Books

- **Text Book:**

  Digital image processing. Author: Gonzalez R.C, Woods R.E, Latest Edition

- **Reference Materials:**

  The Image processing Handbook, Jon C Russ, Sixth edition

  Fundamentals of digital image processing. Author: Anil K. Jain

Chapter 1

Image Processing Basics

- First photograph due to Niepce,
- First on record shown - 1822
- Basic abstraction is the pinhole camera

- First successful commercial photograph due to Eastman in late 19th

First digital picture

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.)

FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. Some errors are visible. (McFarlane.)

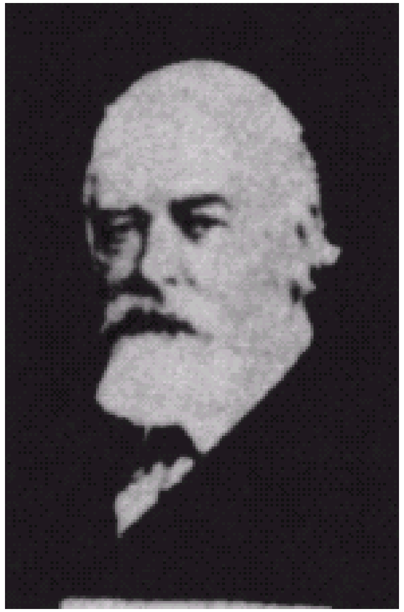
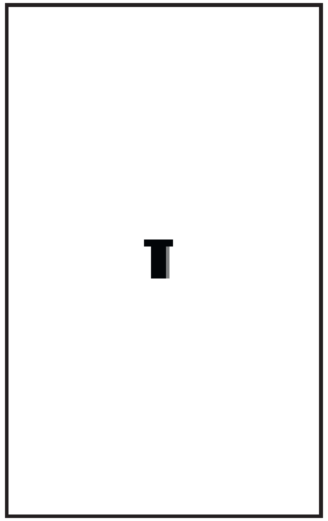


FIGURE 1.3 Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

Digital Image and Digital Image Processing

- Image – A two-dimensional signal that can be observed by human visual system- A 2D function **f**(x,y)
- Digital image – Representation of images by sampling in time and space., **f** are all finite, discrete quantities
- Pixel- A digital image consists of finite number of elements, each element has particular **location and value-pixel**
- Digital image processing – perform digital signal processing operations on digital images

- An image can be defined as a 2D signal that varies over the spatial coordinates *x* and *y*, and can be written mathematically as $f(x, y)$.



(a)

1	1	1	1	1
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0

(b)

Fig. 1.3 Digital image representation (a) Small binary digital image (b) Equivalent image contents in matrix form

The value of the function $f(x, y)$ at every point indexed by a row and a column is called *grey value* or *intensity* of the image.

- We can think of an **image** as a function, f, from R^2 to R:
  - $f(x, y)$ gives the **intensity** at position (x, y)
  - Realistically, we expect the image only to be defined over a rectangle, with a finite range:
    - f: $[a,b]\mathrm{x}[c,d] \rightarrow [0,1]$
- A color image is just three functions pasted together. We can write this as a "vector-valued" function:

$$f(x, y) = \begin{bmatrix} r(x, y) \\ g(x, y) \\ b(x, y) \end{bmatrix}$$

Image Coordinate

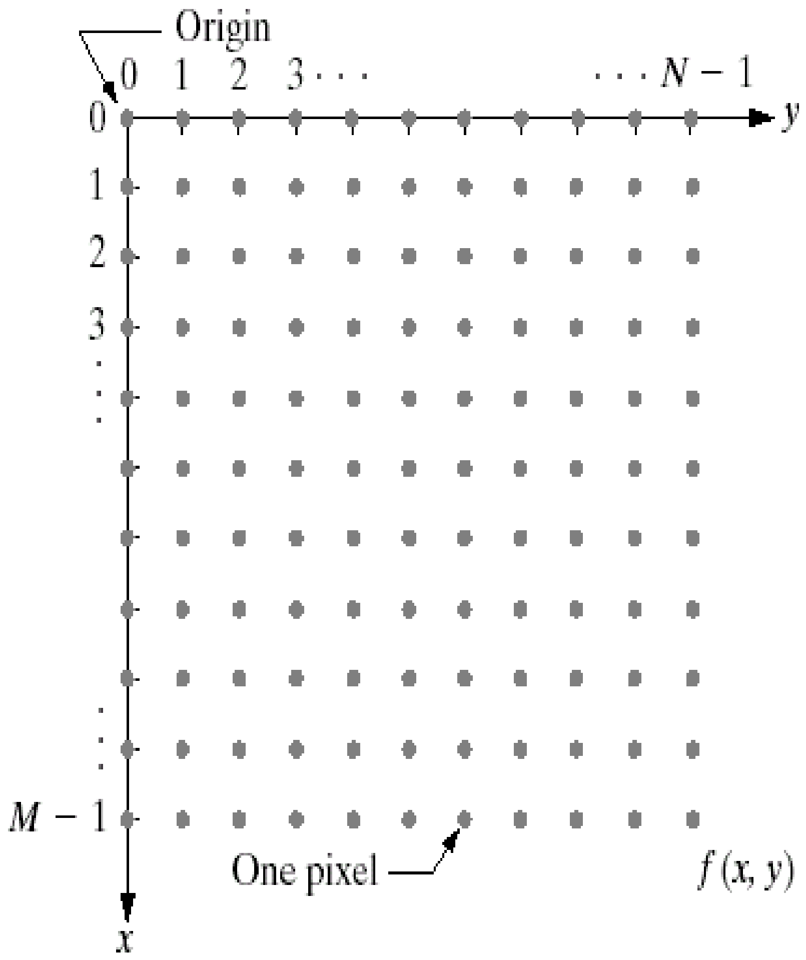


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & & & \\ f(M-1,0) & \cdots & \cdots & f(M-1,N-1) \end{bmatrix}$$

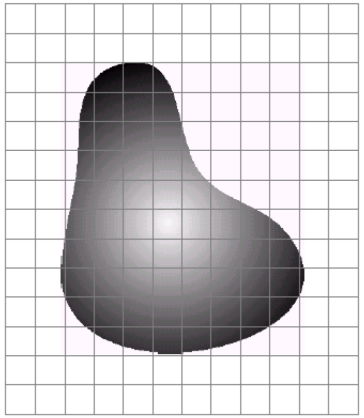
; $M \times N$ matrix

$$\mathbf{A}=\begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0,N-1} \\ \vdots & & & \\ \vdots & & & \\ a_{M-1,0} & \cdots & \cdots & a_{M-1,N-1} \end{bmatrix}$$

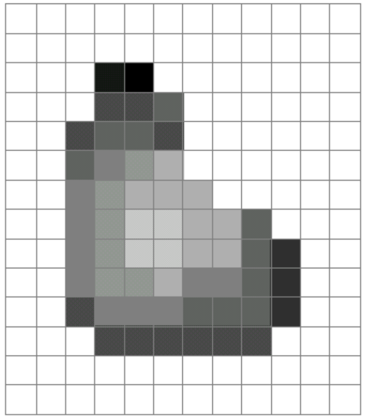
; $a_{ij}= f\,(x=i,\ y=j)$

Digital Image?

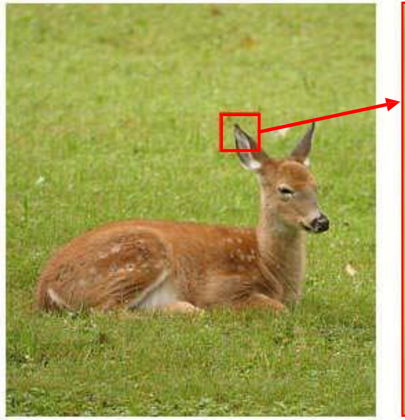
- **Remember:** *digitization* causes a digital image to become an *approximation* of a real scene



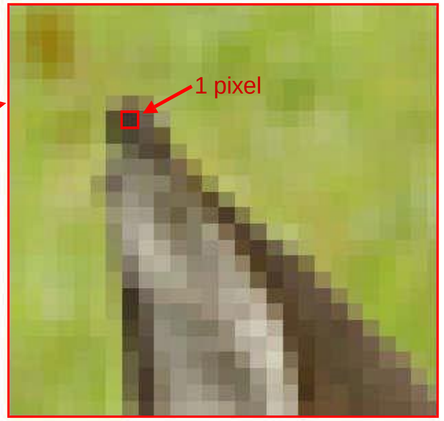
Real image



Digital Image
(an approximation)



Real image



Digital Image
(an approximation)

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Digital Image

- Common image formats include:
  - 1 values per point/pixel (B&W or Grayscale)
  - 3 values per point/pixel (Red, Green, and Blue)
  - 4 values per point/pixel (Red, Green, Blue, + “Alpha” or Opacity)

Grayscale

RGB

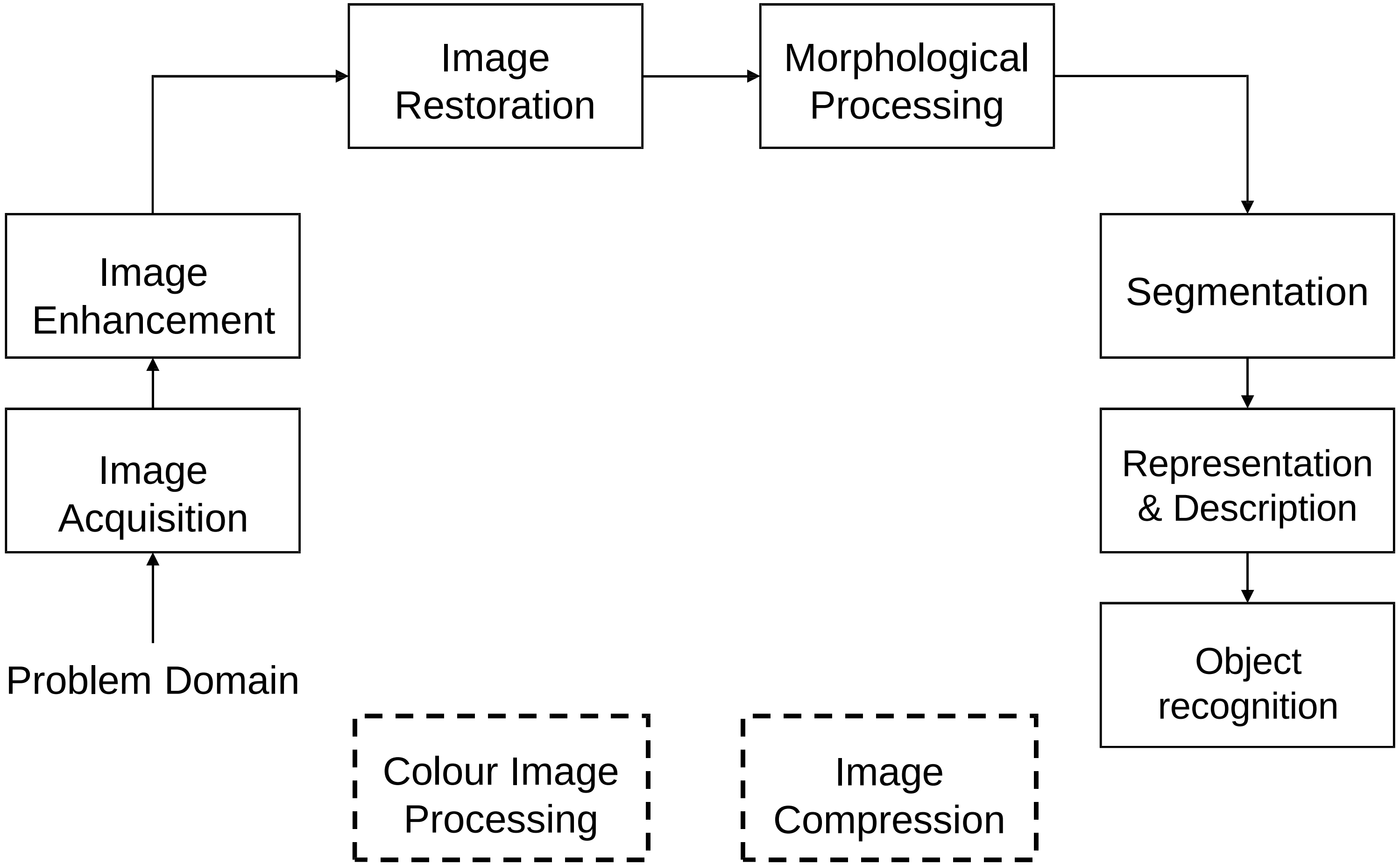
RGBA

- We will start with gray-scale images, extend to color later

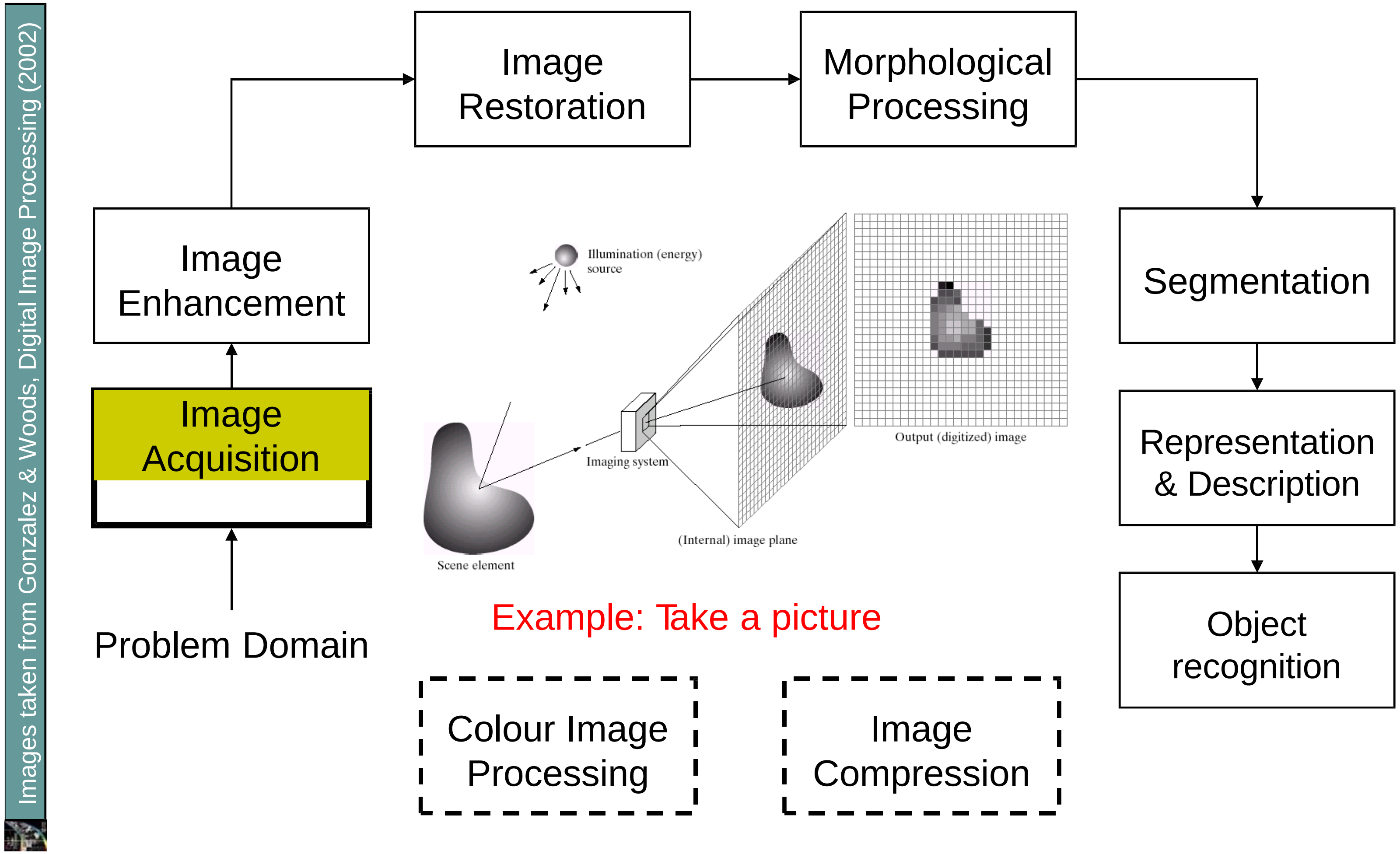
Why DIP?

