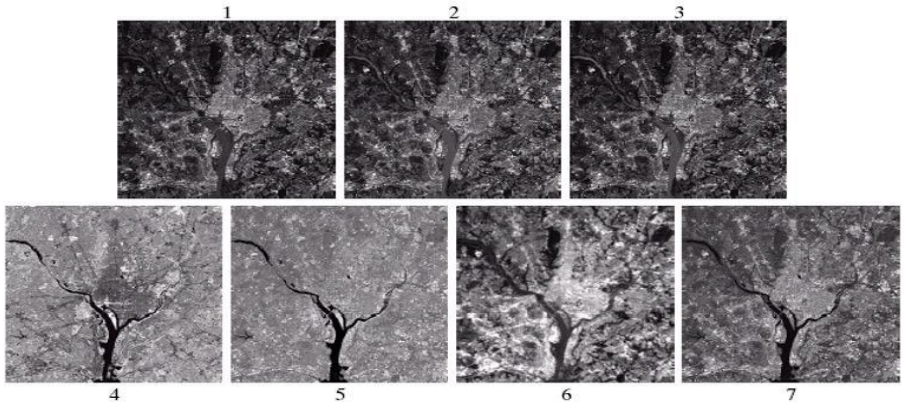
Original MRI Image of a Dog Heart

Edge Detection Image

Examples: GIS

Geographic Information Systems

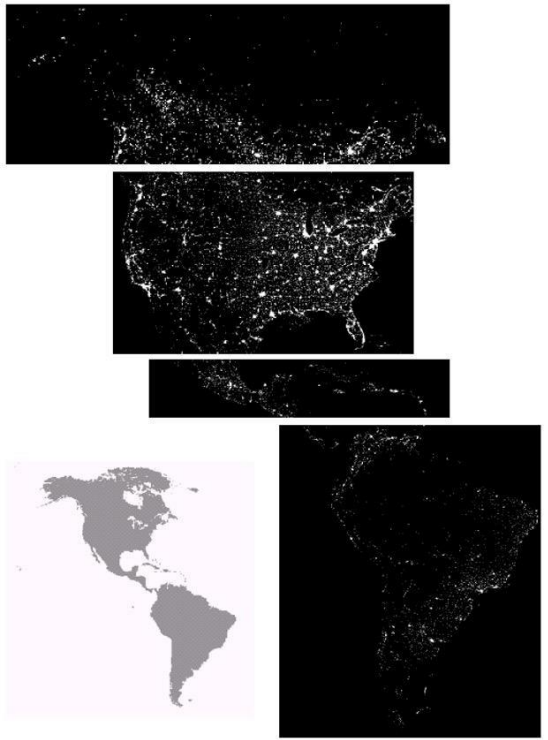
- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology



Examples: GIS (Cont'd…)

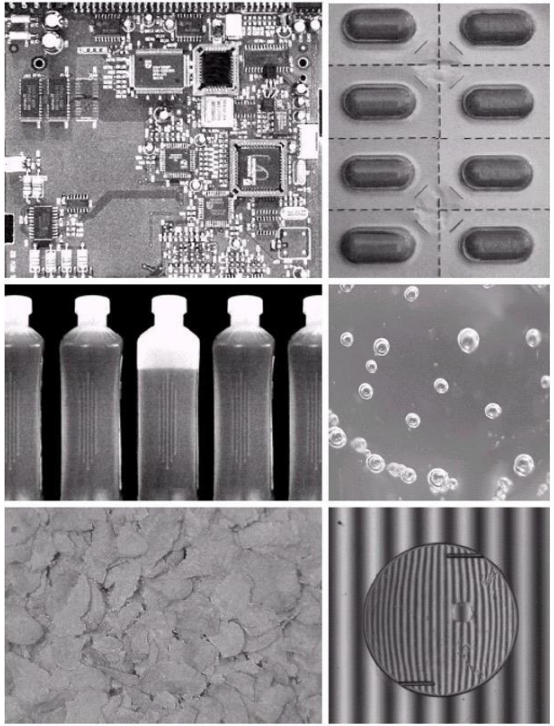
Night-Time Lights of the World data set

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



Examples: Industrial Inspection

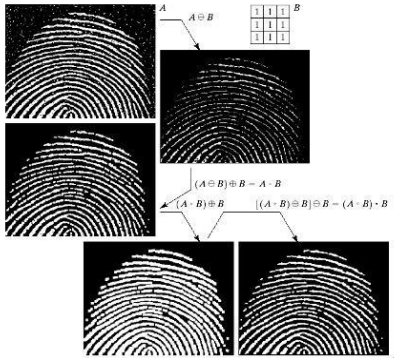
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries



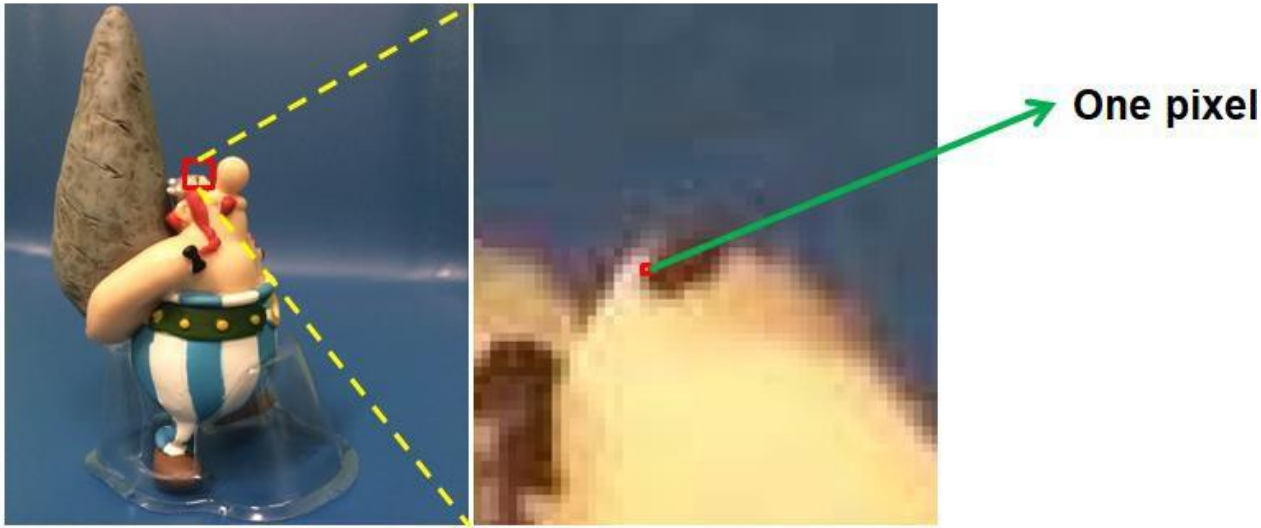
Examples: Law Enforcement

Image processing techniques are used extensively by law enforcers

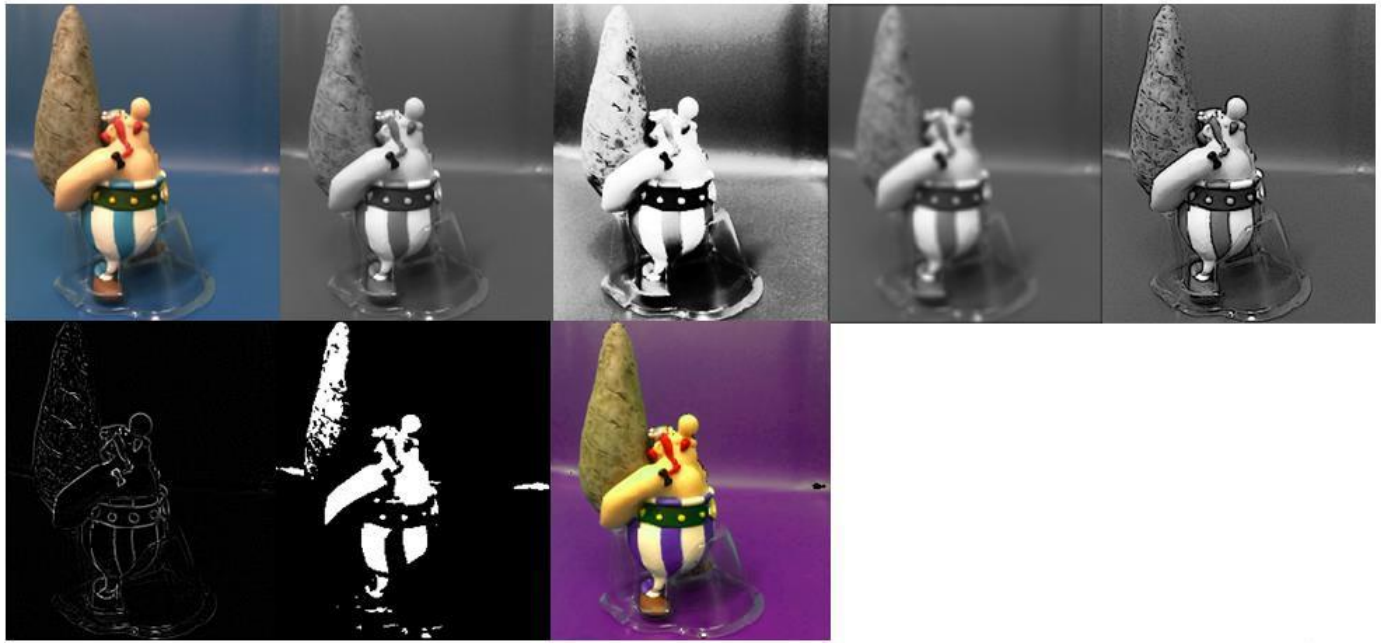
- Number plate recognition for speed cameras/automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images



