DIGITAL IMAGE PROCESSING-1

Lecture 2-3

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DIGITAL IMAGE PROCESSING-1

Introduction to DIP

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Last Session

- Course Introduction and Overview

Today's Session

- Digital image fundamentals
- History of DIP
- Types of images
- Fields that use DIP in EM Spectrum
- Applications of DIP

Course Instructor

- Dr. Shikha Tripathi
  - 28 years of teaching and research experience (TCS, BITS Pilani, Amrita University, PESU)
  - Research Interests:
    - Image /video processing
    - Speech Processing
    - Signal processing and control for robotics
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  - Teaching Assistants: TBA

Image: A two-dimensional function f(x,y) where

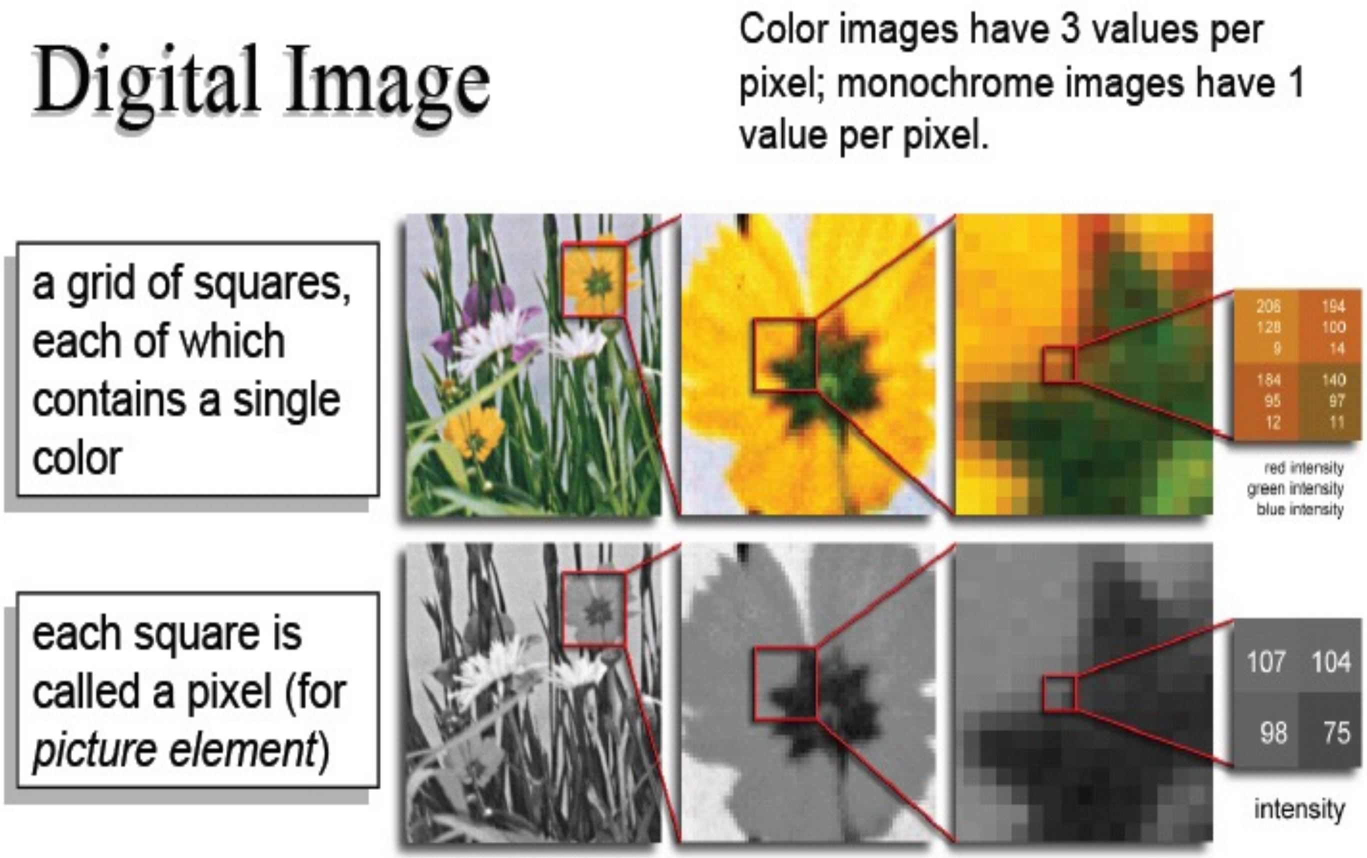
x and *y* are spatial coordinates.