- **One picture worth 1000 words!**
- Support visual communication
- Facilitate inspection, diagnosis of complex systems
  - Human body
  - Manufacturing
- Entertainment
- Keep record, history
- Managing multimedia information
- Security,
  - monitoring,
  - watermarking, etc

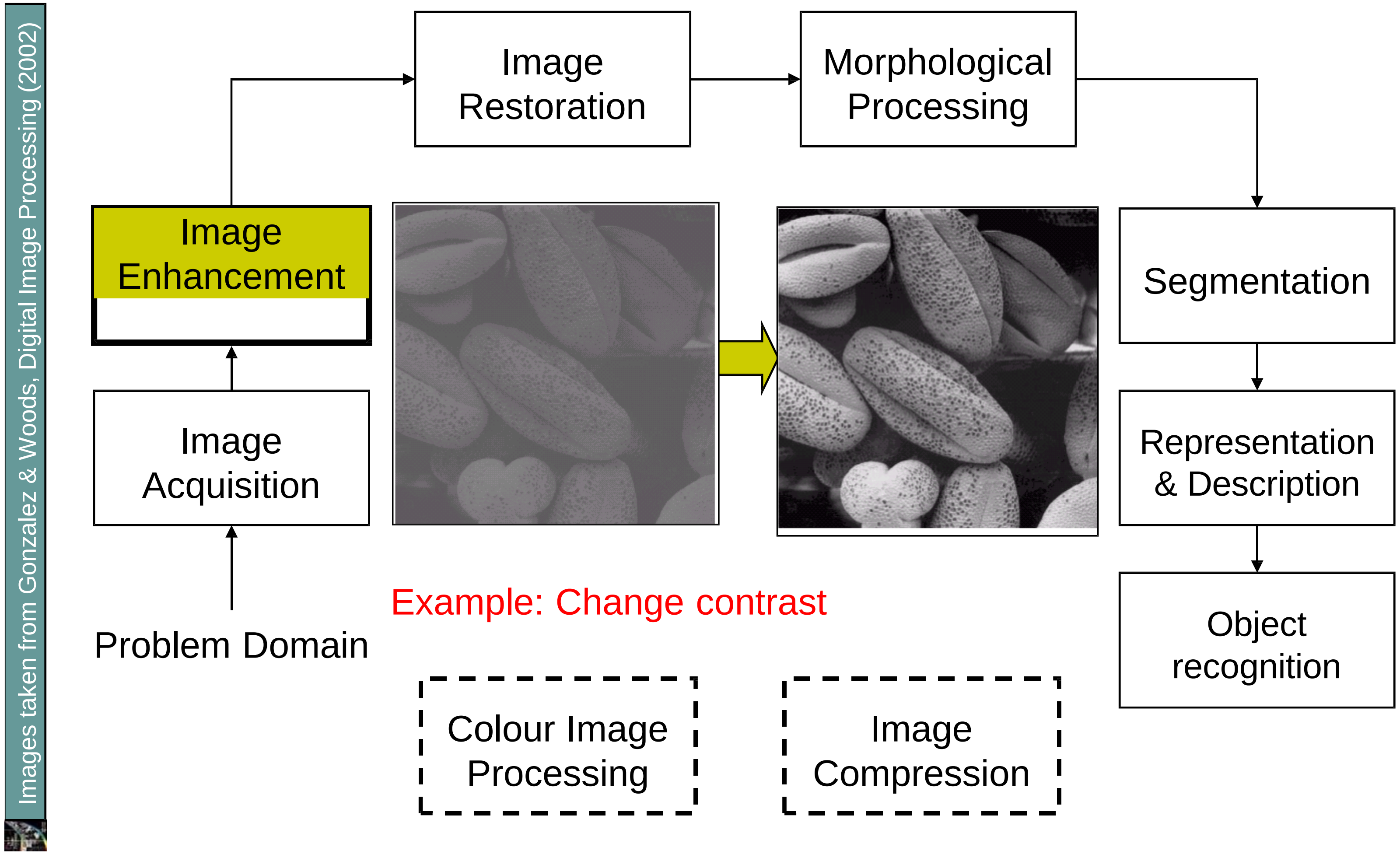
Key Stages in Digital Image Processing



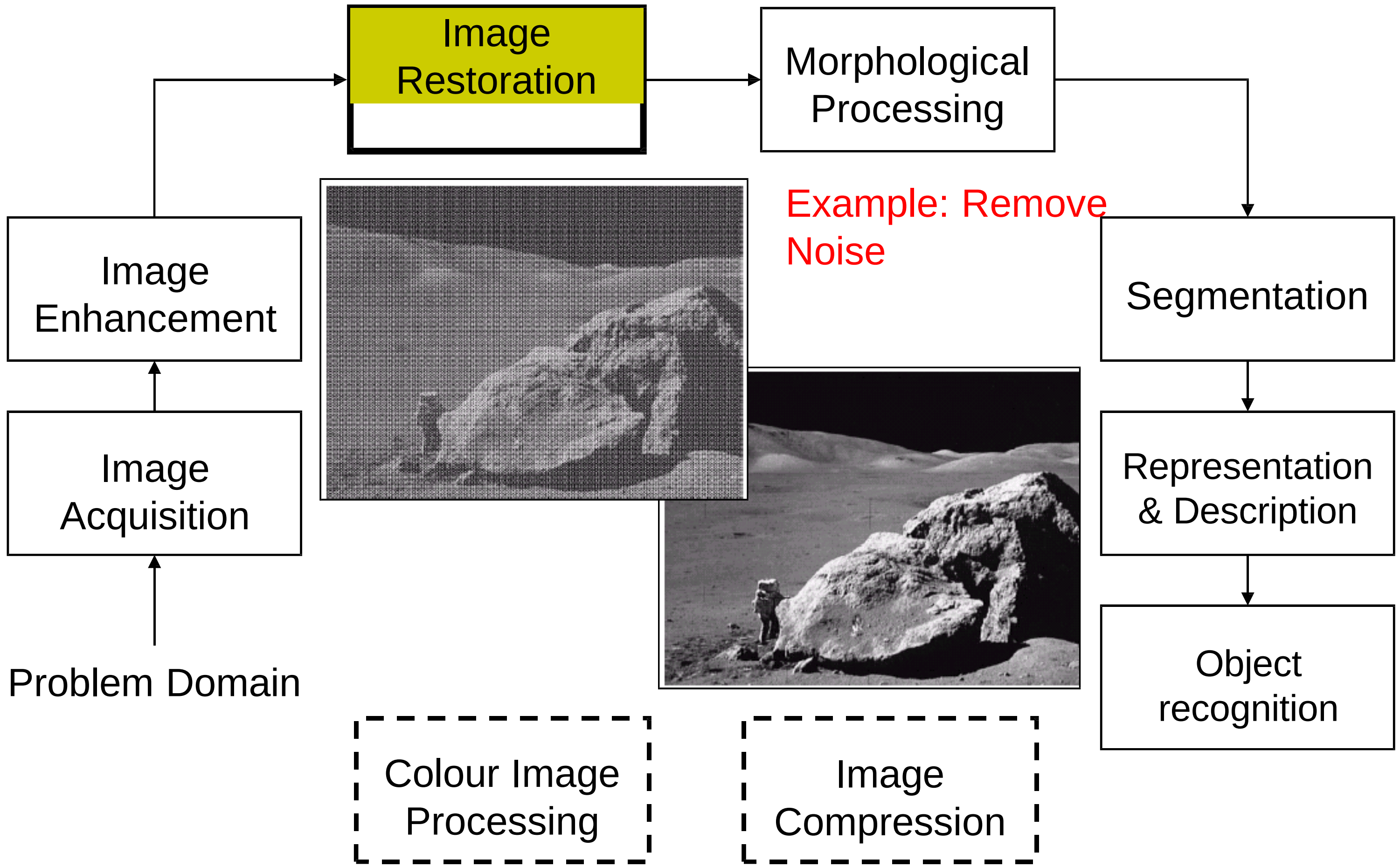
Key Stages in Digital Image Processing: Image Aquisition