Remember *digitization* implies that a digital image is an *approximation* of a real scene

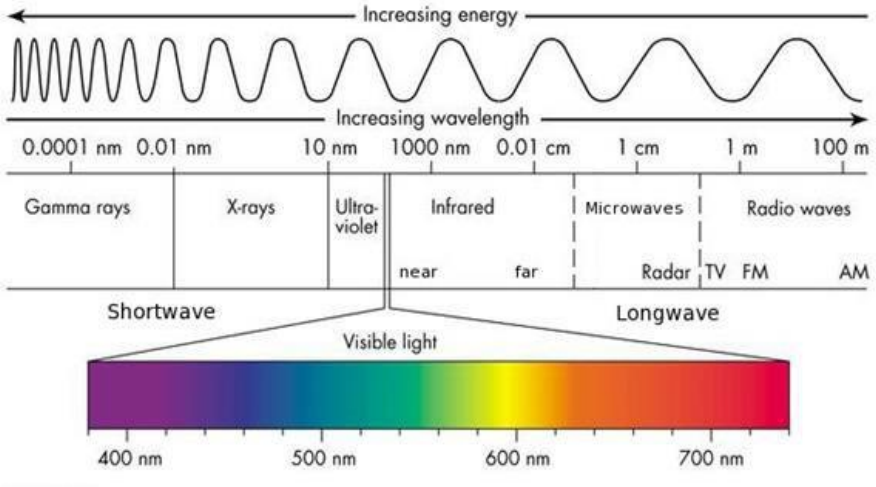


Digital Image Processing

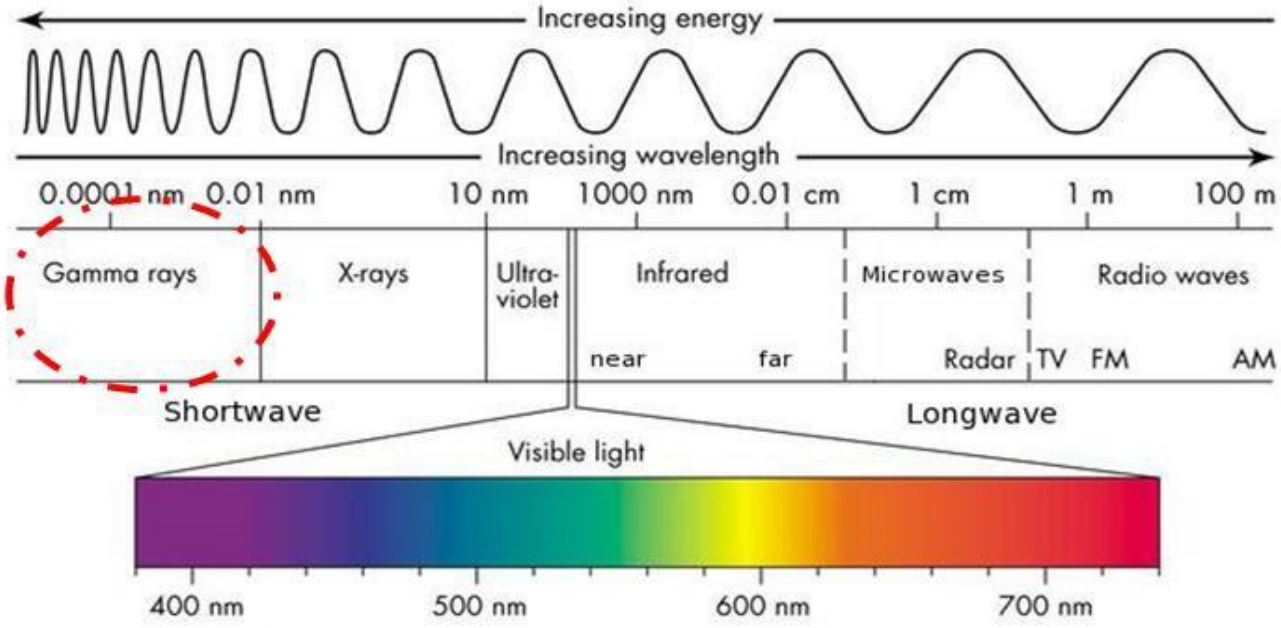


Sources of Digital Images

The principal source for the images is the electromagnetic (EM) energy spectrum.



Gamma rays


Increasing energy
Increasing wavelength
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Gamma rays
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Visible light
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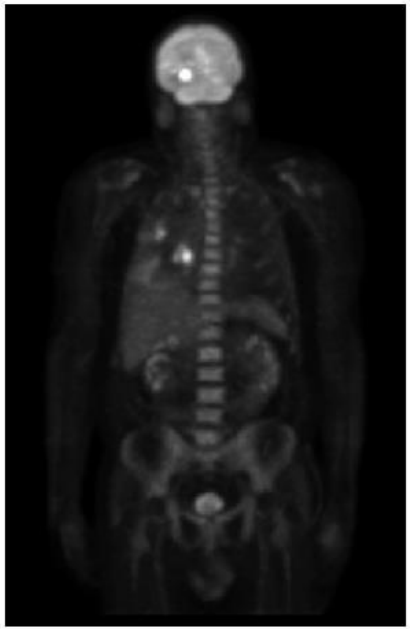
Gamma rays

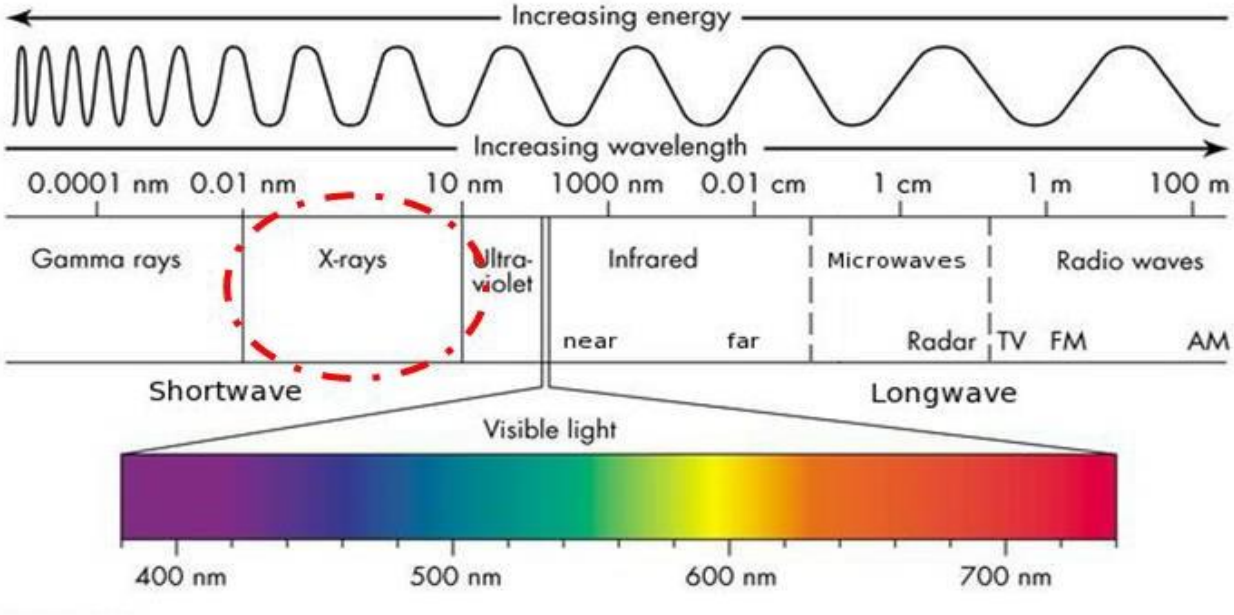
Gamma-Ray
Imaging
Cherenkov
Telescope



Gamma-Ray Imaging
İn nuclear medicine

Gamma-Ray imaging of
A starburst galaxy about
12 million light-years
away

X- rays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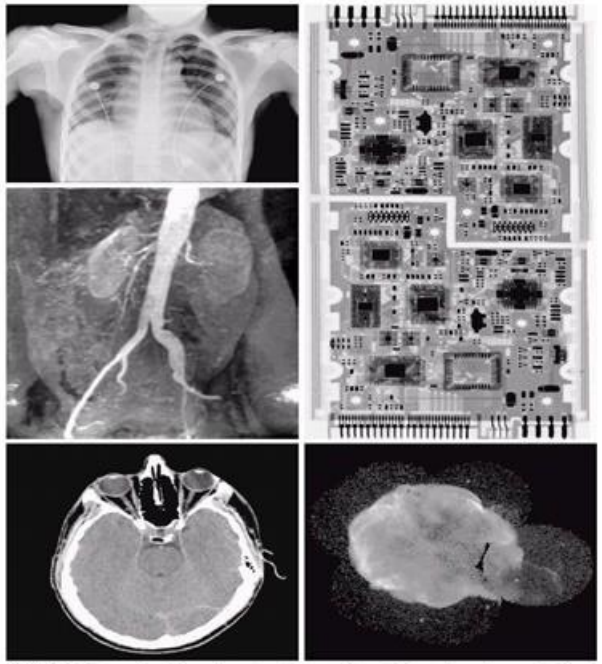
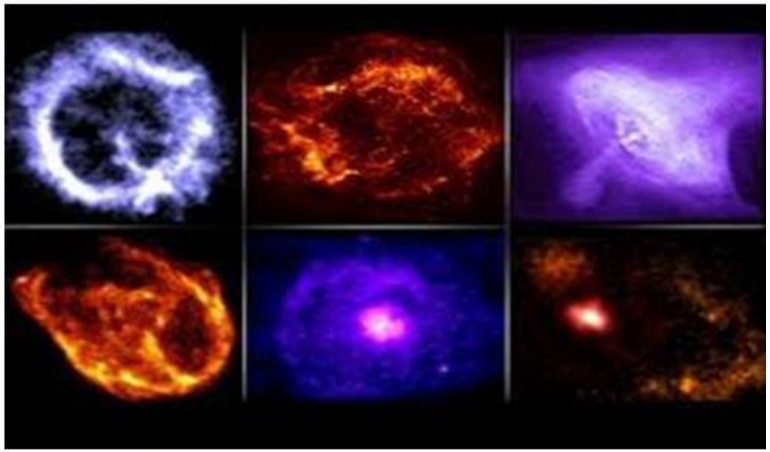
X- rays