The amplitude of *f* is called intensity or gray level at the point (x, y)

Digital Image: When x,y and amplitude values of ‘f’ are all finite, discrete quantities

Digital Image Processing: Processing of digital images by means of a digital computer

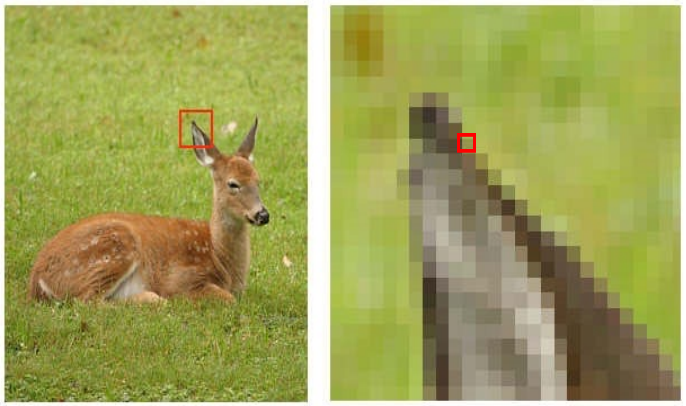
Digital image is composed of a finite number of elements, each of which has a particular location and value



Digital Image
Color images have 3 values per pixel; monochrome images have 1 value per pixel.
a grid of squares, each of which contains a single color
each square is called a pixel (for *picture element*)
208 128 9
194 100 14
184 95 12
140 97 11
red intensity
green intensity
blue intensity
107 104
98 75
intensity

Elements of an Image

- Picture Element
- Pixels
- pels



The smallest square element of a digital image, representing a single color or level of brightness

Digital Image representation in a computer

- 2D light intensity function: $f(x,y) = r(x,y) \times i(x,y)$

where r : reflectivity of the surface (0-1)

i : intensity of the light incident (0-infinity)

- **Information is present at all points/pixels in an image**

Digital Image representation in a computer

- Representation using a finite dimension matrix of n rows and m columns

- Standard sizes:

  256x256/ 512x512/ 1024x1024/ 640x480 etc

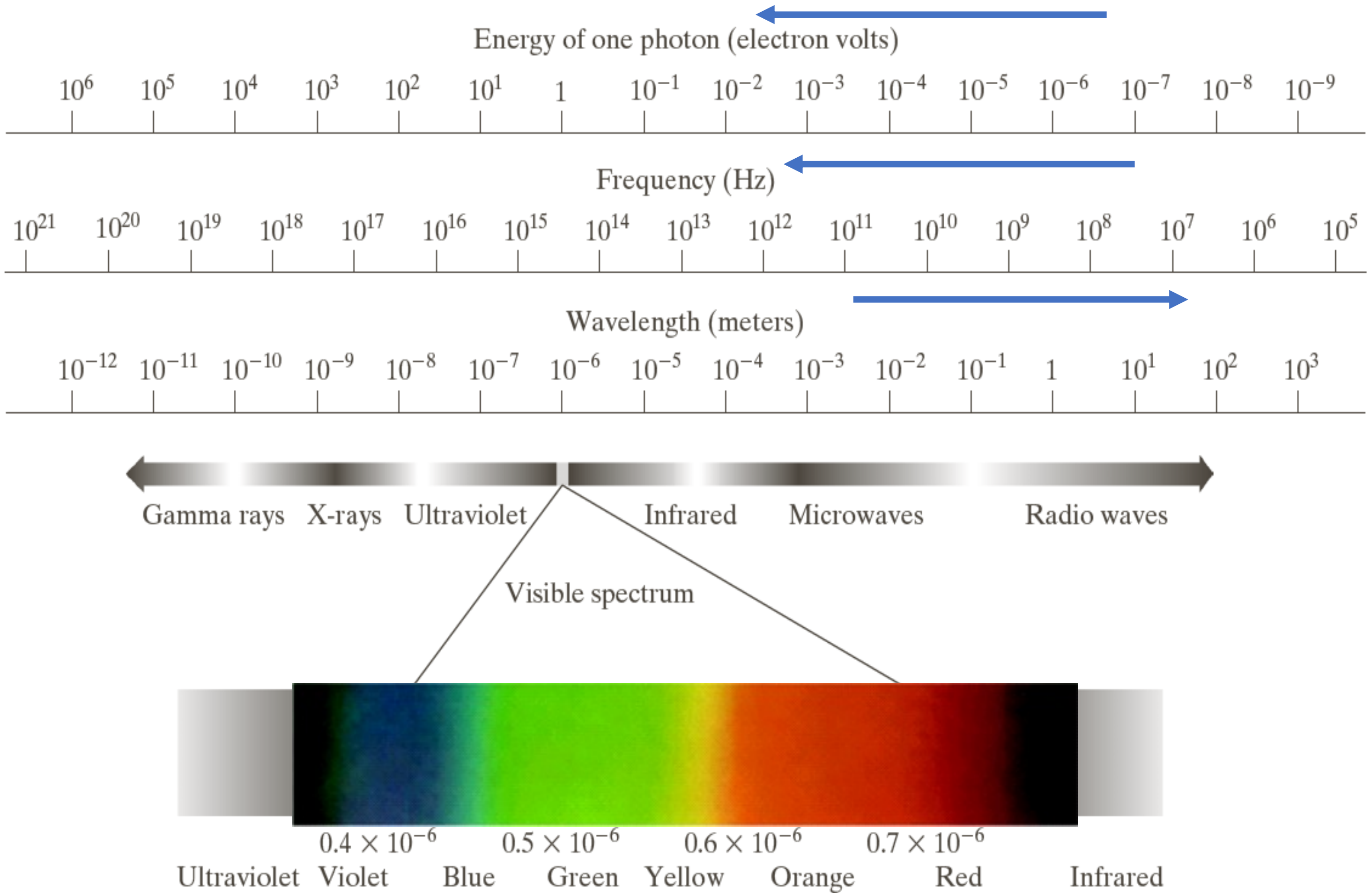
Image Processing

- Act of converting a captured image from one form to another

Image Processing / Digital Signal Processing (DSP)

- **DSP:** deals with processing of 1-D signals
- **Image Processing:** deals with visual information that is often in 2 or more dimensions
- **Image processing is logical extension of DSP**

Light and Electromagnetic spectrum



Computer Vision / Human Visual System (HVS)

- Computer Vision: Machine covers the entire electromagnetic spectrum (gamma to radio waves)
- Human Visual System: Limited to visual band of EM spectrum [(0.4-0.6)*10^{-6} m]
- **Imaging machines can operate on images generated by sources that humans are not accustomed to associating with images: ultrasound, electron microscopy and computer generated images**

Computer Vision / Human Visual System (HVS) Cont..