Key Stages in Digital Image Processing: Image Enhancement

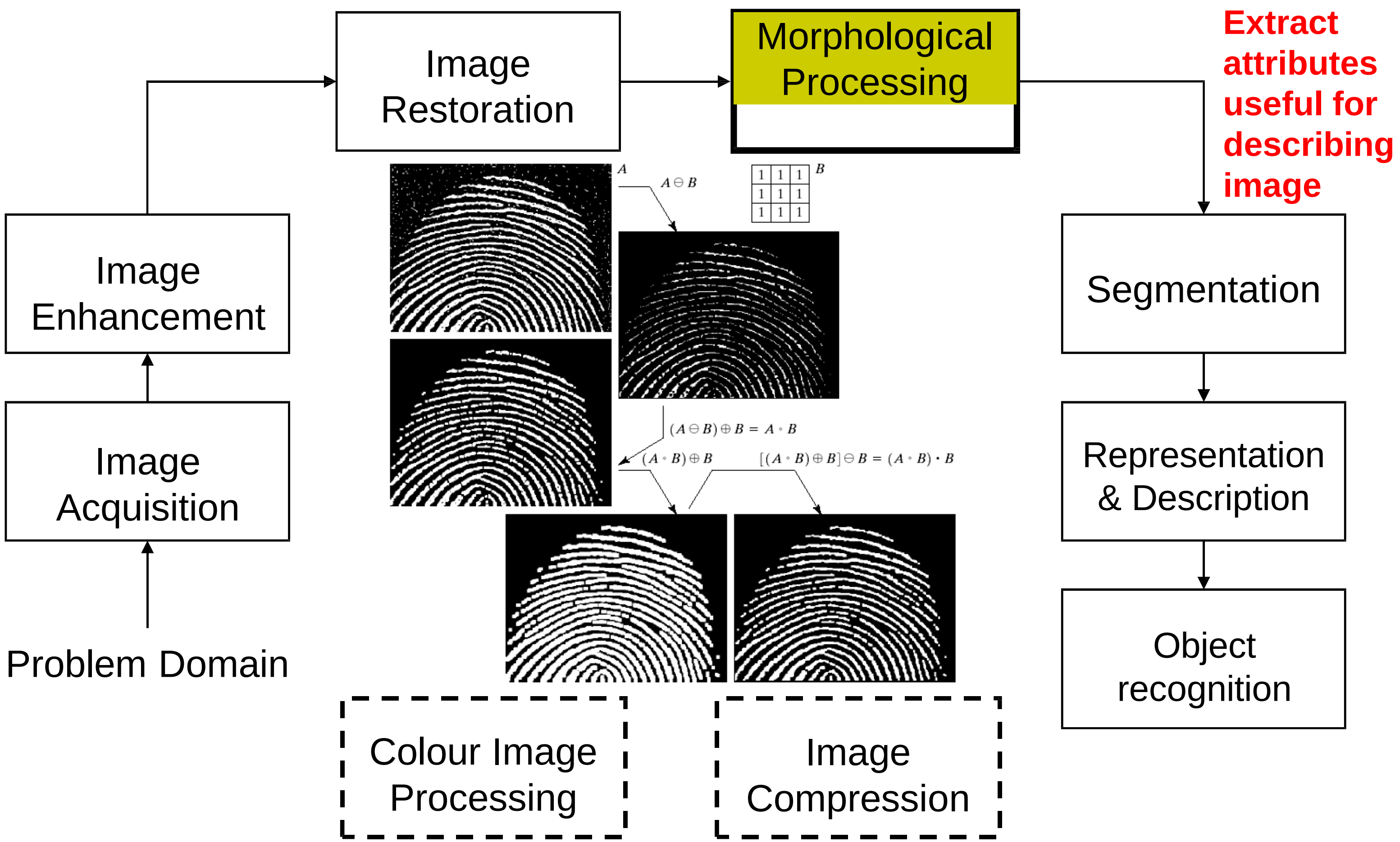


Key Stages in Digital Image Processing: Image Restoration



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Morphological Processing



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Segmentation

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Restoration

Morphological Processing

Divide image into constituent parts

Image Enhancement

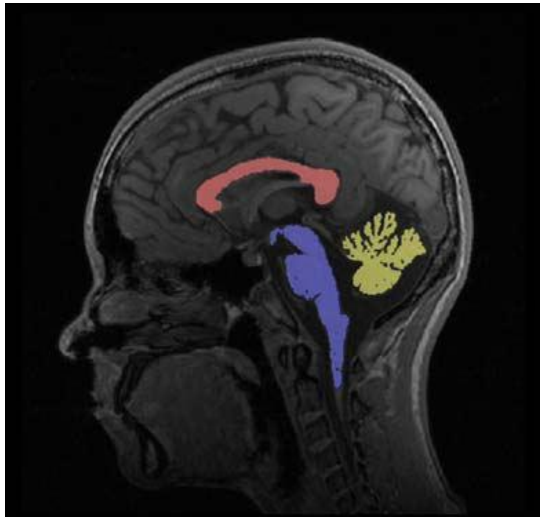
Segmentation

Image Acquisition

Representation & Description

Problem Domain

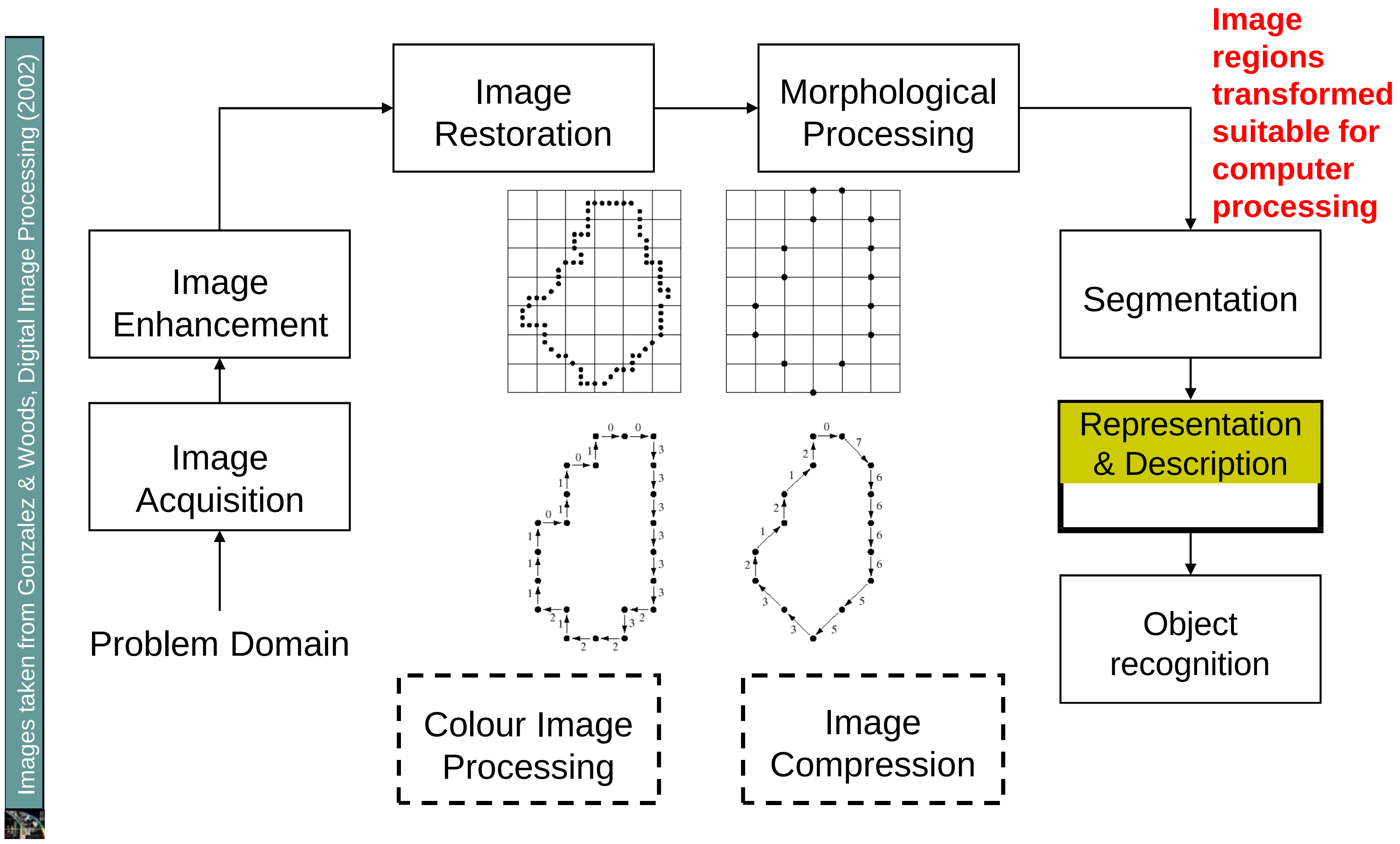
Object recognition



Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Object Recognition



Key Stages in Digital Image Processing: Representation & Description

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Restoration

Morphological Processing

Finds & Labels objects in scene (e.g. motorbike)

Image Enhancement

Segmentation

Image Acquisition

Representation & Description

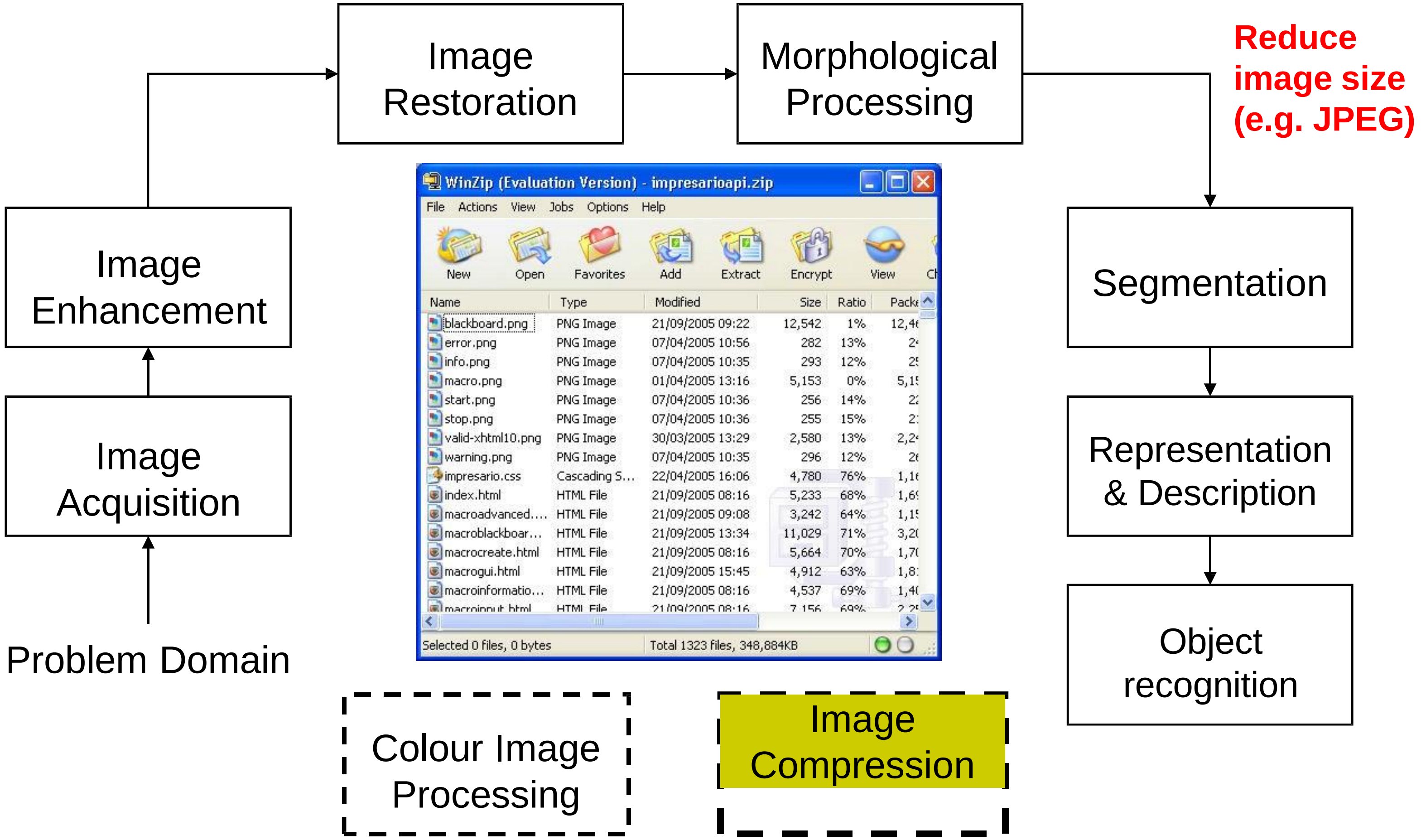
Object recognition

Problem Domain

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Image Compression

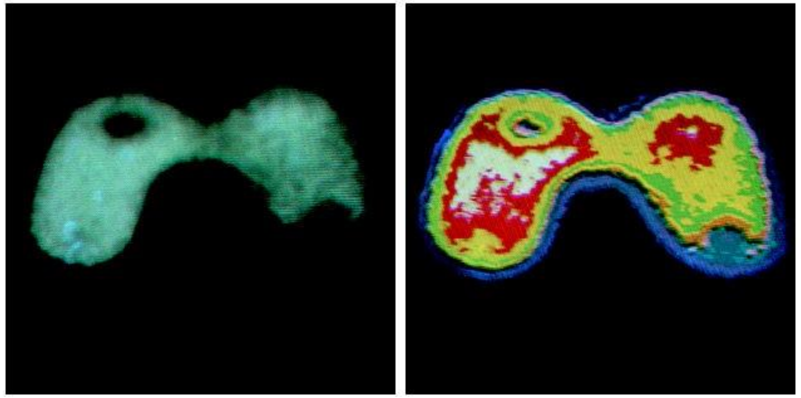


Key Stages in Digital Image Processing: Colour Image Processing

Image Restoration

Morphological Processing

Image Enhancement



Segmentation

Image Acquisition

Representation & Description

Object recognition

Problem Domain

Consider color images (color models, etc)

Colour Image Processing

Image Compression

Mathematics for Image Processing

- Calculus
- Linear algebra
- Probability and statistics
- Differential Equations (PDEs and ODEs)
- Differential Geometry
- Harmonic Analysis (Fourier, wavelet, etc)

IP vs. Computer Vision

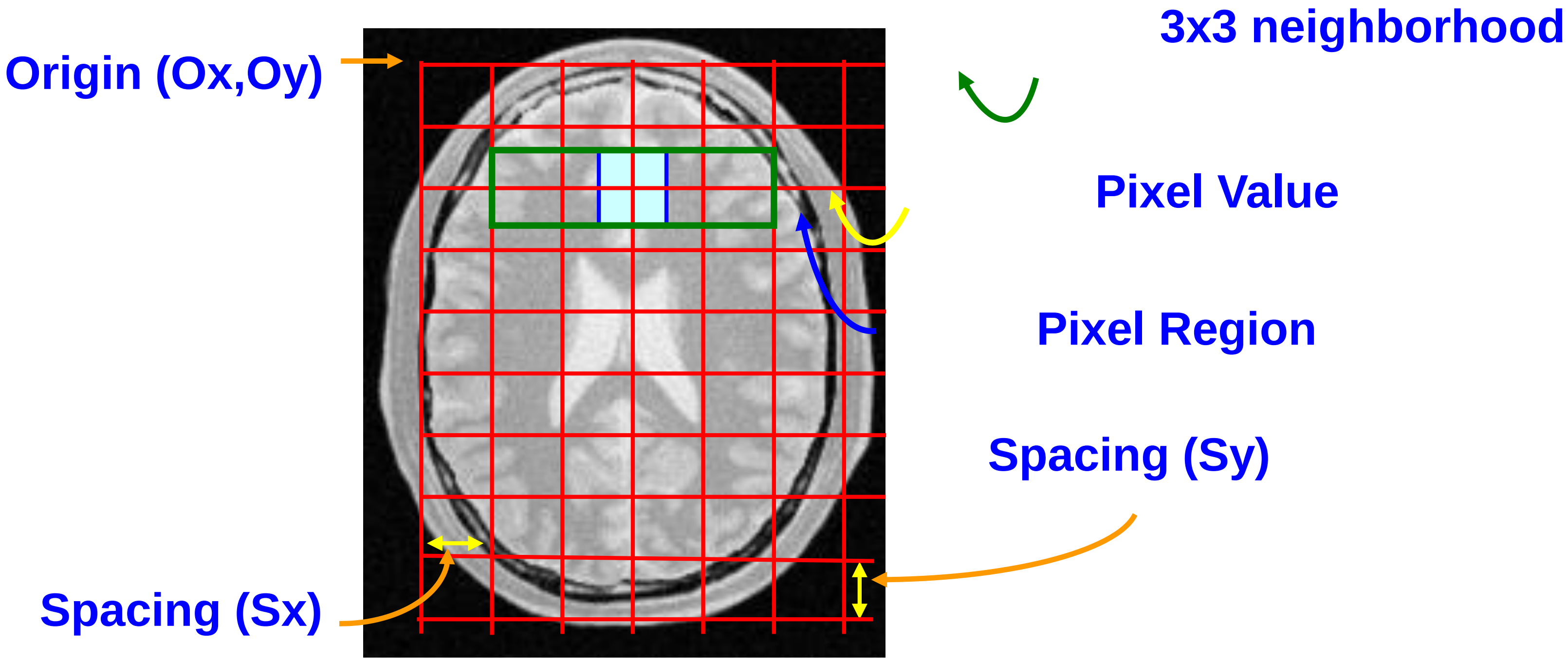
Vision continuum

Image processing	Image analysis	Computer vision
Low-level	Mid-level	High-level
▪Filtering ▪Enhancement ▪Restoration ▪Edge detection ▪Compression	▪Segmentation ▪Classification	▪Recognition ▪AI
Image-in Image-out	Image-in Feature-out	Image-in Decision-out

Low level image processing

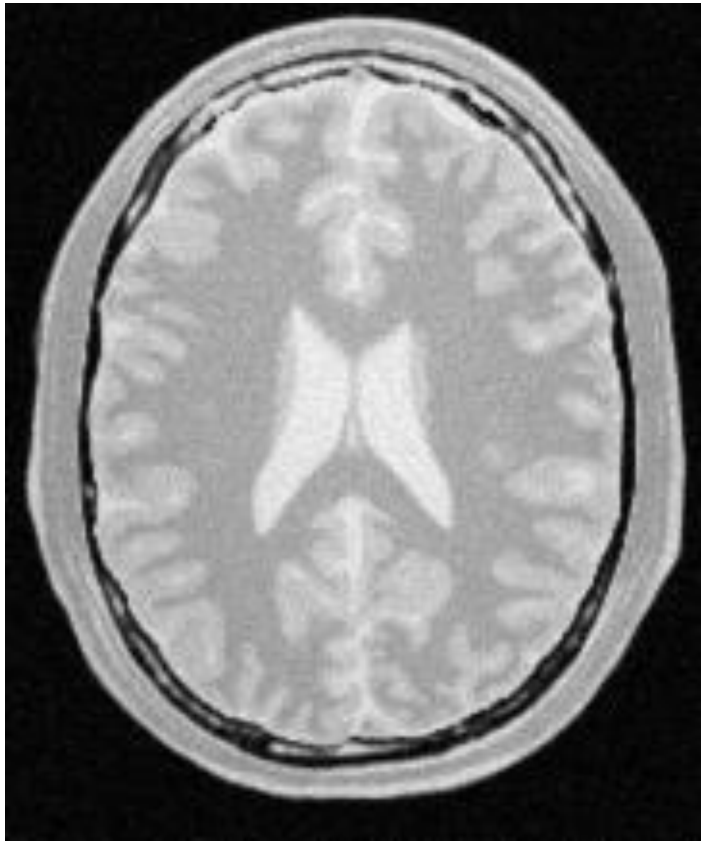
- Very little knowledge about the content of the images.
- Data are the original images, represented as matrices of intensity values, i.e. sampling of a continuous field using a discrete grid.
- **Focus of this course**.