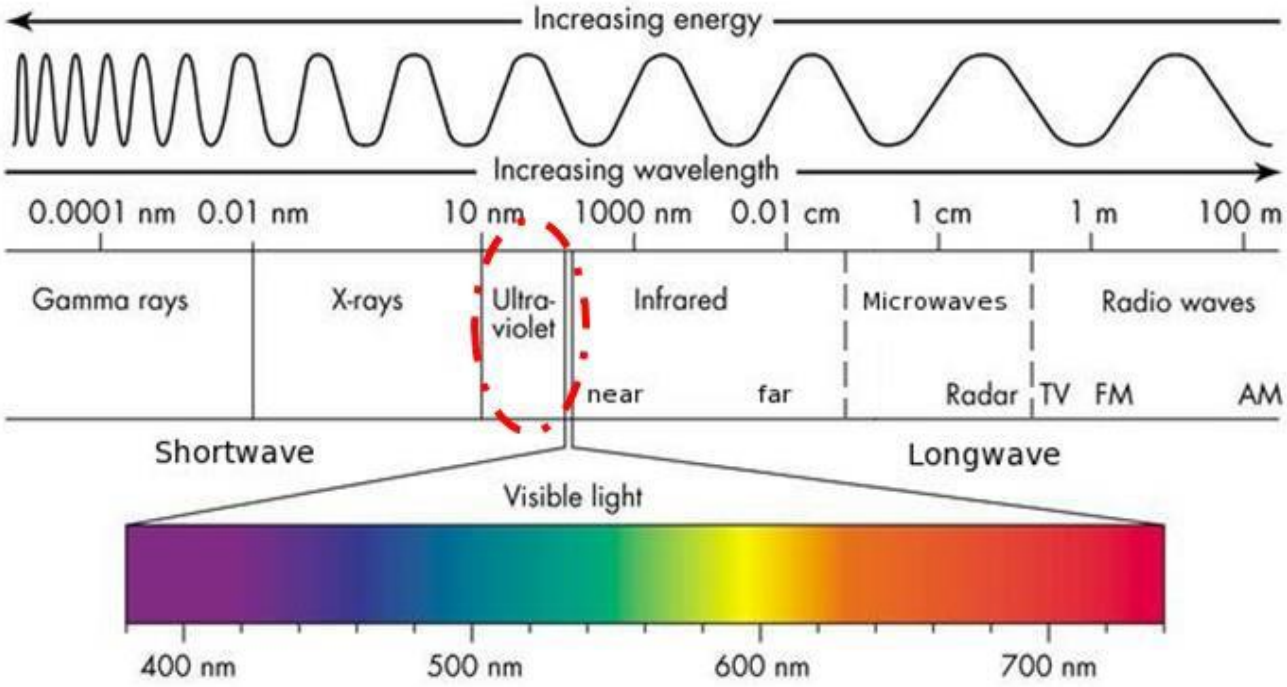
a b c d e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center. (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School. (d) Mr. Joseph E. Pascente, Lixi, Inc., and (e) NASA.)



X-ray images from the space
The Chandra X-Ray Observatory

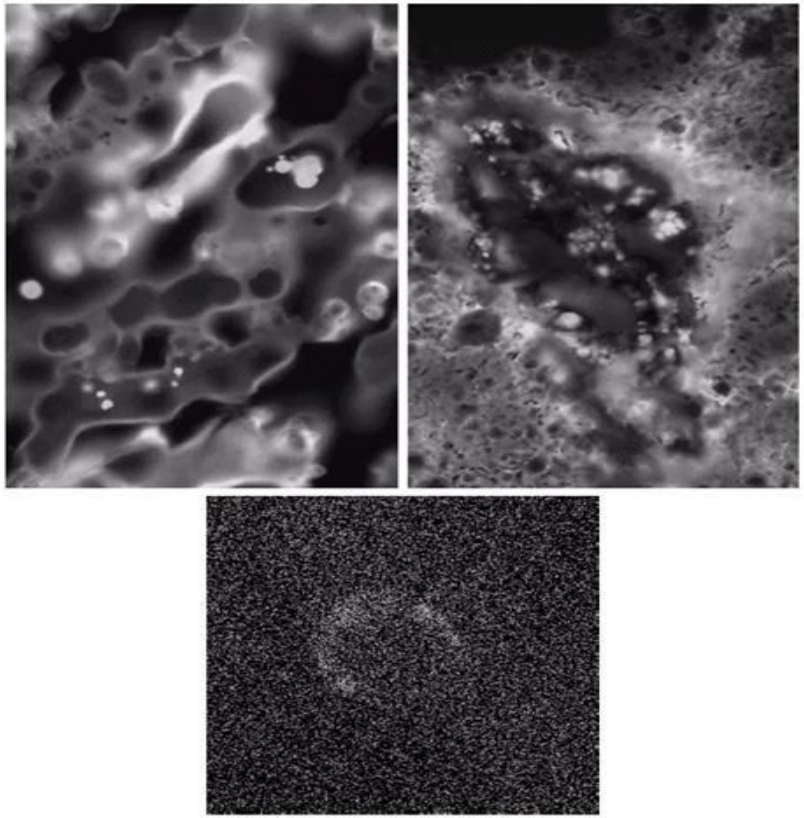
Ultra-violet



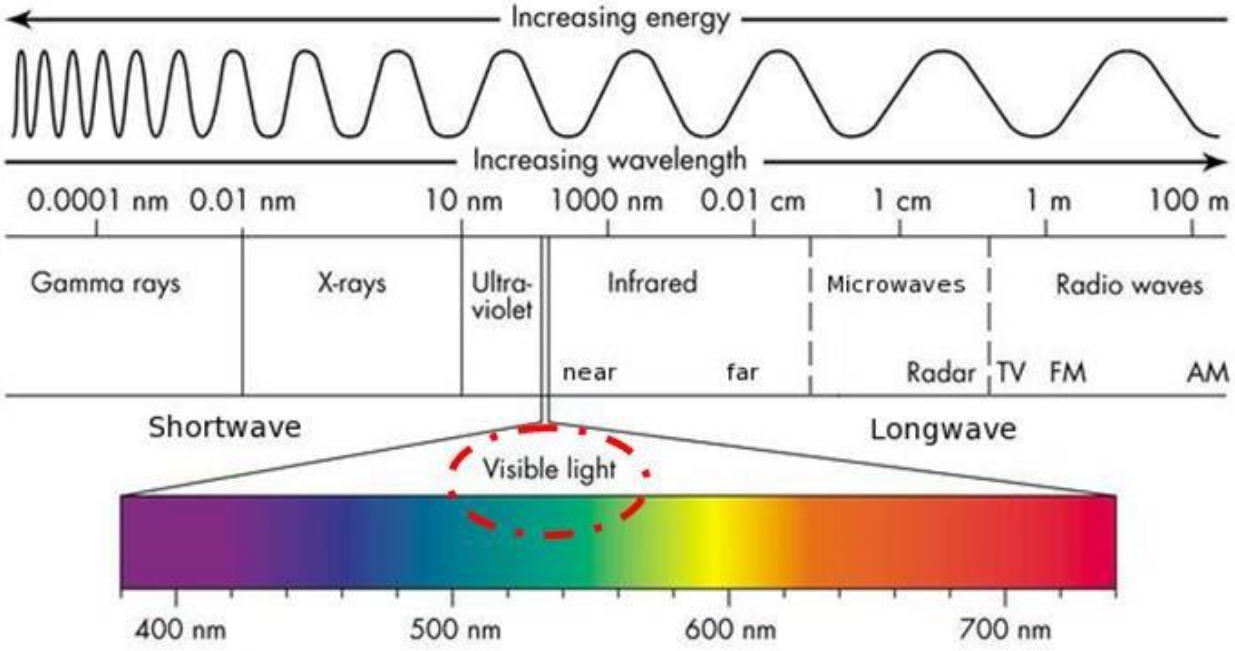
Ultra-violet

a b
c

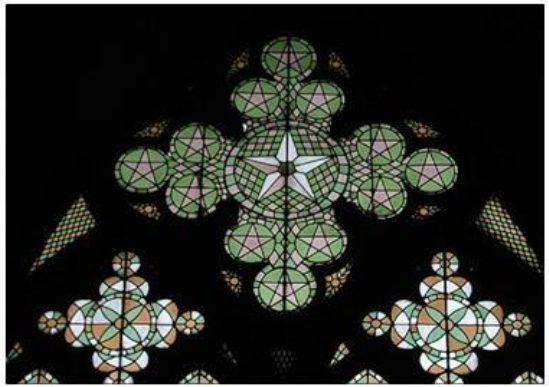
FIGURE 1.8
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