“Unlike humans, who are limited to the visual band of the electromagnetic spectrum, imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves”

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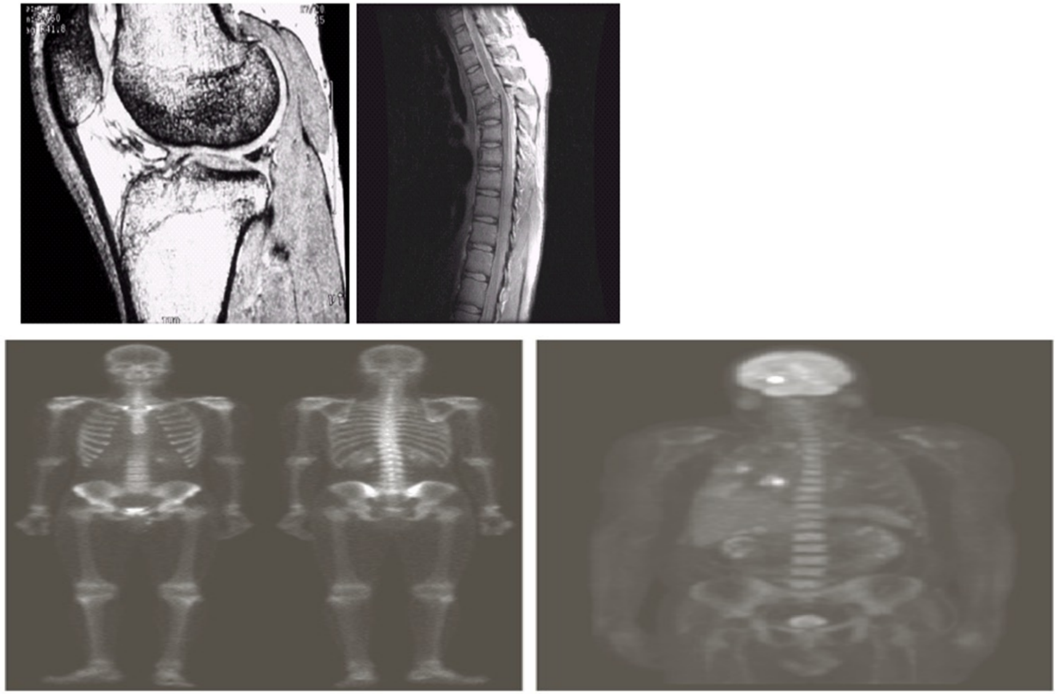
Computer Vision / Human Visual System (HVS) Cont..

Chest X-Ray

Head CT



MRI-Human, Knee and spine, Gamma Ray - Bone Scan, PET image

Courtesy: Gonzalez, Digital Image Processing

Image Processing / Image Analysis / Computer Vision

- **Computer Vision:** Goal is to emulate human vision, including learning and being able to make inferences and take actions based on visual inputs
  - **It is a branch of Artificial Intelligence (AI) whose objective is to emulate human intelligence**
- **Image Analysis(image understanding)** is in between **image processing and computer vision**

Image Processing to Computer Vision

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

Low Level Process	Mid Level Process	High Level Process
Image Processing: **Input:** Image **Output:** Image **Examples:** Noise removal, image sharpening	**Image Analysis:** **Input:** Image **Output:** Attributes **Examples:** Object recognition, segmentation(partitioning image into regions or objects)	**Computer Vision:** **Input:** Attributes **Output:** Understanding **Examples:** Scene understanding, autonomous navigation
Input and output are images	Input is image & outputs are attributes extracted form image(edge,contour etc..)	Involves "making sense " Like cognitive functions associated with human vision

History of Digital Image Processing

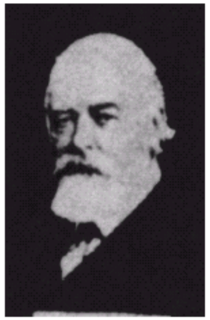
Early 1920s: One of the first applications of digital imaging was in the news-paper industry

- The Bartlane cable picture transmission service (3 hr transmission)
  - 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

History of Digital Image Processing

Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

- New reproduction processes based on photographic techniques (made from tapes)
- Increased number of tones in reproduced images