Low level image processing



Low level image processing

- Image compression
- Noise reduction
- Edge extraction
- Contrast enhancement
- Segmentation
- Thresholding
- Morphology
- Image restoration



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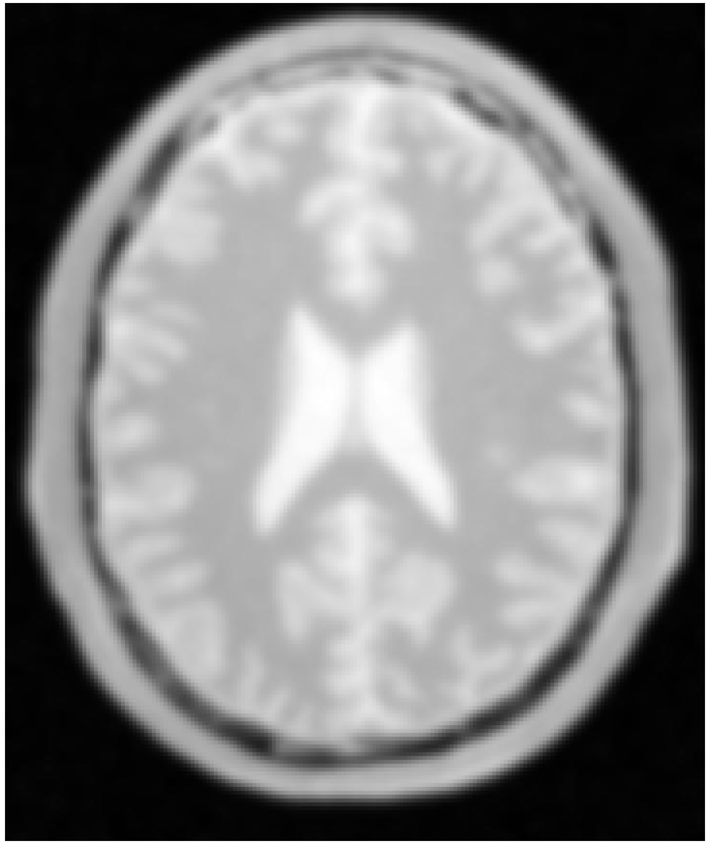

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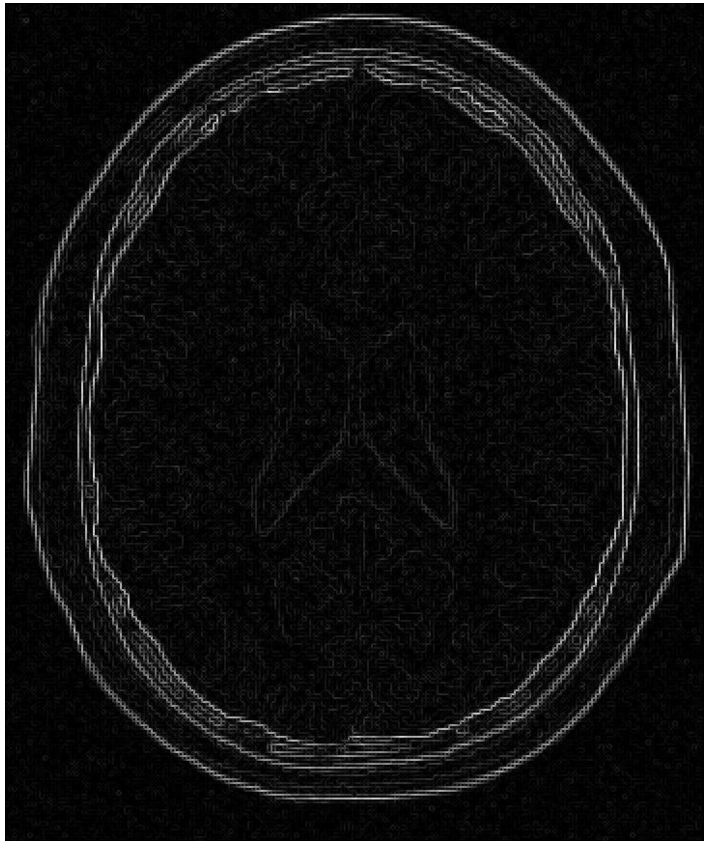

Low level image processing

- Image compression
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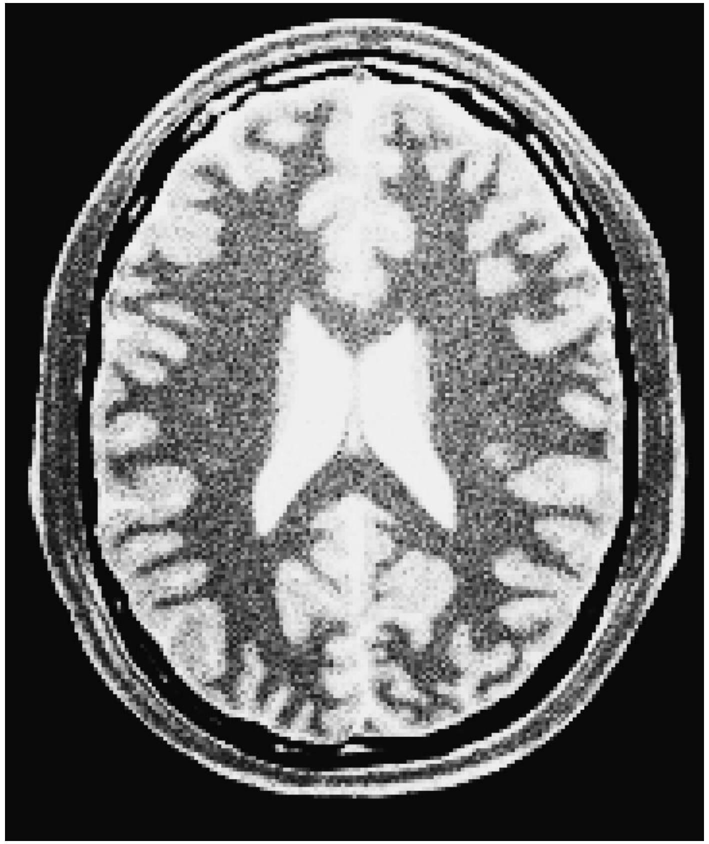

Low level image processing

- Image compression
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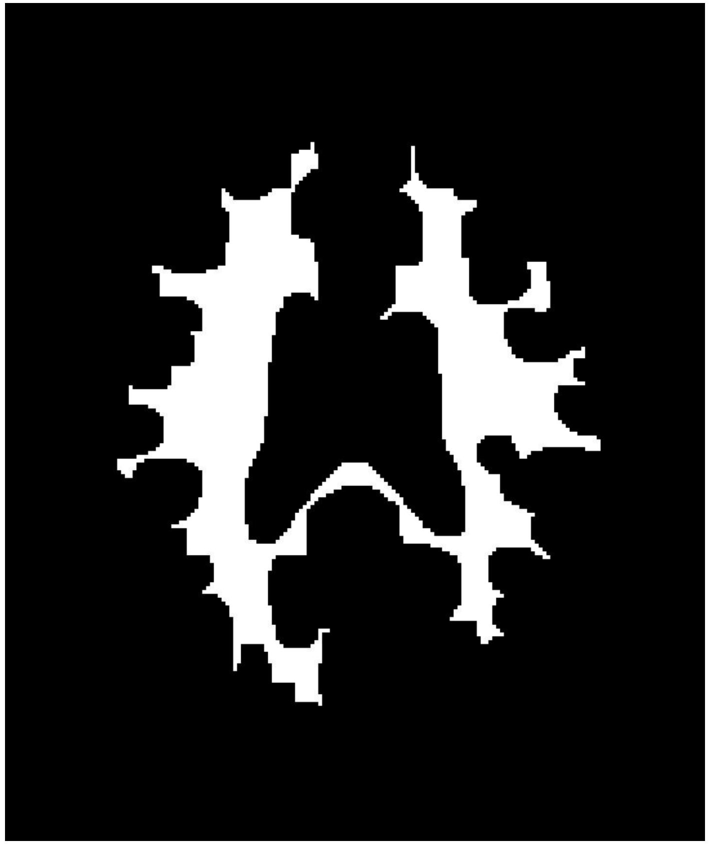

Low level image processing

- Image compression
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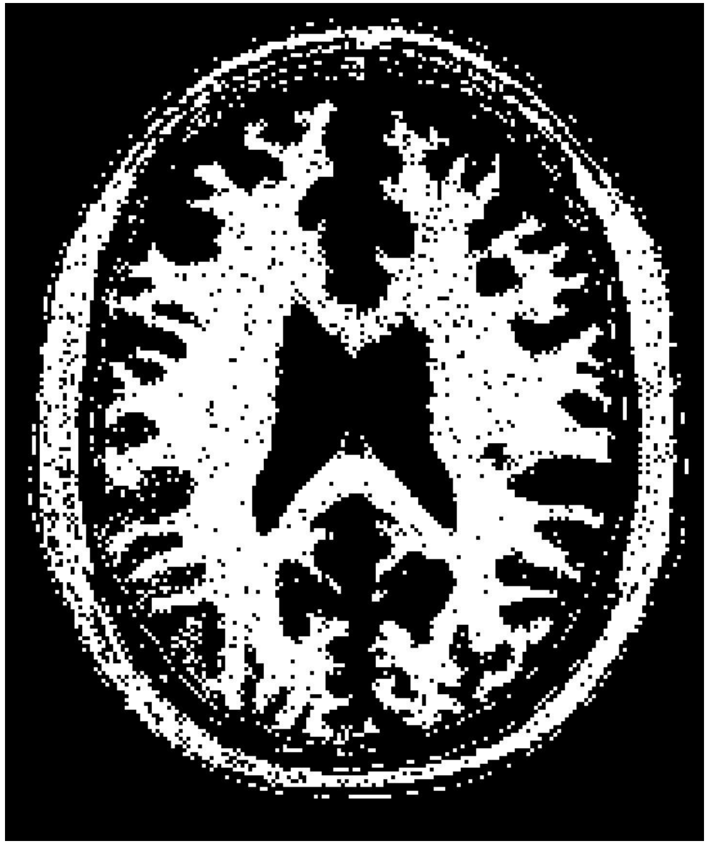

Low level image processing

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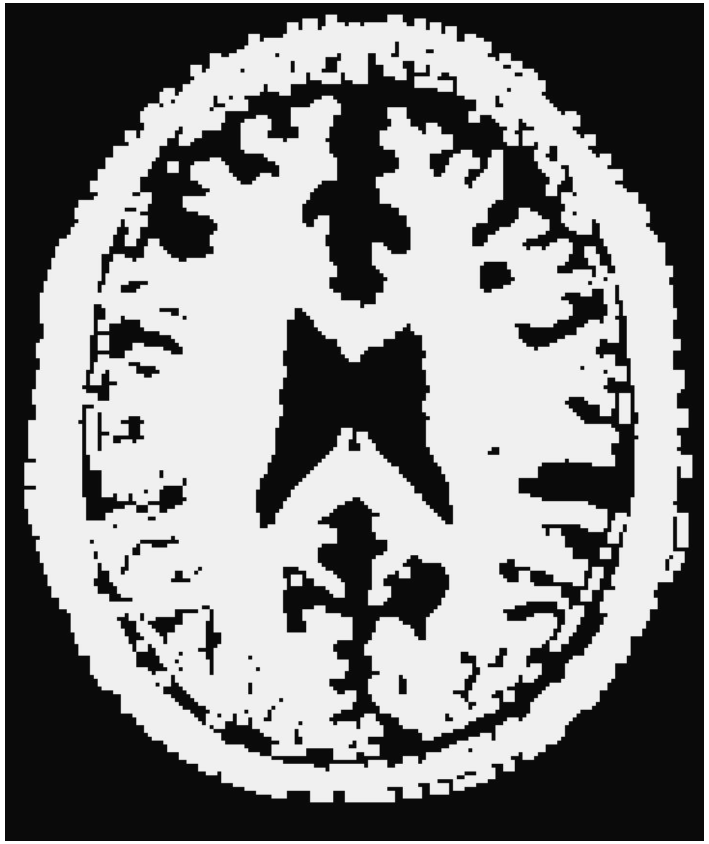

Low level image processing

- Image compression
- Noise reduction
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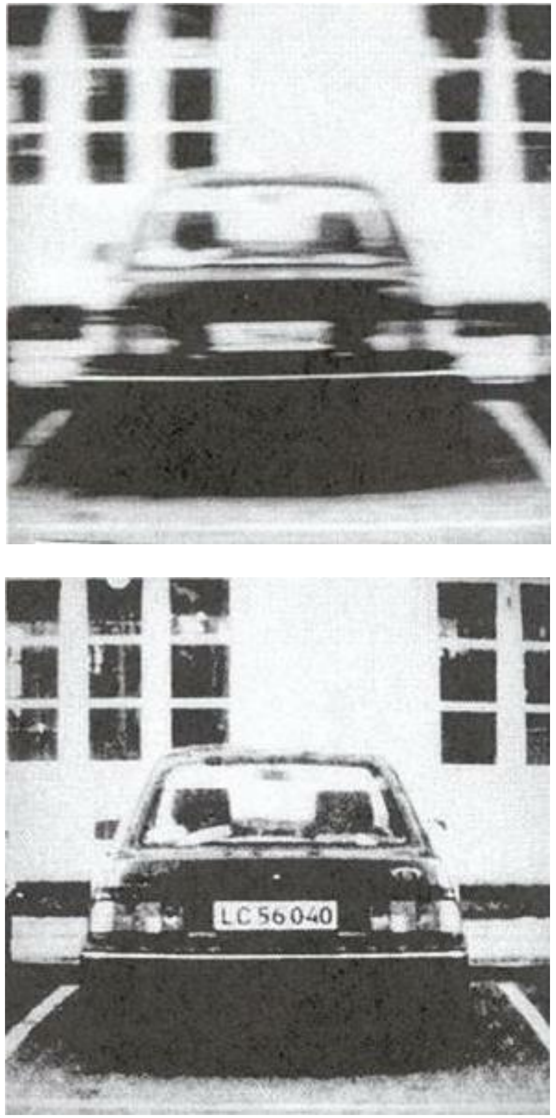
- Image restoration



High level image understanding

- To imitate human cognition according to the information contained in the image.
- Data represent knowledge about the image content, and are often in symbolic form.
- Data representation is specific to the high-level goal.

High level image understanding

- What are the high-level components?
- What tasks can be achieved?