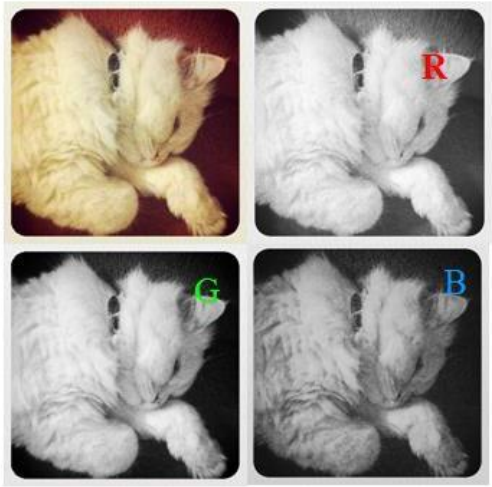


Visible light

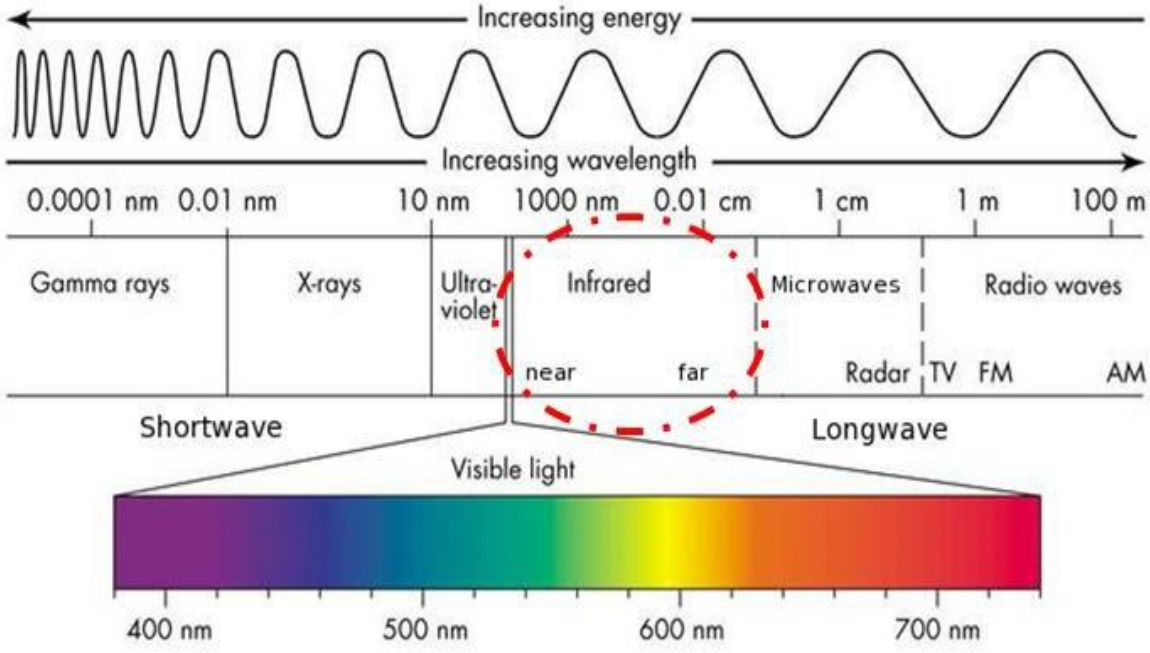


Visible light





Infrared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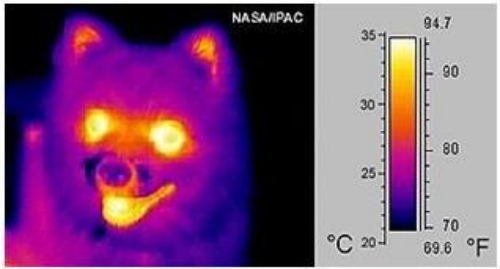
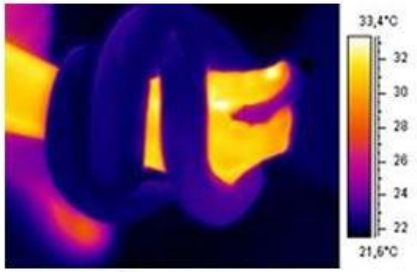
Infrared



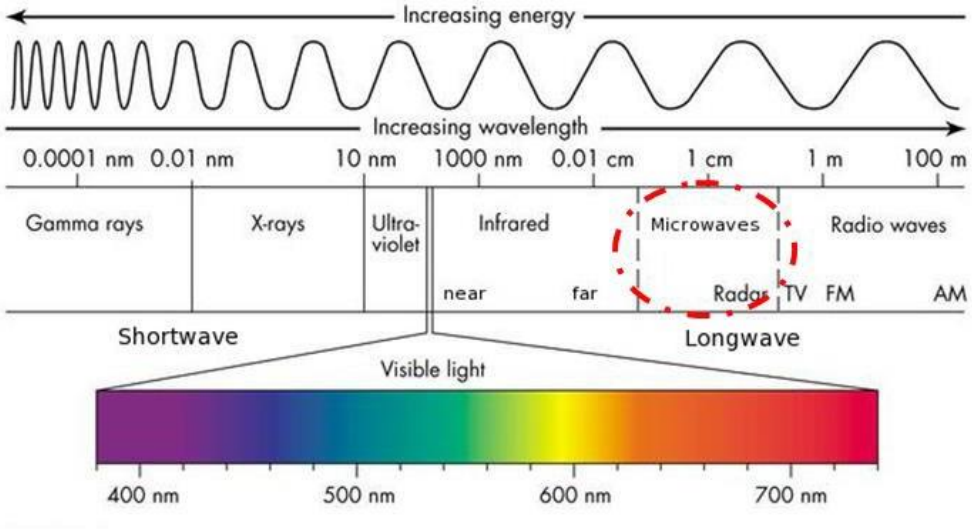
infrared ("thermal") image



Snake around the arm

Messier 51 in ultraviolet (GALEX), visible (DSS), and near infrared (2MASS). *Courtesy of James Fanson.*

Microwaves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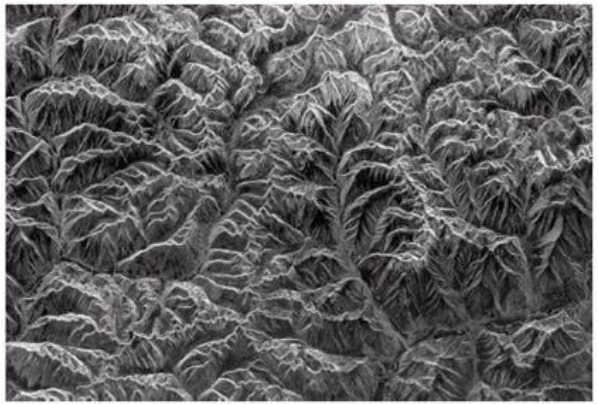
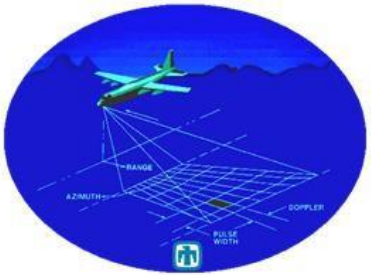
Microwaves

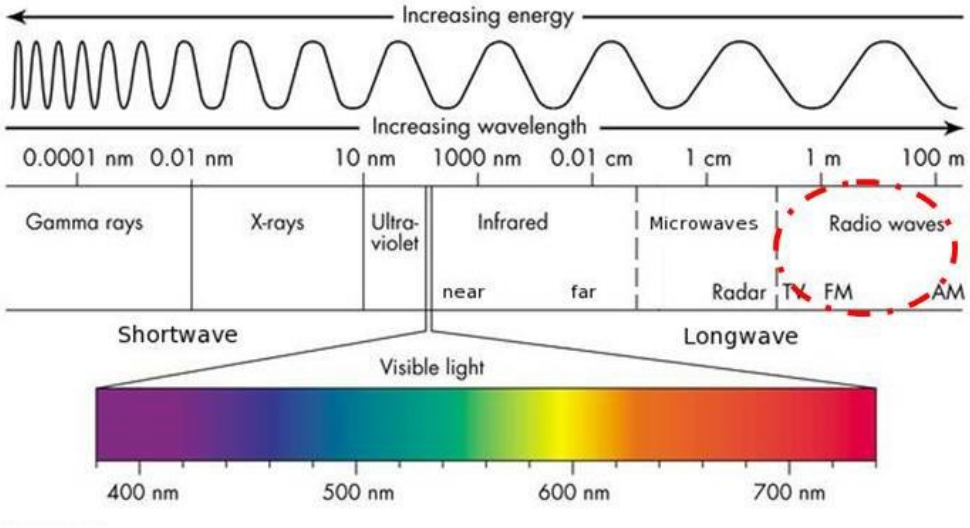
FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)