Improved digital image

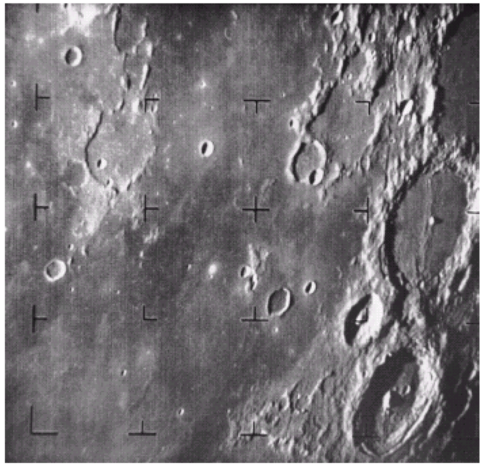
Early 15 tone digital image

History of Digital Image Processing

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

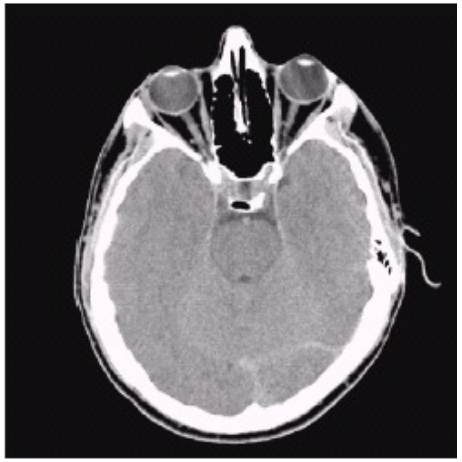
- Such techniques were used in other space missions including the Apollo landings