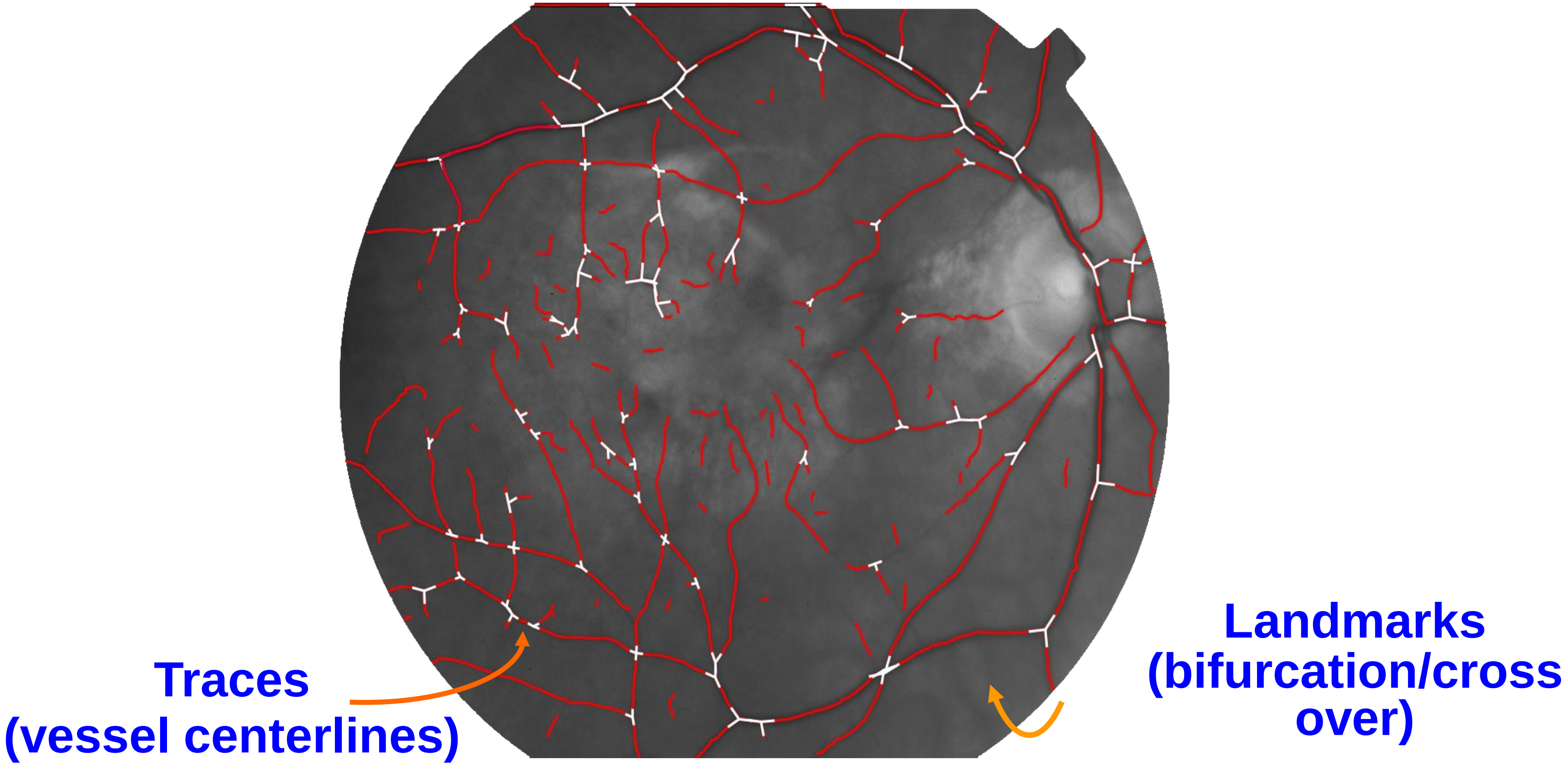


IMAGE PROCESSING ENVIRONMENT

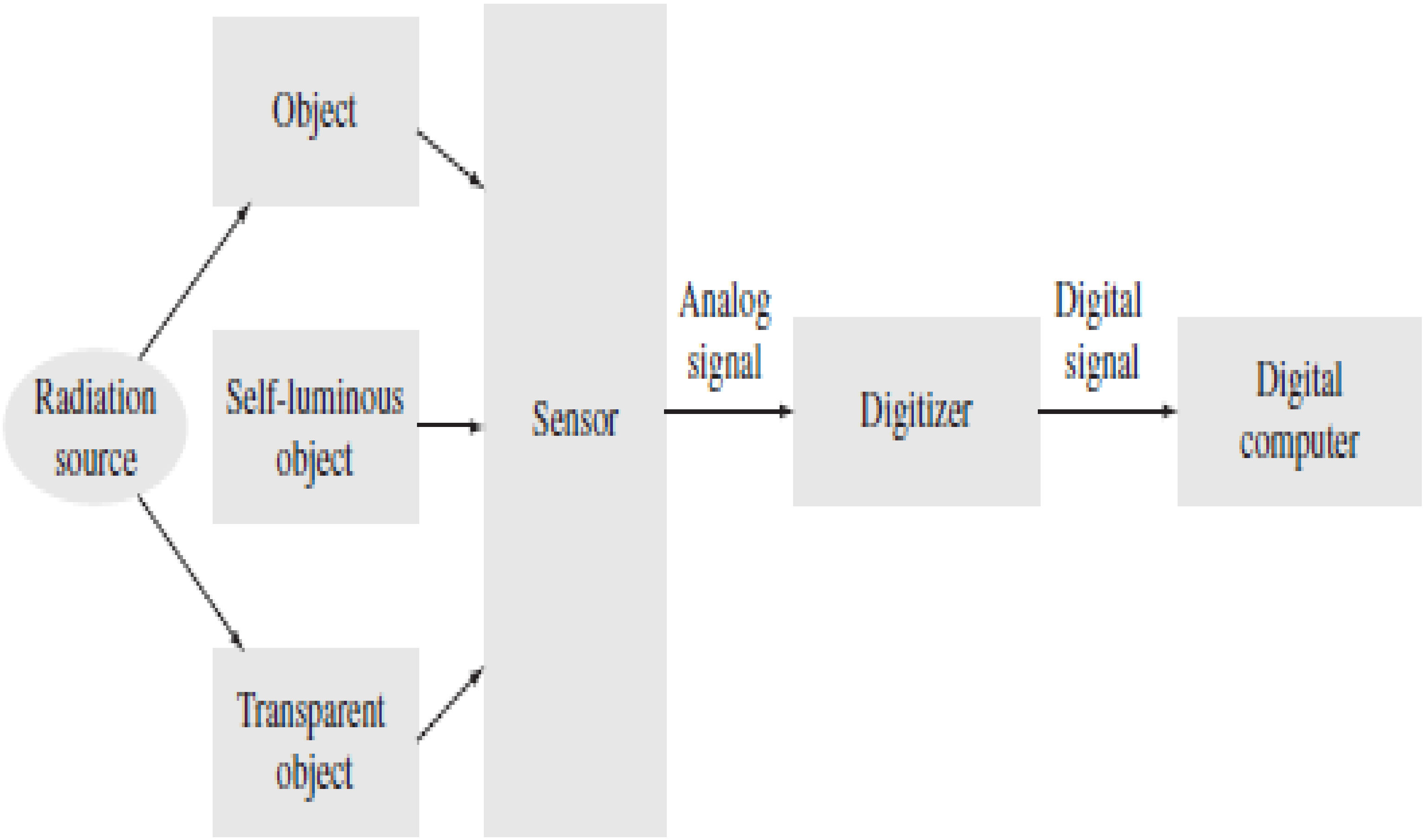


Fig. 1.1 Image processing environment

Reflective mode Imaging

- *Reflective mode imaging* represents the simplest form of imaging and uses a sensor to acquire the digital image. All video cameras, digital cameras, and scanners use some types of sensors for capturing the image.

Emissive type imaging

- *Emissive type imaging* is the second type, where the images are acquired from self-luminous objects without the help of a radiation source. In emissive type imaging, the objects are self-luminous. The radiation emitted by the object is directly captured by the sensor to form an image. Thermal imaging is an example of emissive type imaging.

Transmissive Imaging

- *Transmissive imaging* is the third type, where the radiation source illuminates the object. The absorption of radiation by the objects depends upon the nature of the material. Some of the radiation passes through the objects. The attenuated radiation is sensed into an image.

Image Types

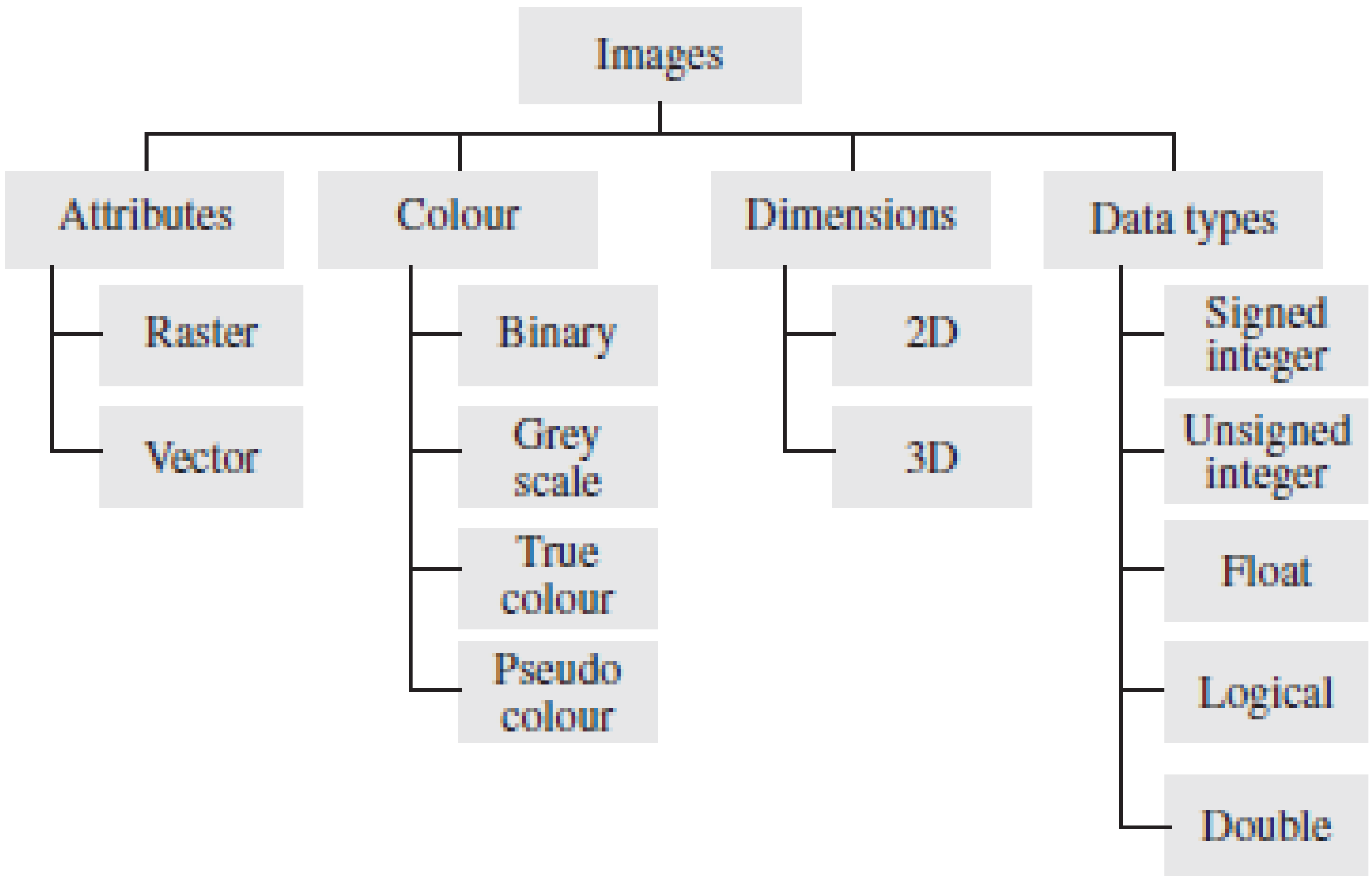


Fig. 1.4 Classification of images

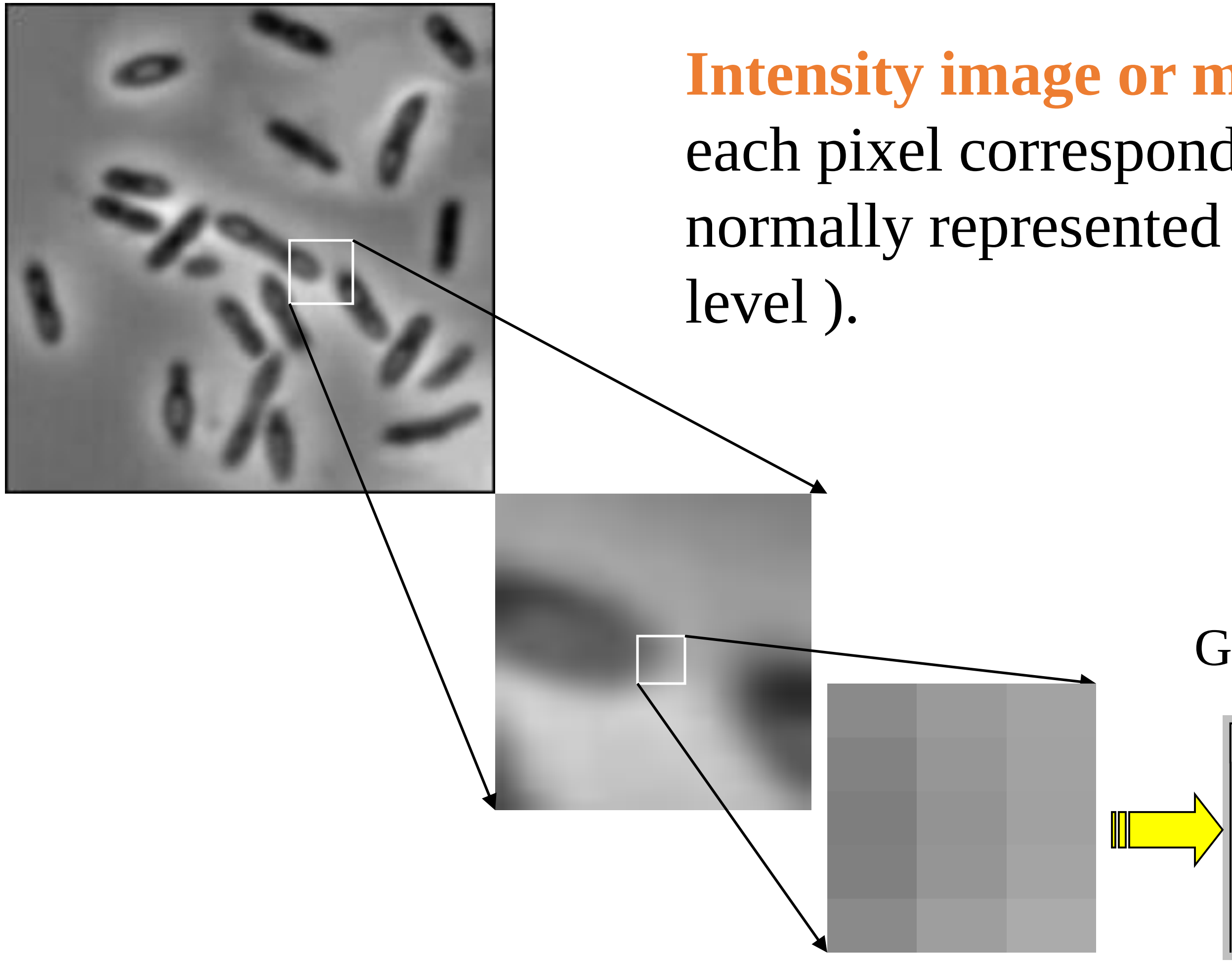
Types of Image

- In binary images, the pixels assume a value of 0 or 1. So one bit is sufficient to represent the pixel value. Binary images are also called bi-level images.

- In true colour images, the pixel has a colour that is obtained by mixing the primary colours red, green, and blue. Each colour component is represented like a grey scale image using eight bits. Mostly, true colour images use 24 bits to represent all the colours.

Digital Image Types : Intensity Image

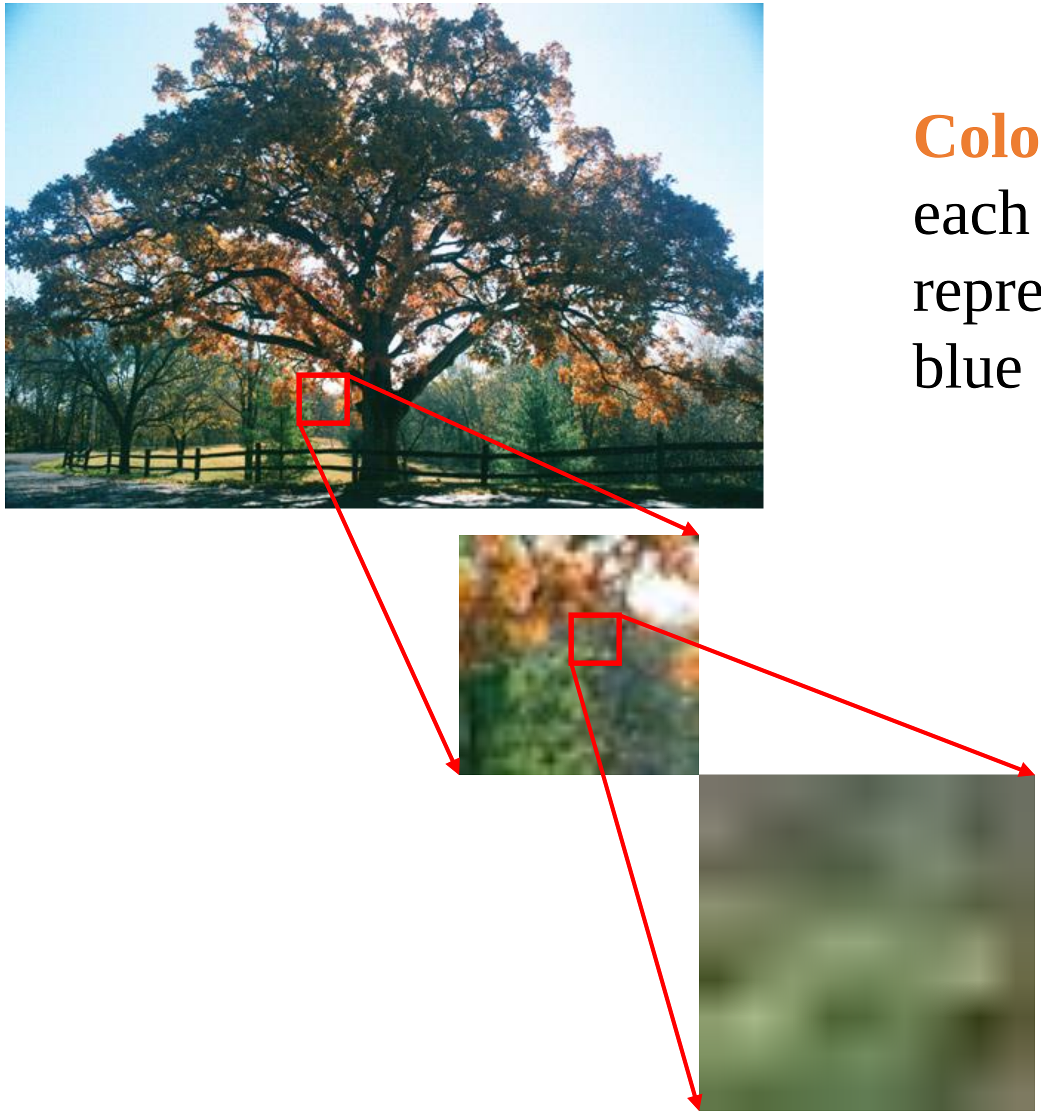
Intensity image or monochrome image
each pixel corresponds to light intensity normally represented in gray scale (gray level).



Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Digital Image Types : RGB Image



Color image or RGB image: each pixel contains a vector representing red, green and blue components.

RGB components

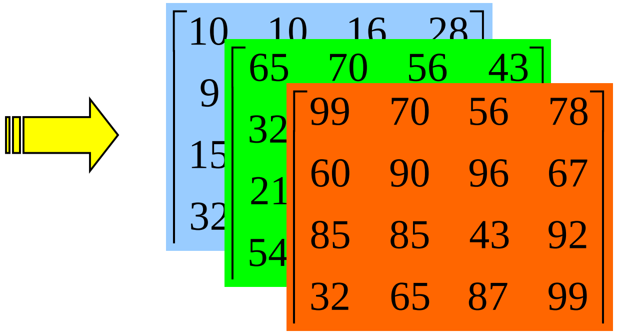


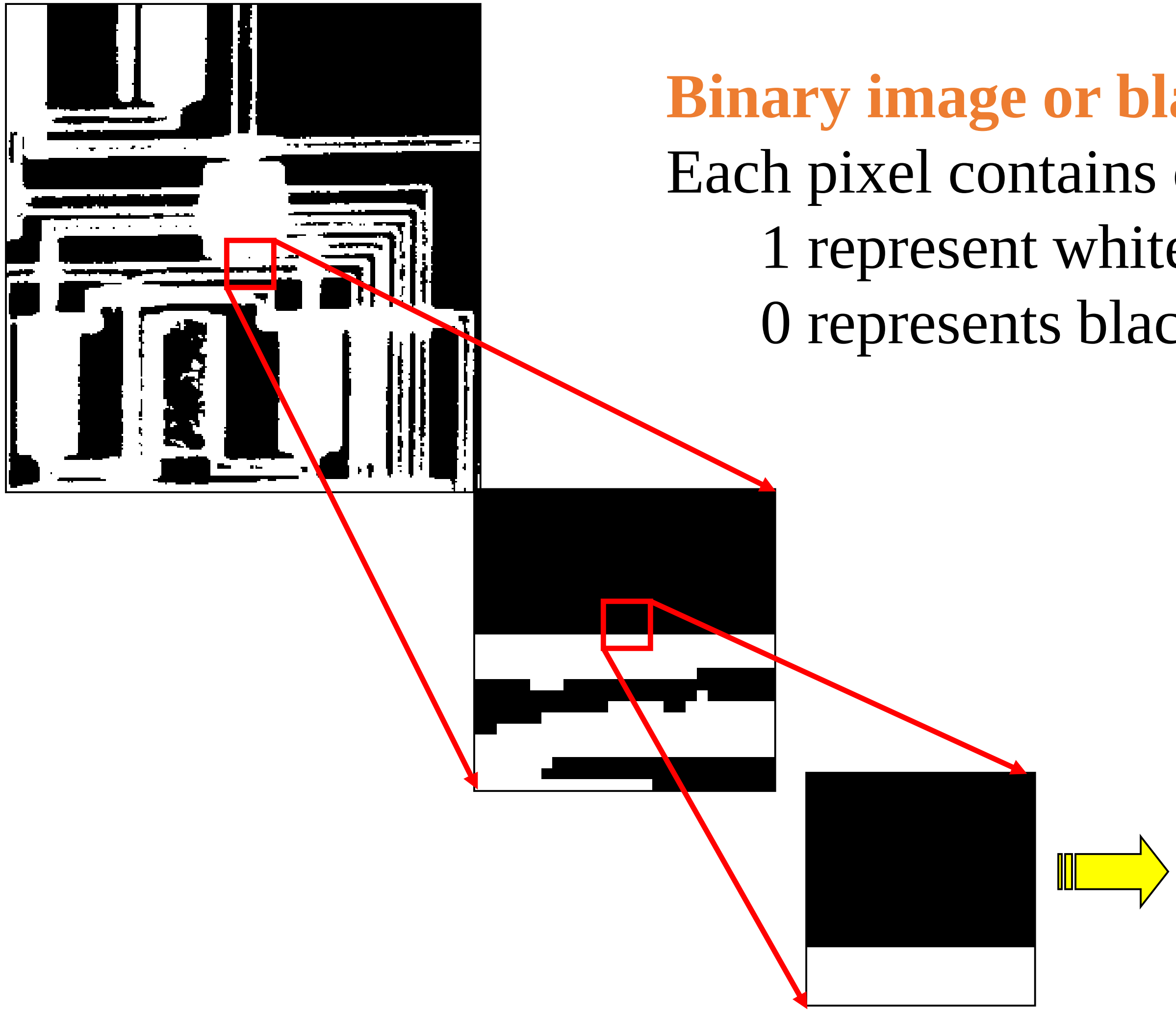
Image Types : Binary Im***age***

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



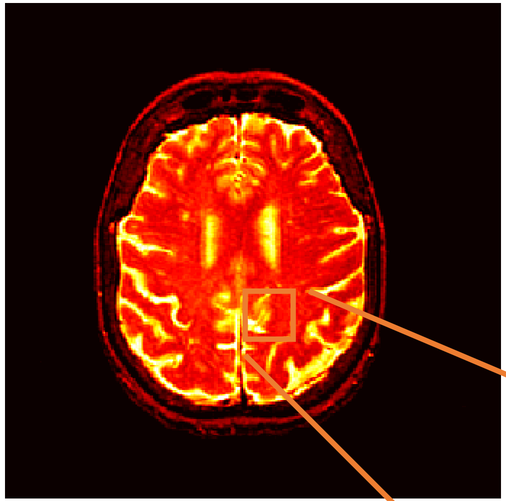
Binary data

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Image Types : Index *Image*

Index image

Each pixel contains index number pointing to a color in a color table



$$\begin{bmatrix} 1 & 4 & 9 \\ 6 & 4 & 7 \\ 6 & 5 & 2 \end{bmatrix}$$

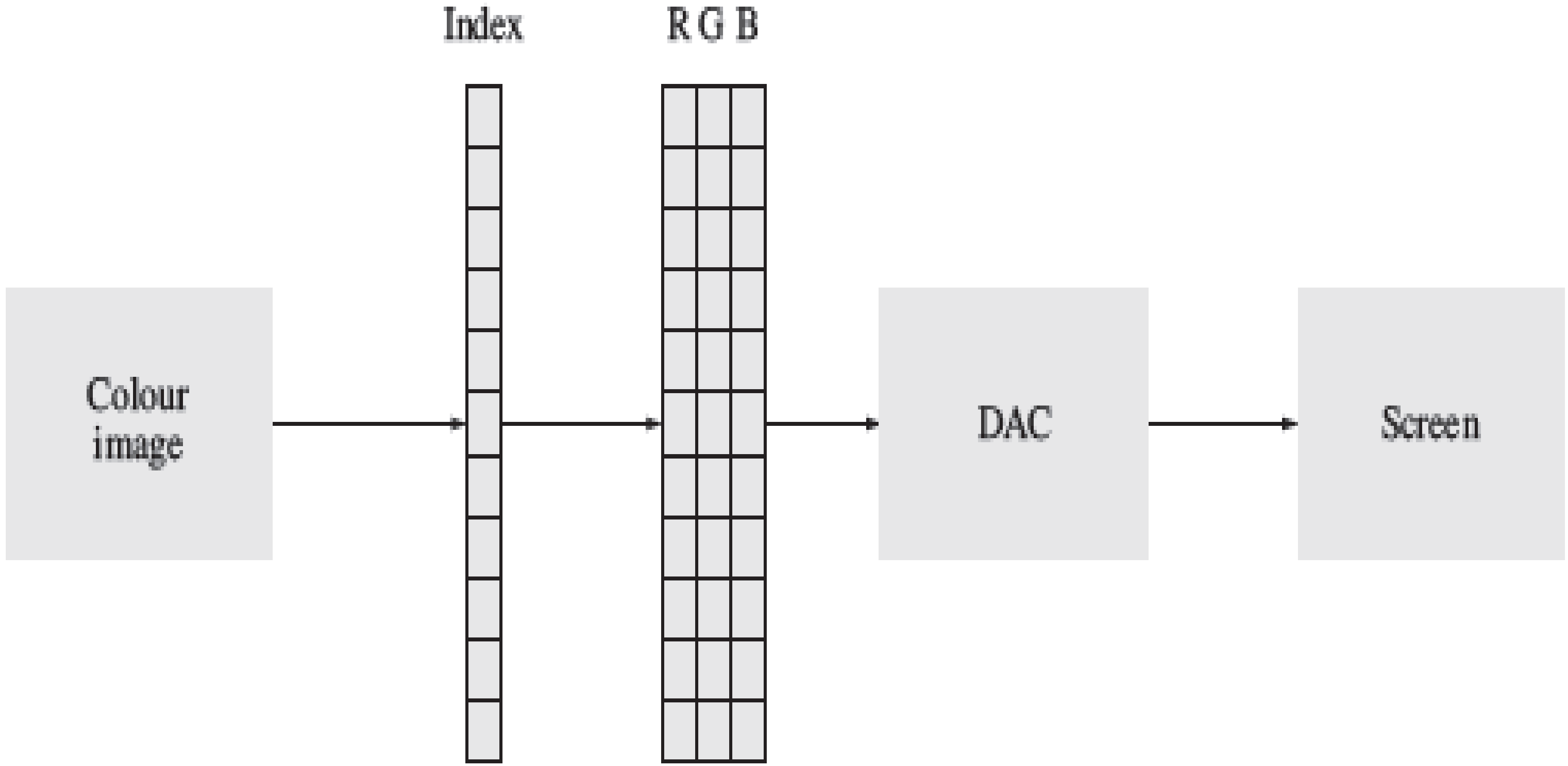
Index value

Color Table

Index No.	Red component	Green component	Blue component
1	0.1	0.5	0.3
2	1.0	0.0	0.0
3	0.0	1.0	0.0
4	0.5	0.5	0.5
5	0.2	0.8	0.9
…	…	…	…

Indexed Image

- A special category of colour images is the indexed image. In most images, the full range of colours is not used. So it is better to reduce the number of bits by maintaining a colour map, gamut, or palette with the image.



(c)

Fig. 1.6 True colour images (a) Original image and its colour components (b) Storage structure of colour images (c) Storage structure of an indexed image
(Refer to CD for colour images)

Pseudocolour Image

- Like true colour images, Pseudocolour images are also used widely in image processing. True colour images are called three-band images. However, in remote sensing applications, multi-band images or multi-spectral images are generally used. These images, which are captured by satellites, contain many bands.

Dimensions & Data Types

- **Types of Images Based on Dimensions**

  2D and 3D

- **Types of Images Based on Data Types**

  Single, double, Signed or unsigned.