Synthetic Aperture Radar System

Radio Waves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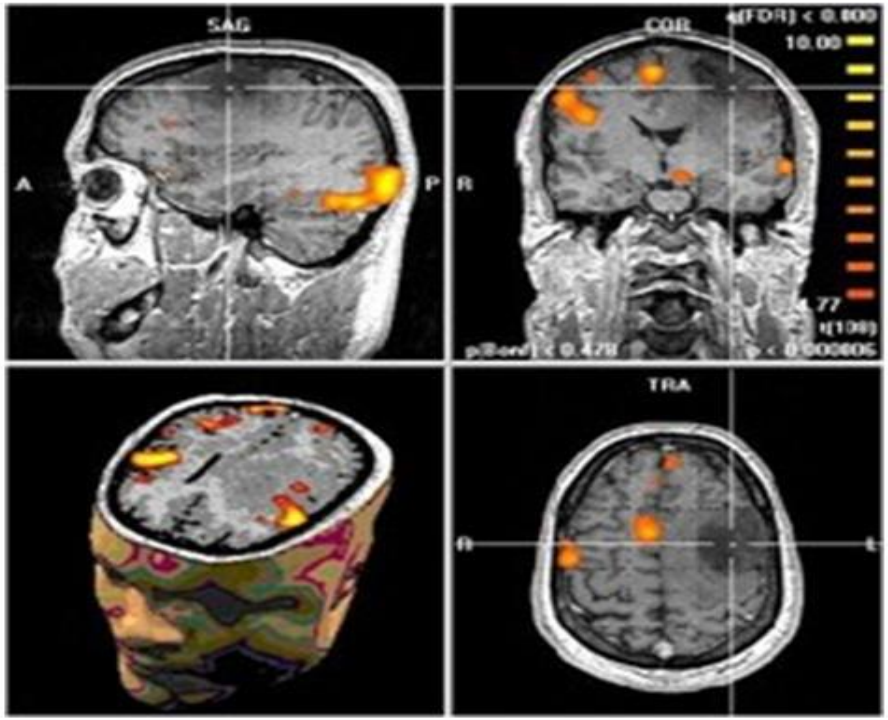
Radio Waves



MRI image slices from the brain

Digital Images based on the EM Spectrum

An example showing Imaging in all of the bands

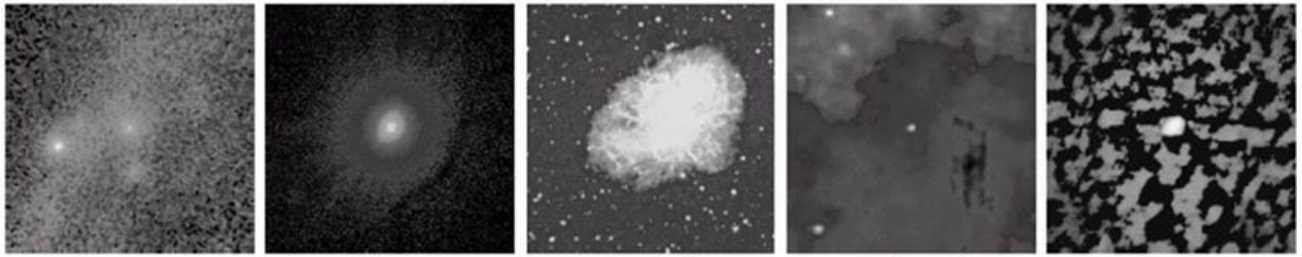
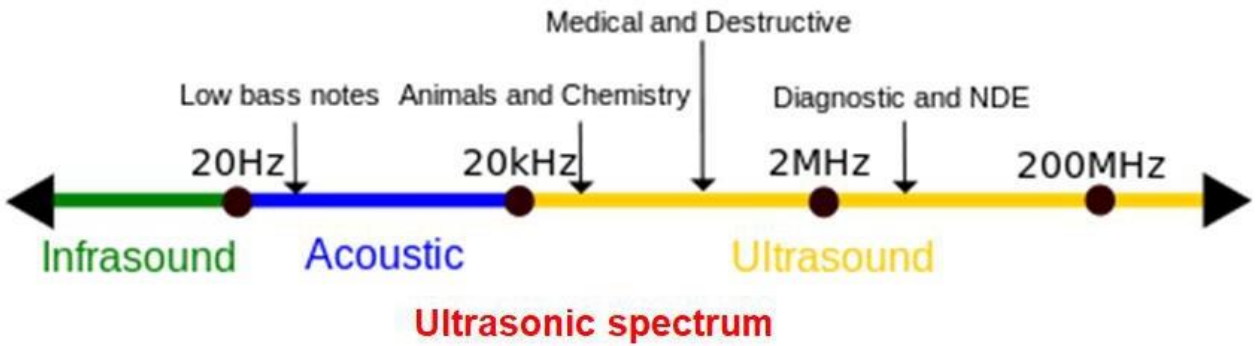


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Visible light

Ultrasound Imaging

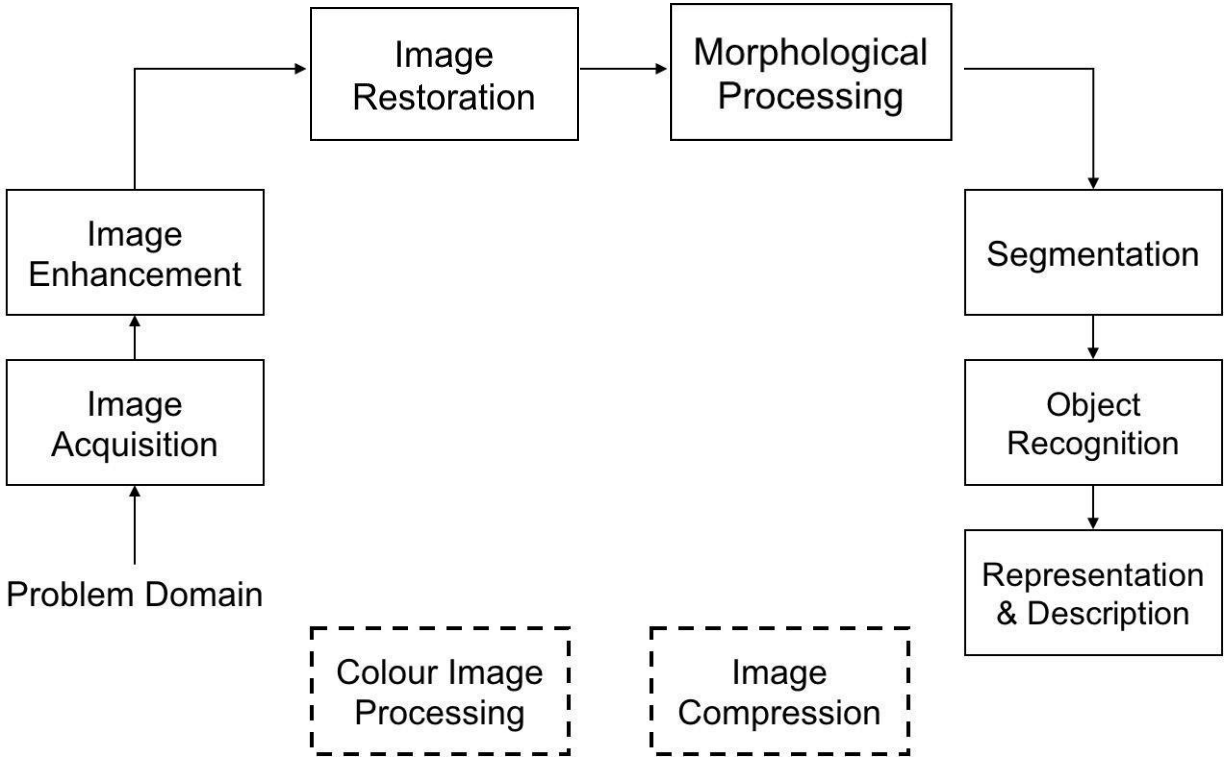


Ultrasonic spectrum

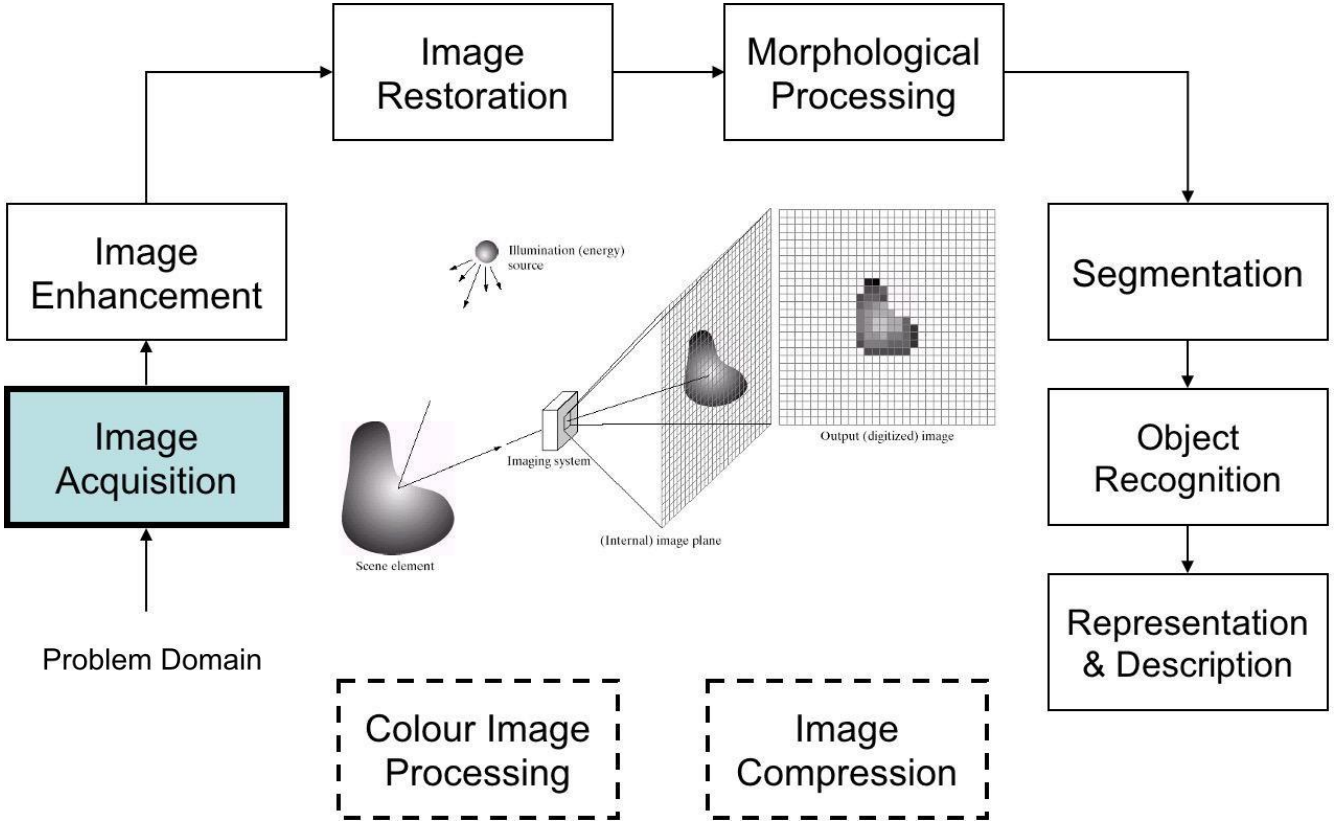
Ultrasonic Baby image during pragnancy

Ultrasound image acquisition device

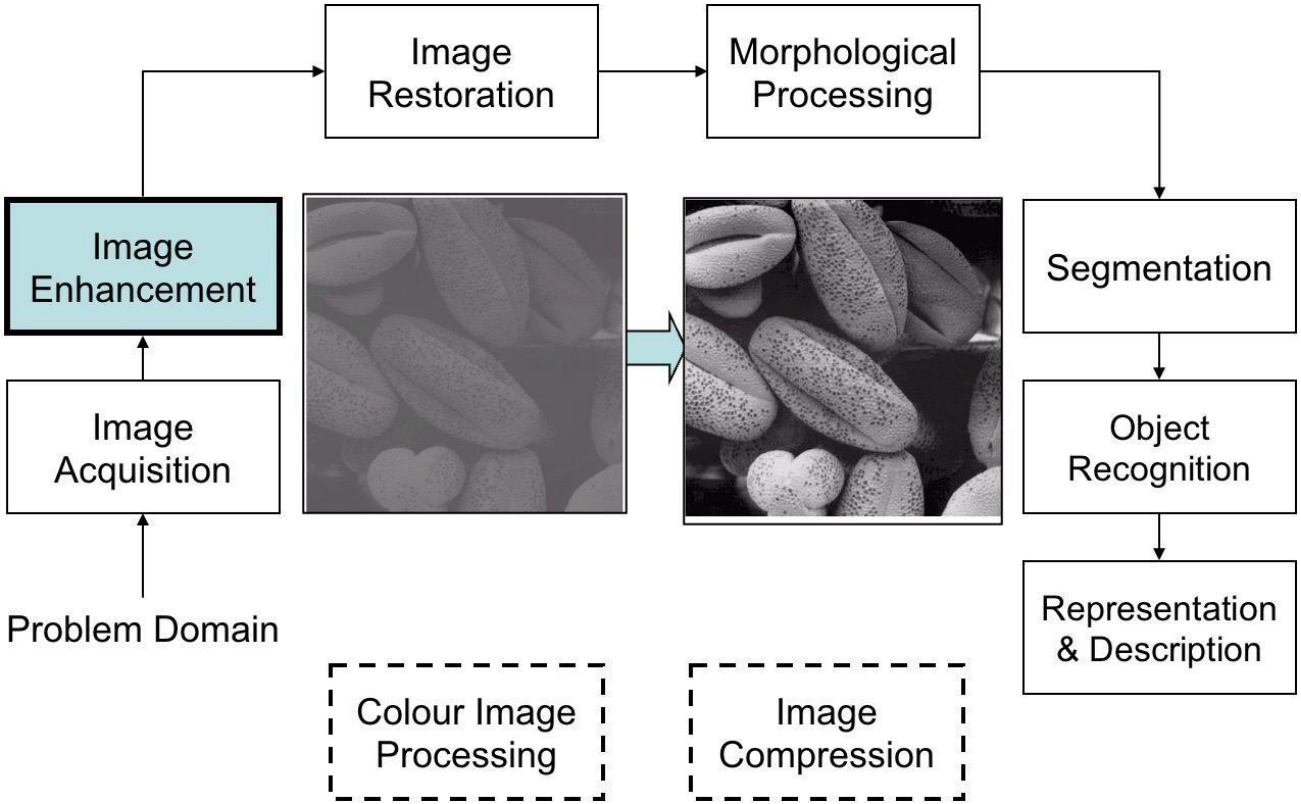
Key Stages in Digital Image Processing



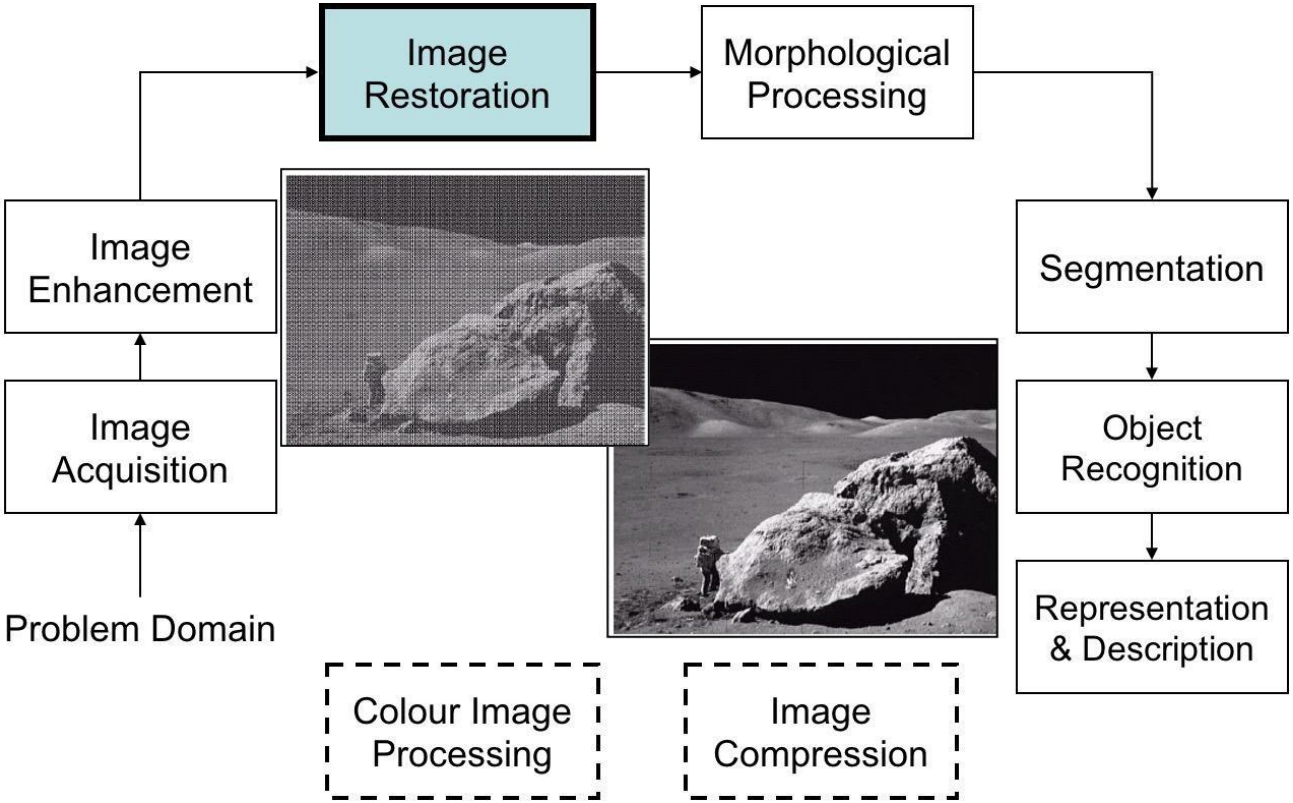
Key Stages in Digital Image Processing: Image Aquisition