DIGITAL IMAGE PROCESSING OPERATIONS

Fig. 1.7 Image processing operation

Image Analysis

Fig. 1.8 Image analysis operation

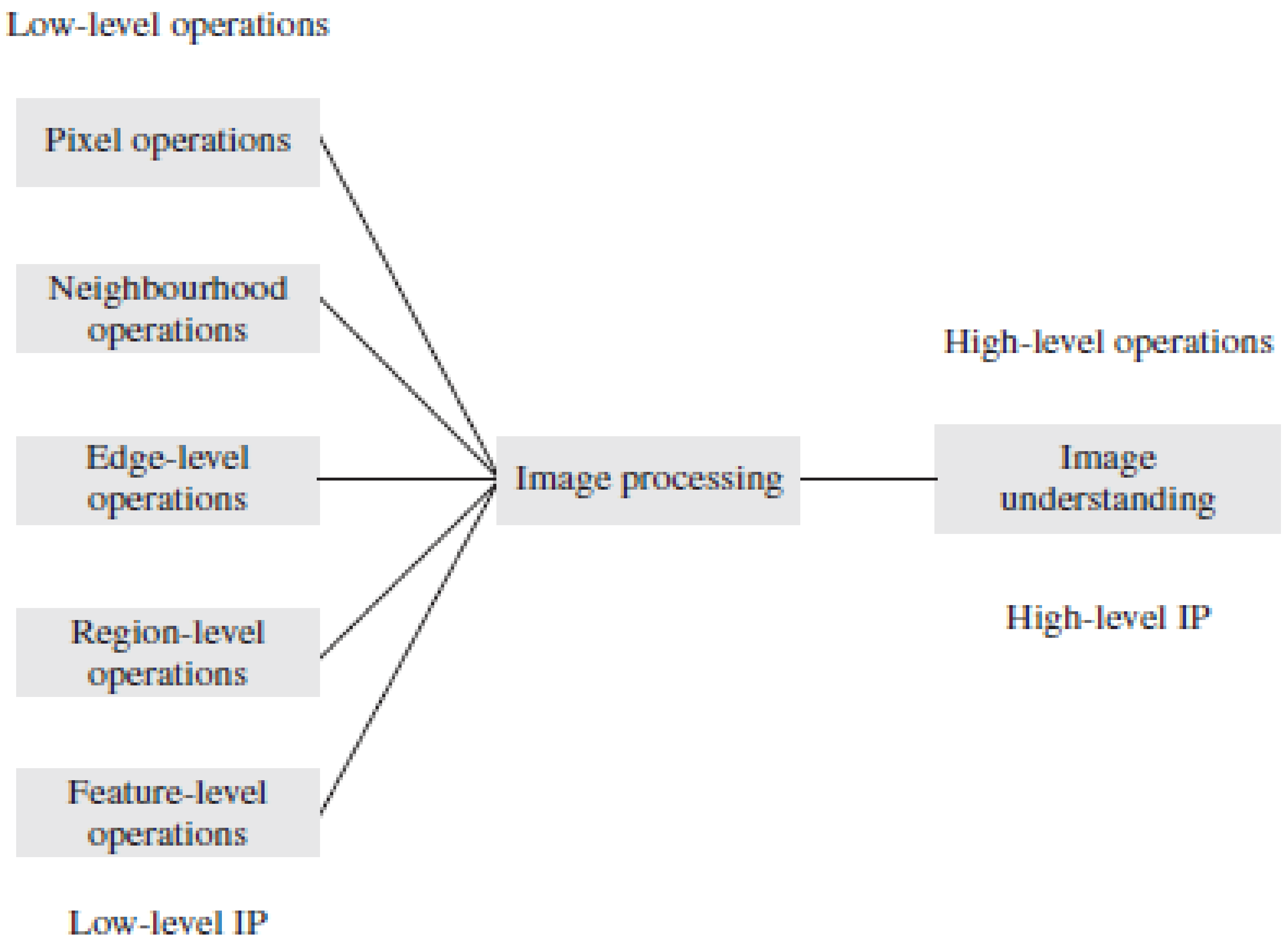


Fig. 1.9 Levels of image processing operations

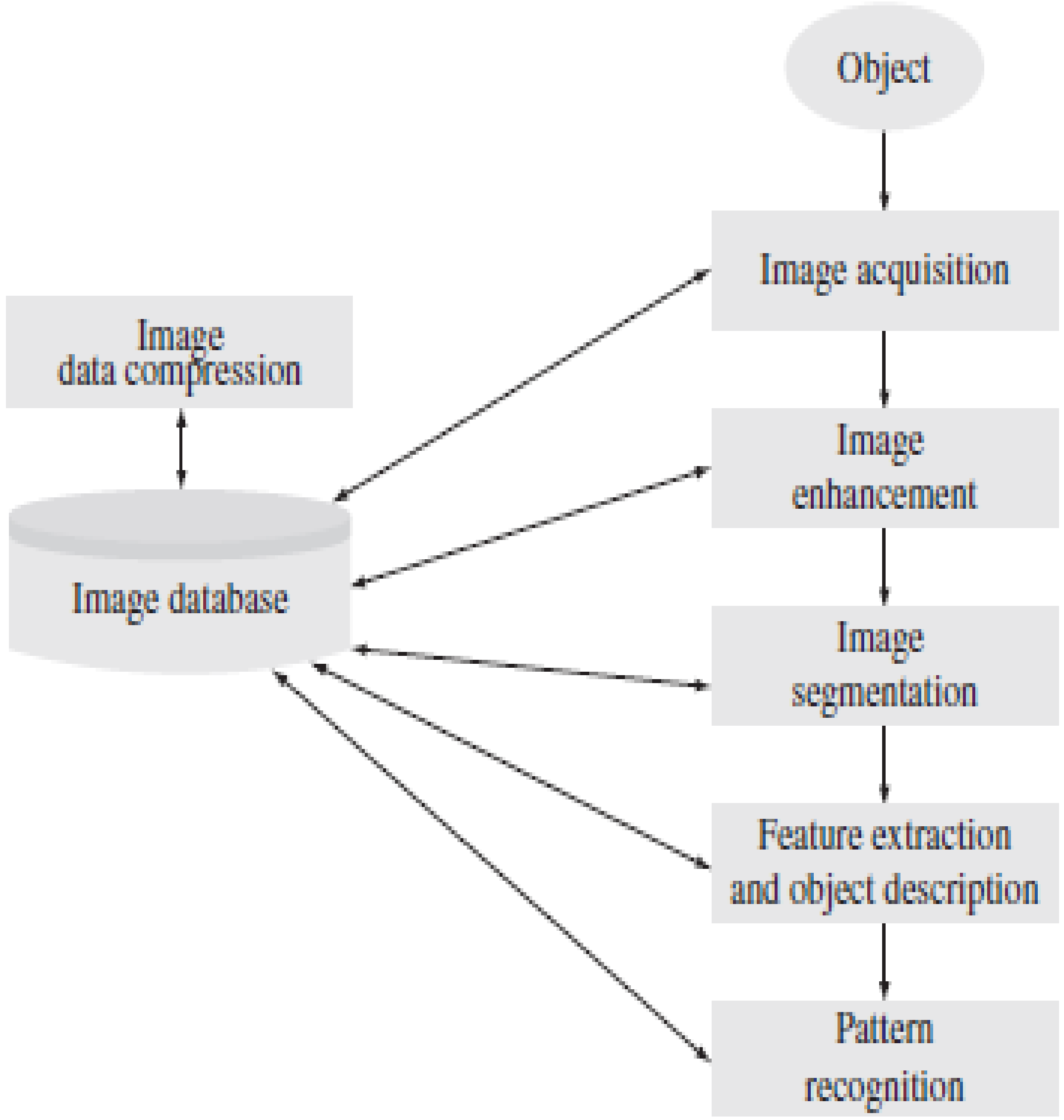
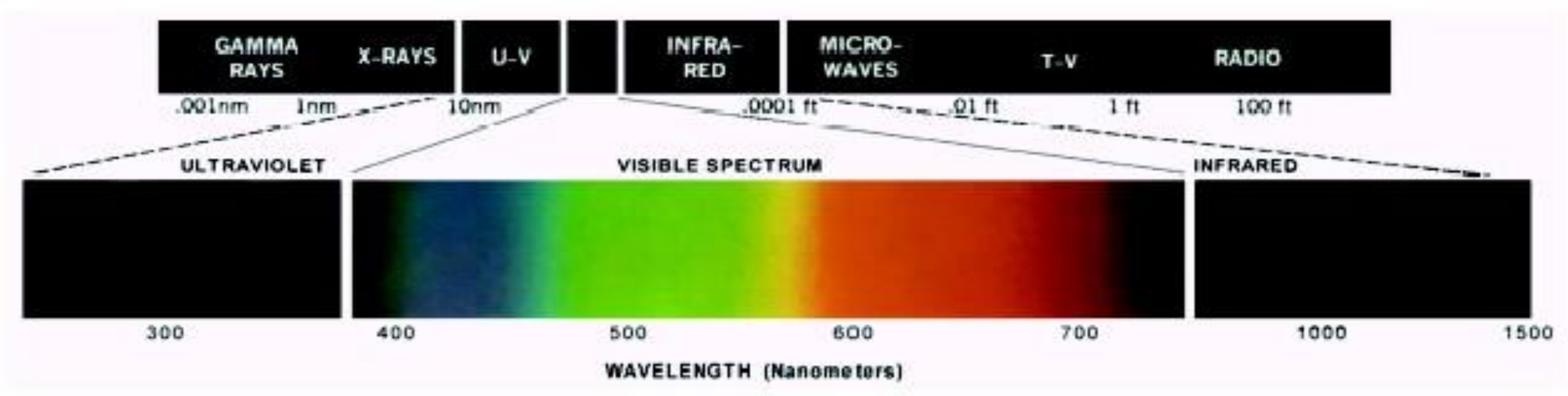


Fig. 1.10 Steps in image processing

Light And The Electromagnetic Spectrum

- Light: just a particular part of electromagnetic spectrum that can be sensed by the human eye
- The electromagnetic spectrum is split up according to the wavelengths of different forms of energy

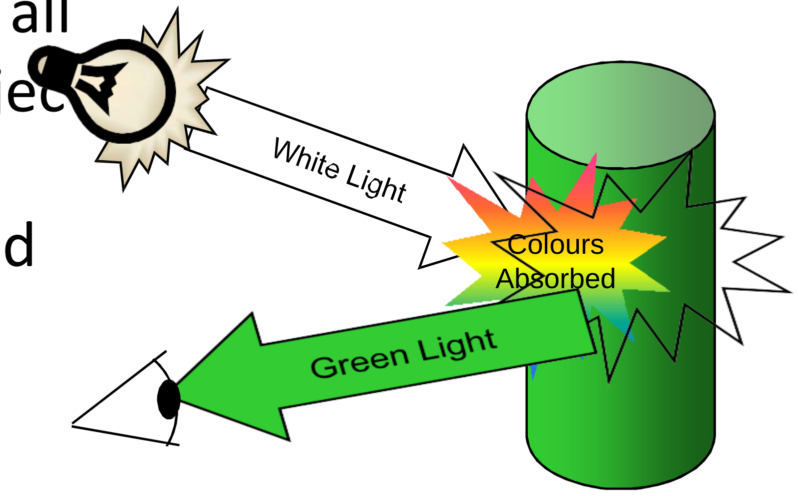


Reflected Light

- The colours humans perceive are determined by nature of light reflected from an object

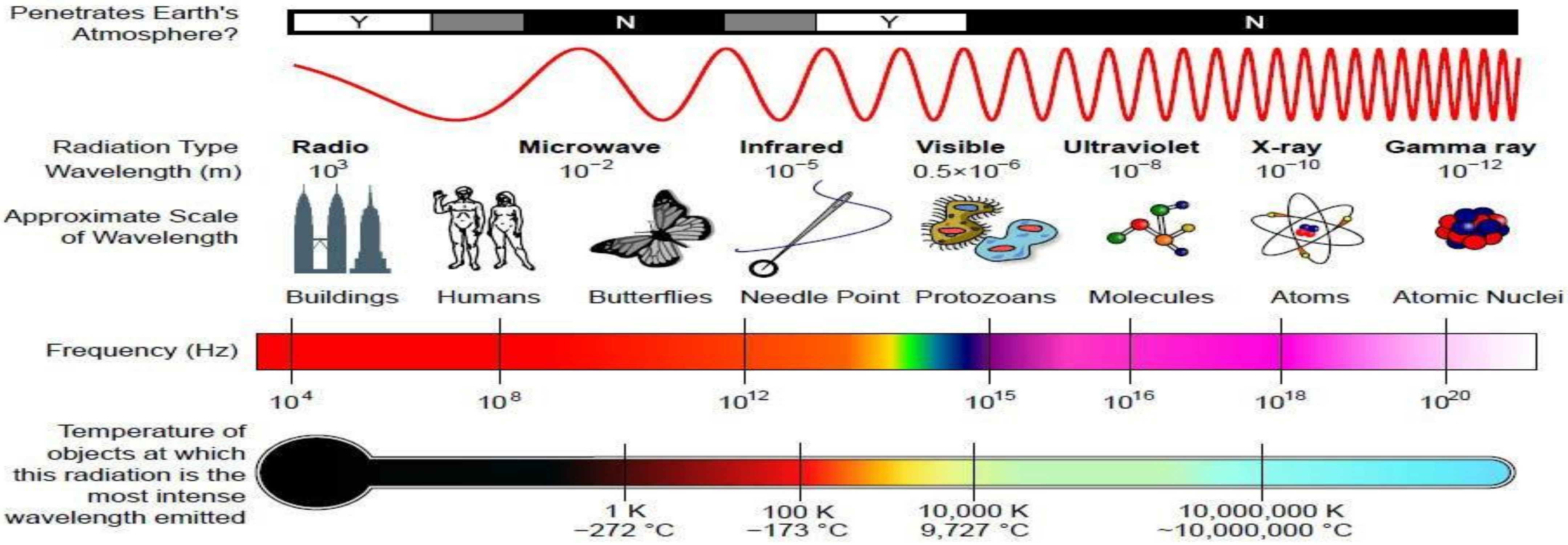
- For example, if white light (contains all wavelengths) is shone onto green objec

it absorbs most wavelengths absorbed except green wavelength (color)



Electromagnetic Spectrum and IP

- Images can be made from any form of EM radiation



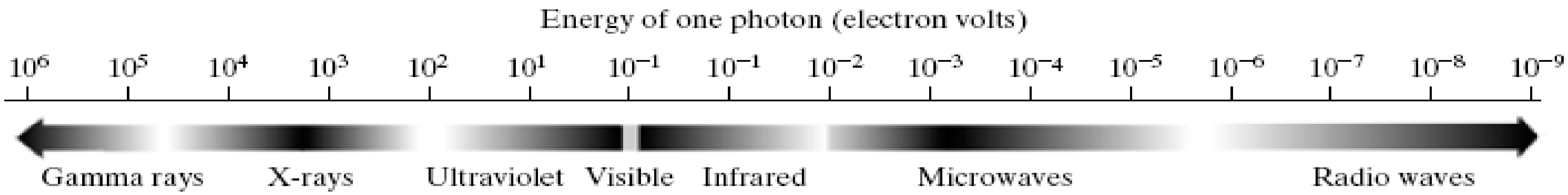
From Wikipedia

Images from Different EM Radiation

- Radar imaging (radio waves)
- Magnetic Resonance Imaging (MRI) (Radio waves)
- Microwave imaging
- Infrared imaging
- Photographs
- Ultraviolet imaging telescopes
- X-rays and Computed tomography
- Positron emission tomography (gamma rays)PET
- Ultrasound (not EM waves)

Categorizing Images

One can categorize images according to their source.
One of the main sources is due to electromagnetic spectrum.



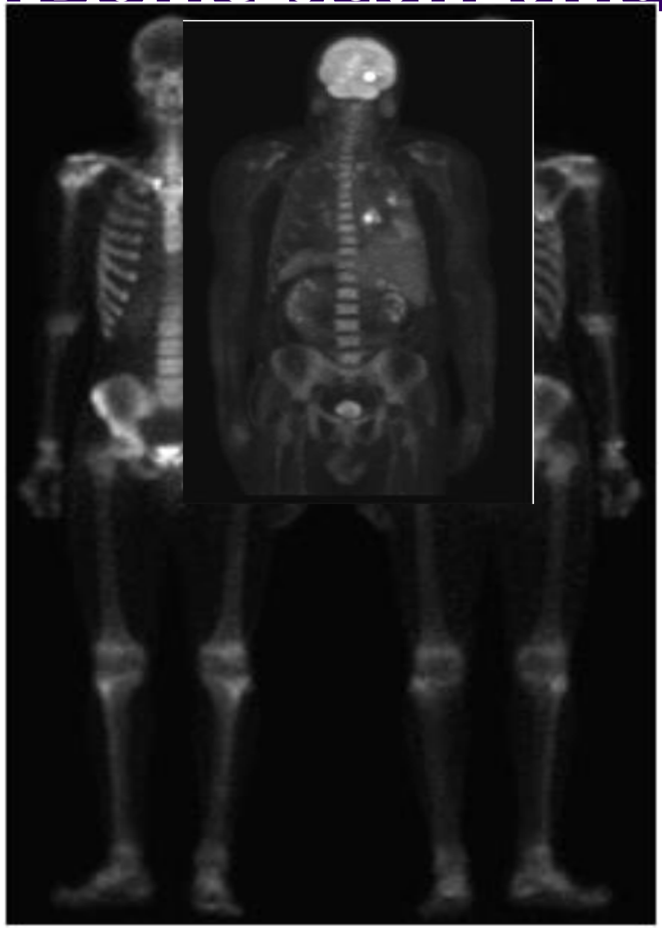
The electromagnetic spectrum arranged according to energy per photon

The spectra band ranges from gamma rays (**high energy**), X-rays, Ultraviolet, Visible, Infrared, Microwaves to radio waves (**low energy**).
Other sources are acoustic, ultrasonic and electronic (electron beams used in electron microscopy).

Gamma Ray Imaging

These are used in nuclear medicine and astronomical observations.
In medicine, it is used for complete bone scan.
The nuclear imaging is also used in positron emission tomography (PET).
It can render the 3-D image of patients.
It can detect tumors in the brain and lungs.
The images of stars which exploded about 15000 years ago, can be captured using gamma rays.