Key Stages in Digital Image Processing: Image Enhancement

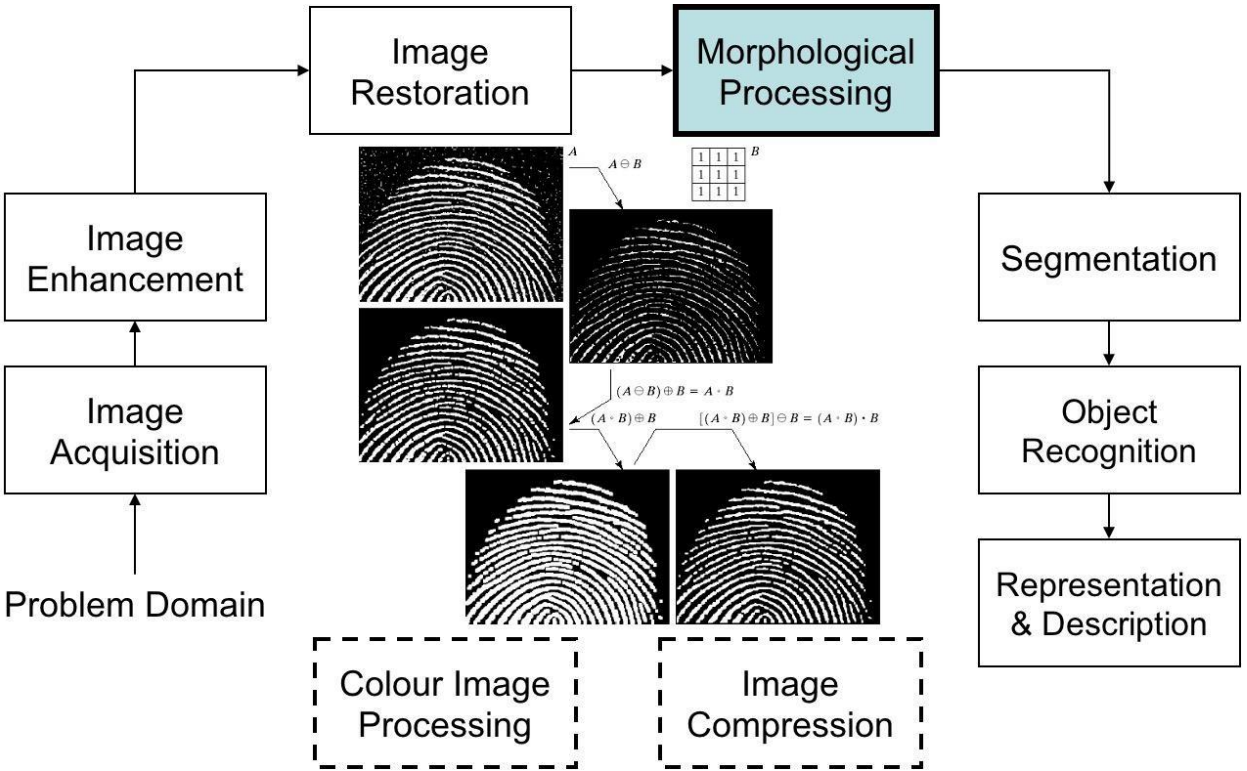


Key Stages in Digital Image Processing: Image Restoration

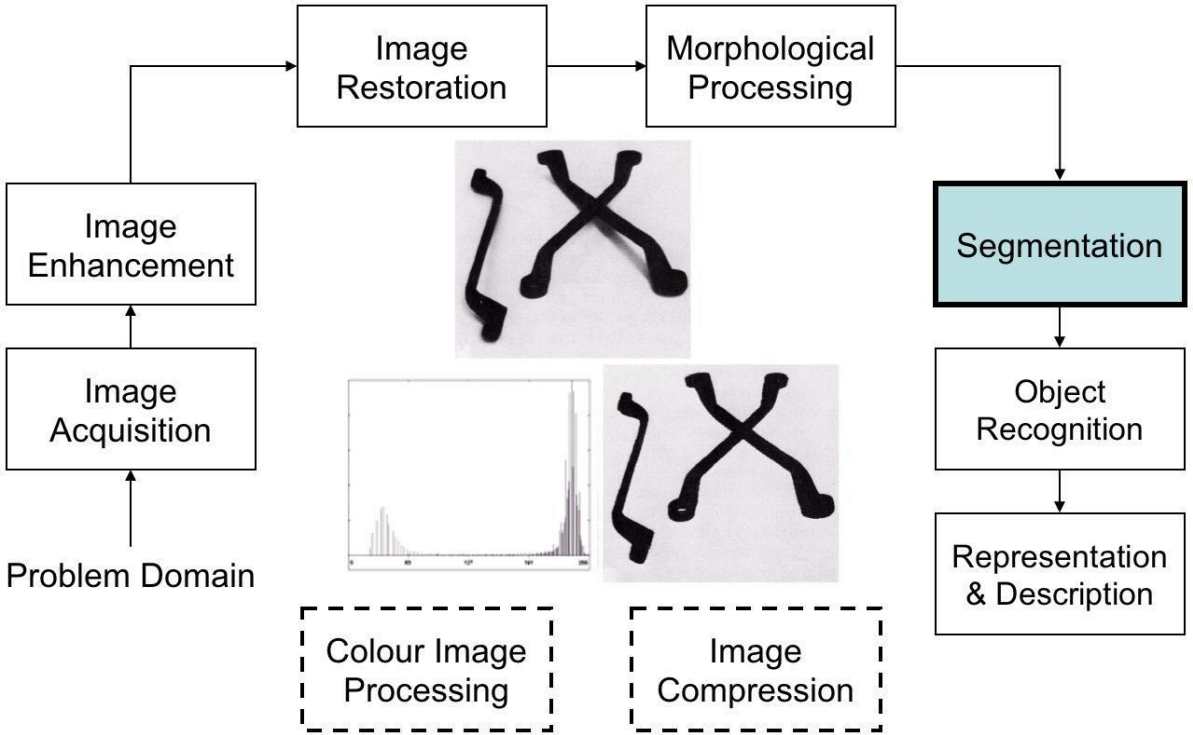


Key Stages in Digital Image Processing:

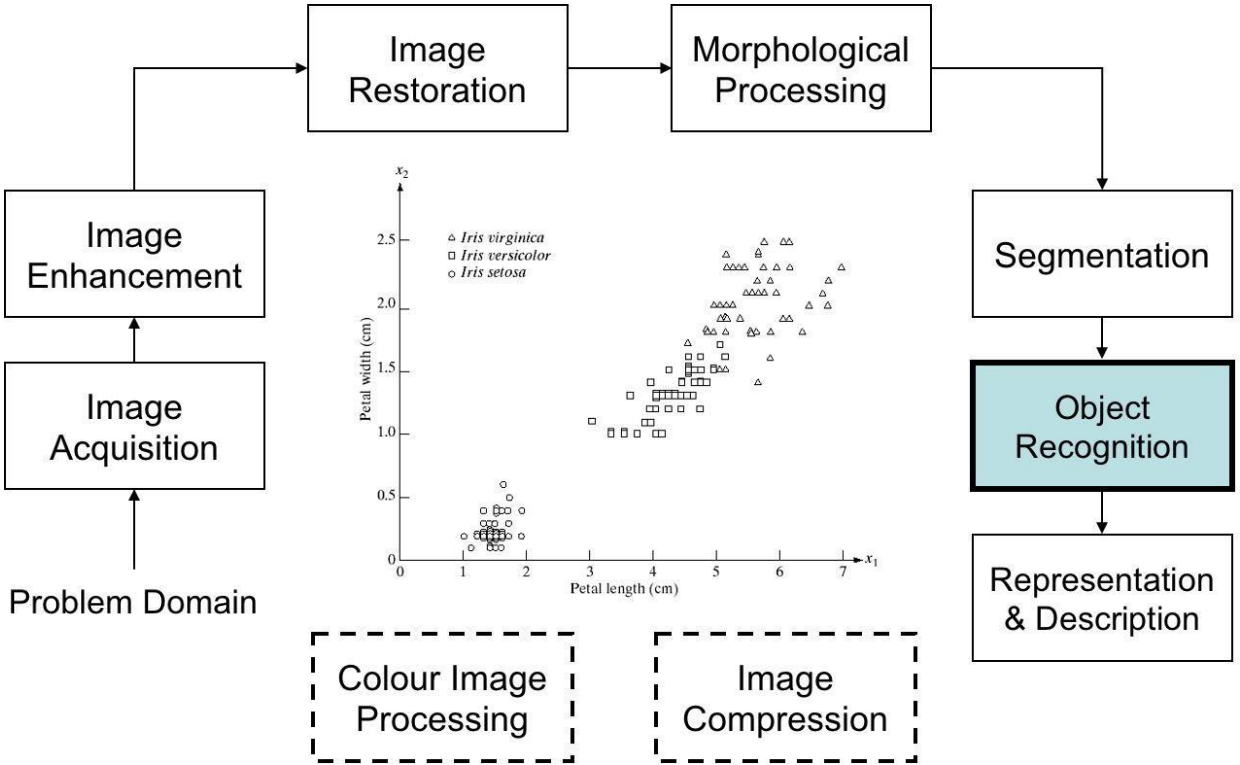
Morphological Processing



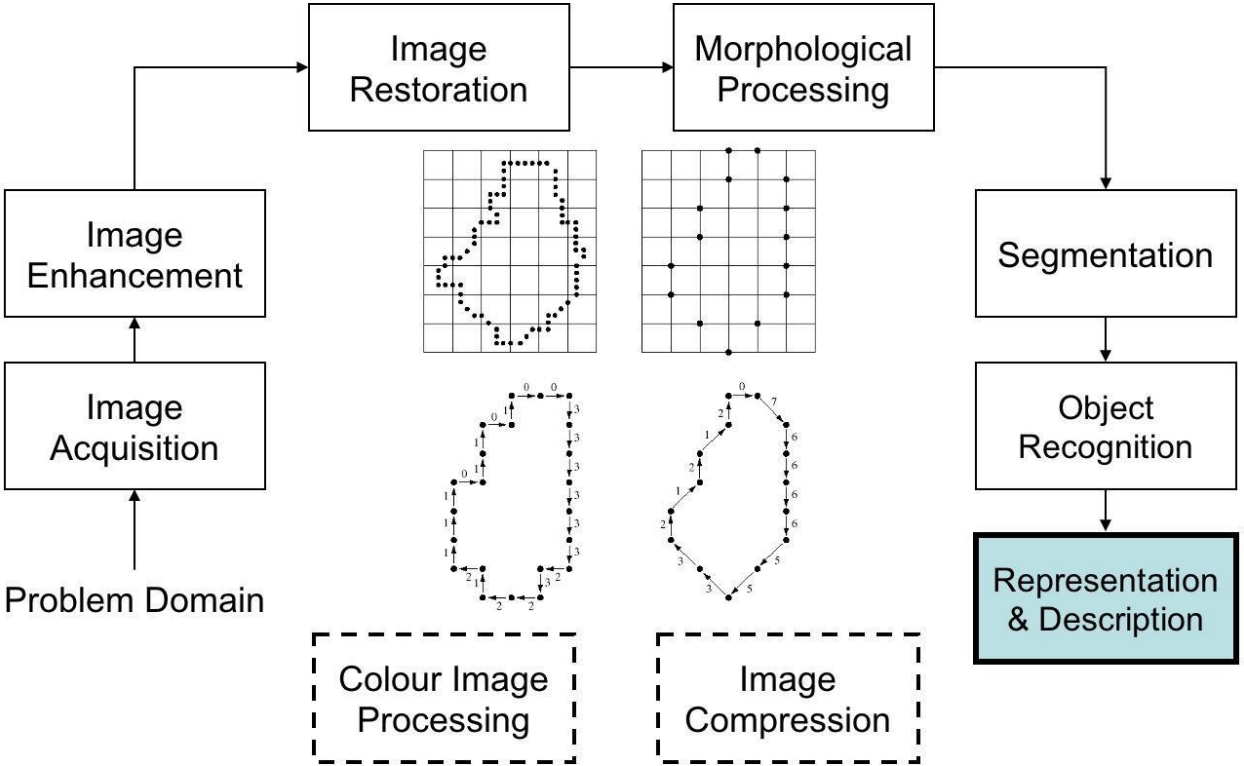
Key Stages in Digital Image Processing: Image Segmentation



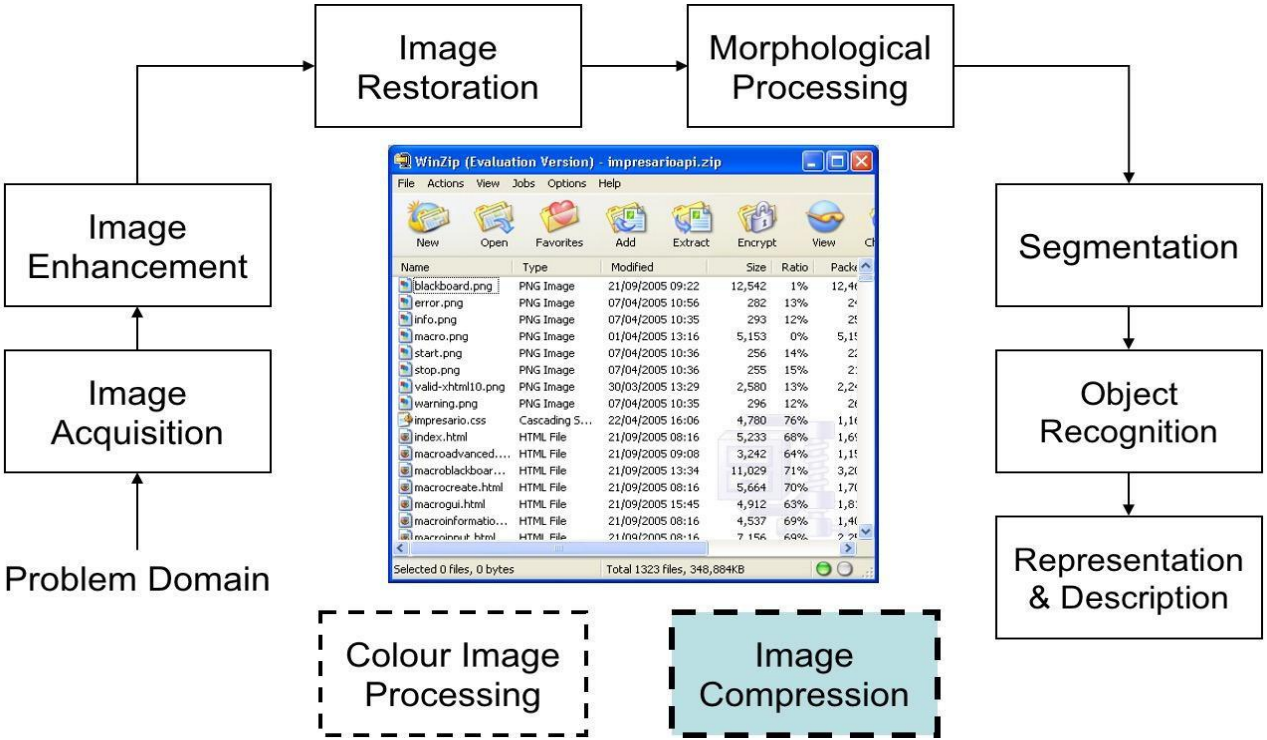
Key Stages in Digital Image Processing: Object Recognition



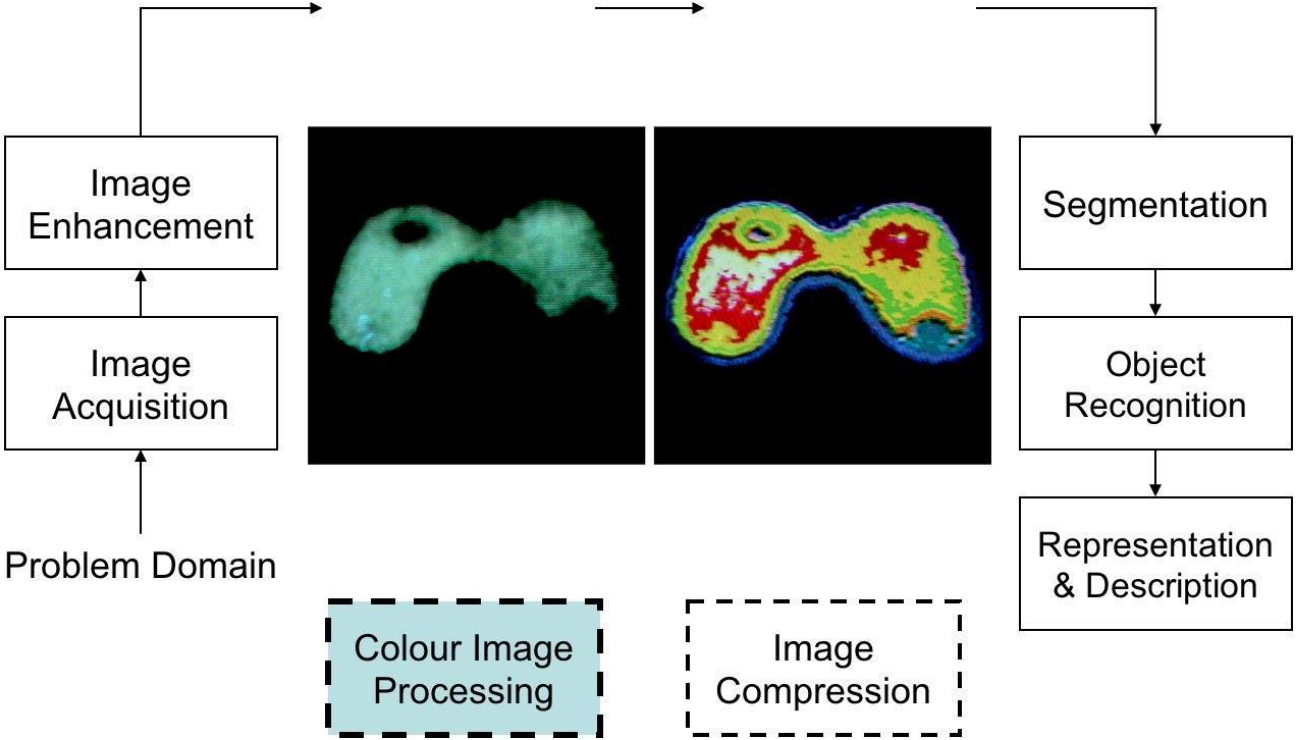
Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Color Image Processing



Summary

We have looked at:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

Next time we will start to see how it all works…