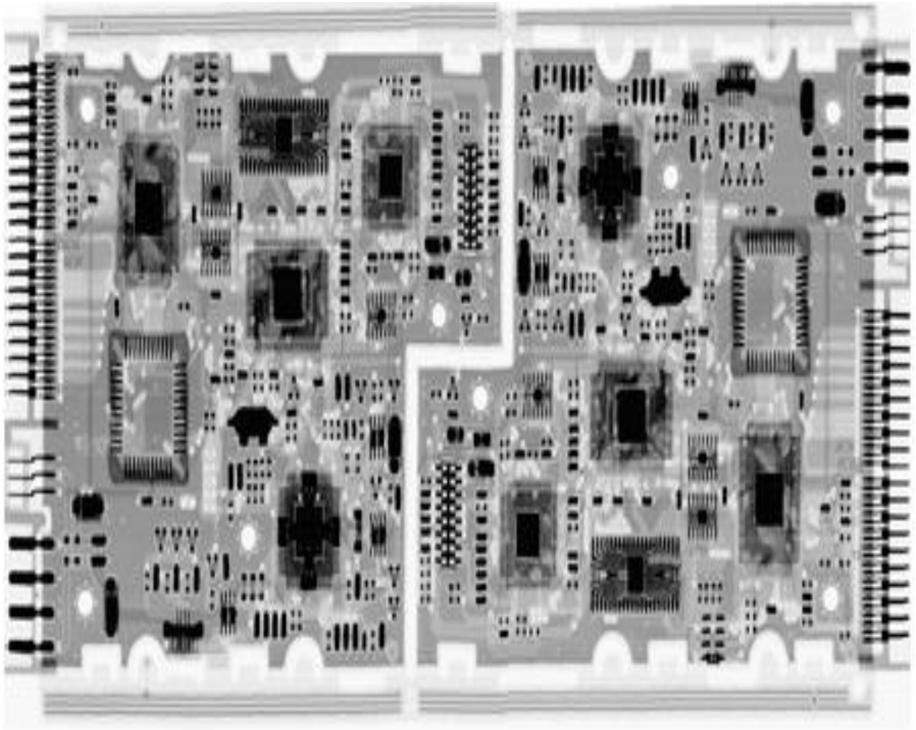
Examples of Gamma Ray Images (Bone scan and PET images)



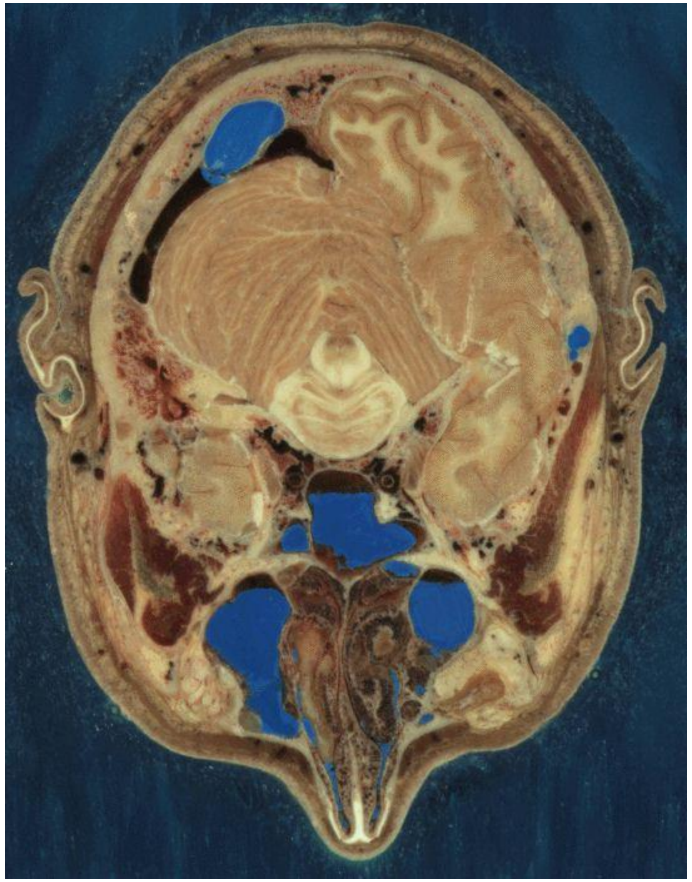
X-ray Imaging

It is also used in medicine and astronomy.
We can get images of blood vessels in angiography.
It is also used in Computerized Axial Tomography (CAT) to generate 3-D rendition of a patient.
High energy X-ray images are used in industrial processes (electronic circuit board).

Examples of X-ray Images
(Chest X-ray and Circuit boards)



Examples of DIP:
CT: Computer Tomography

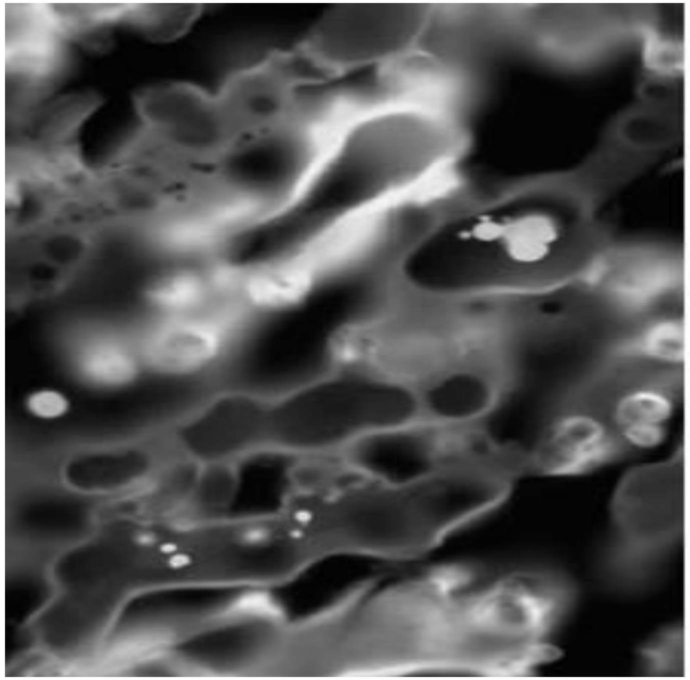


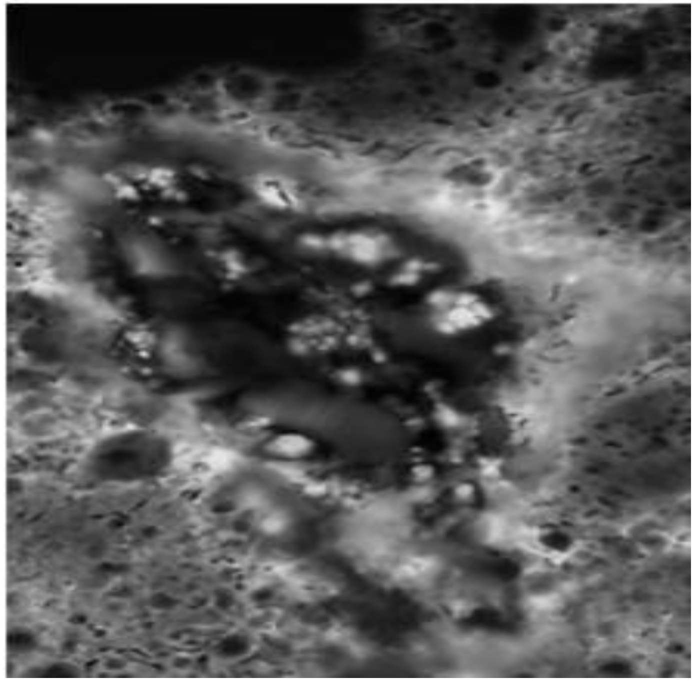
- http://www.nlm.nih.gov/research/visible/image/head.jpg
- Section through Visible Human Male - head, including cerebellum, cerebral cortex, brainstem, nasal passages (from Head subset)
- This is an example of the “visible human project” sponsored by NIH
- DIP techniques applicable:
  - Enhancement
  - Segmentation

Ultraviolet Imaging

It is used in lithography, industrial inspection, microscopy, lasers, biological imaging and astronomical observations.
Corn, cereals, onions caused by parasitic fungi can be identified using this imaging technique.

Examples of Ultraviolet Images (Normal corn vs Smut corn)



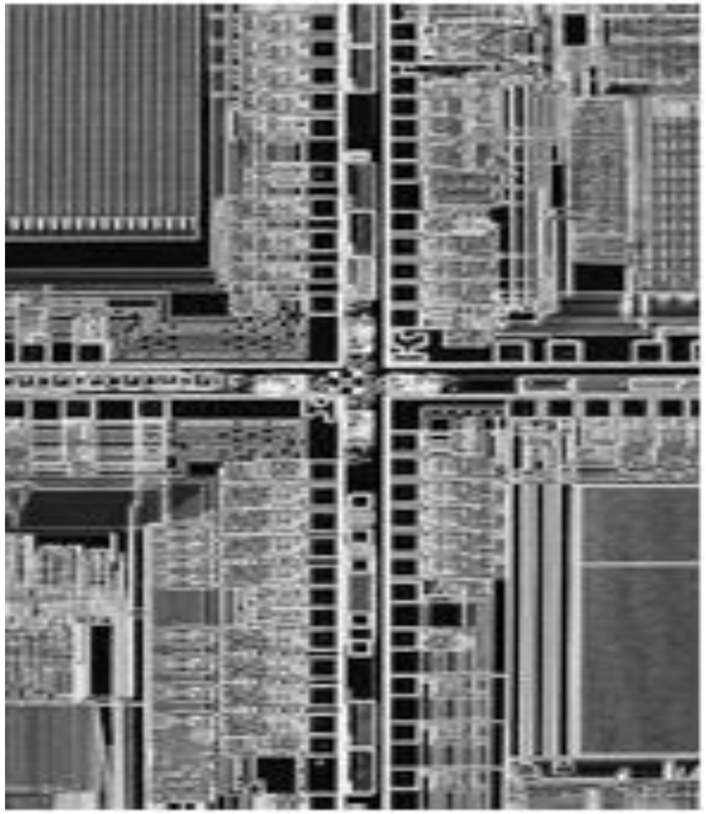


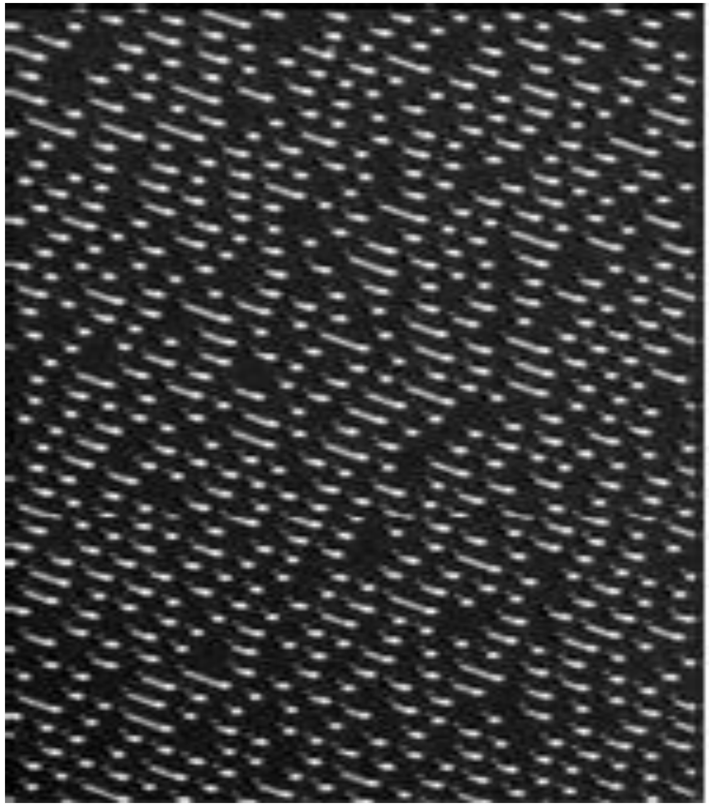
Visible and Infrared Images

It is used in light microscopy, astronomy, remote sensing, industry and law enforcement.
It is mainly used in weather observation and prediction.
Visual inspection of manufactured goods use visible spectrum.
Automated counting, license plate reading, tracking and identifying bills, etc belong to visible images.

Infrared images are used for night vision systems.

Examples of visible and infrared images (Microprocessor and surface of an audio CD)





Microwave Images
(Thumb print and paper currency)

Radar images belong to this category. It can penetrate the inaccessible regions of earth's surface.

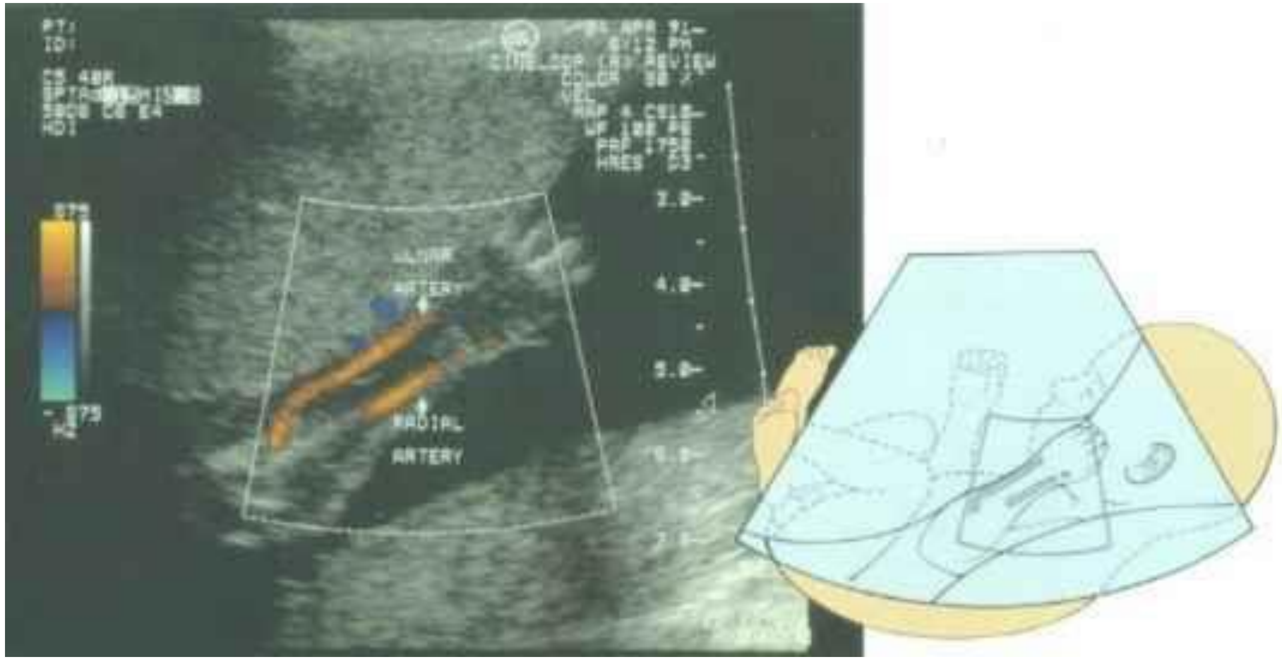
Radio Images
(MRI of human knee and spine)

It is used in Magnetic Resonance Imaging (MRI).

Acoustic imaging

The images use sound energy.
They are used in geological exploration, industry and medicine.
It is also used in mineral and oil exploration.
Ultrasonic images are used in obstetrics to determine the health of unborn babies and determining the sex of the baby.

Ultrasound Image



- Profiles of a fetus at 4 months, the face is about 4cm long
- Ultra sound image is another imaging modality
- The fetal arm with the major arteries (radial and ulnar) clearly delineated.

http://www.parenthood.com/us.html

Cross-sectional image of a seismic model

The arrow points to a hydrocarbon (oil and/or gas) trap.