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

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



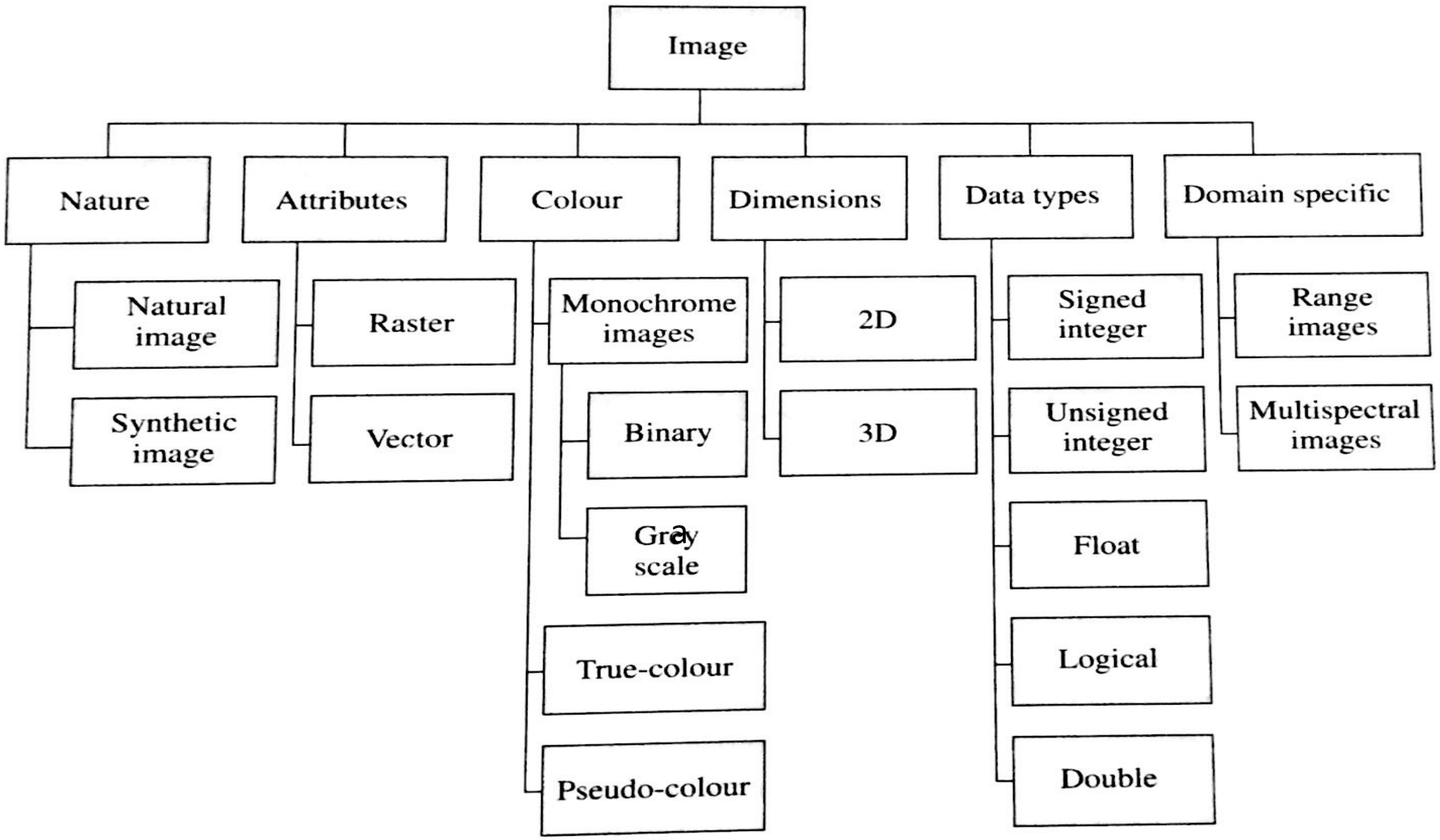
Typical head slice CAT image

History of Digital Image Processing

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
- Robotics
- ………..

Types of Images



Types of Images: Based on Attributes

- Raster Images:
  - Pixel based (quality dependent on number of pixels. So enlarging or blowing-up results in quality reduction)
- Vector images
  - Use basic geometric attributes such as lines and circles to describe an image (notion of resolution is not present)

Types of Images: Based on Color

- Monochrome images
  - Binary/Bi-level
    - Pixels assume values 0(black) or 1(white)
    - Used in representing basic shapes and line drawings
    - Used as masks and IP operations producing binary images at intermediate stages
  - Gray scale
    - Have many shades of gray between black and white.
    - 8 bits (256 levels) are enough to represent as HVS can distinguish only 32 different gray levels.(0:black ; 255:white)
    - Additional bits are necessary to cover noise margins
    - Most medical images like X-rays, CT images, MRIs and ultrasound images are gray scale images (May require more than 8 bits)

Types of Images: Based on Color Cont..

- True colour (full colour)
  - Almost similar to actual objects
  - Represent full range of available colours
  - Do not use any lookup table but store pixel information with full precision
  - Pixel colour obtained by mixing Red, Green and Blue using 8 bits for each colour. Hence use 24 bits for all colours. They are 3-band images
- Pseudo colour
  - False colour images where colours are added artificially based on interpretation of data
  - They are Multi-band / Multi-spectral images
    - Remote sensing applications: images captured by satellites contain many bands(information beyond human perceptual range)

Types of Images: Based on Dimension

- 2D: Rectangular array of pixels
- 3D: If depth or any other characteristic is considered
  - Volume image,scene or object,
  - Medical imaging: CT image, MRIs and microscopy images
  - Range images in remote sensing

Types of Images: Based on Data Types

- Singed integer (-2^{n-1} to $2^{n-1}-1$: -128 to +127 for 8 bits)
- Unsigned integer (0 to $2^{n}-1$: 0 to 255 for 8 bits)
- Float
- Double

Types of Images: Based on Domain

- Based on domains and applications where such images are encountered
  - **Range Images**
    - Pixel values denote distance between object and camera (depth images)
    - Encountered in computer vision
  - **Multispectral/Multiband Images**
    - Taken at different bands of visible or infrared or ultraviolet regions of EM wave
    - Just as colour images have 3 bands, multispectral images have many bands that may include infrared and ultraviolet regions of EM spectrum
    - Encountered in remote sensing applications

Fields That use DIP in EM Spectrum

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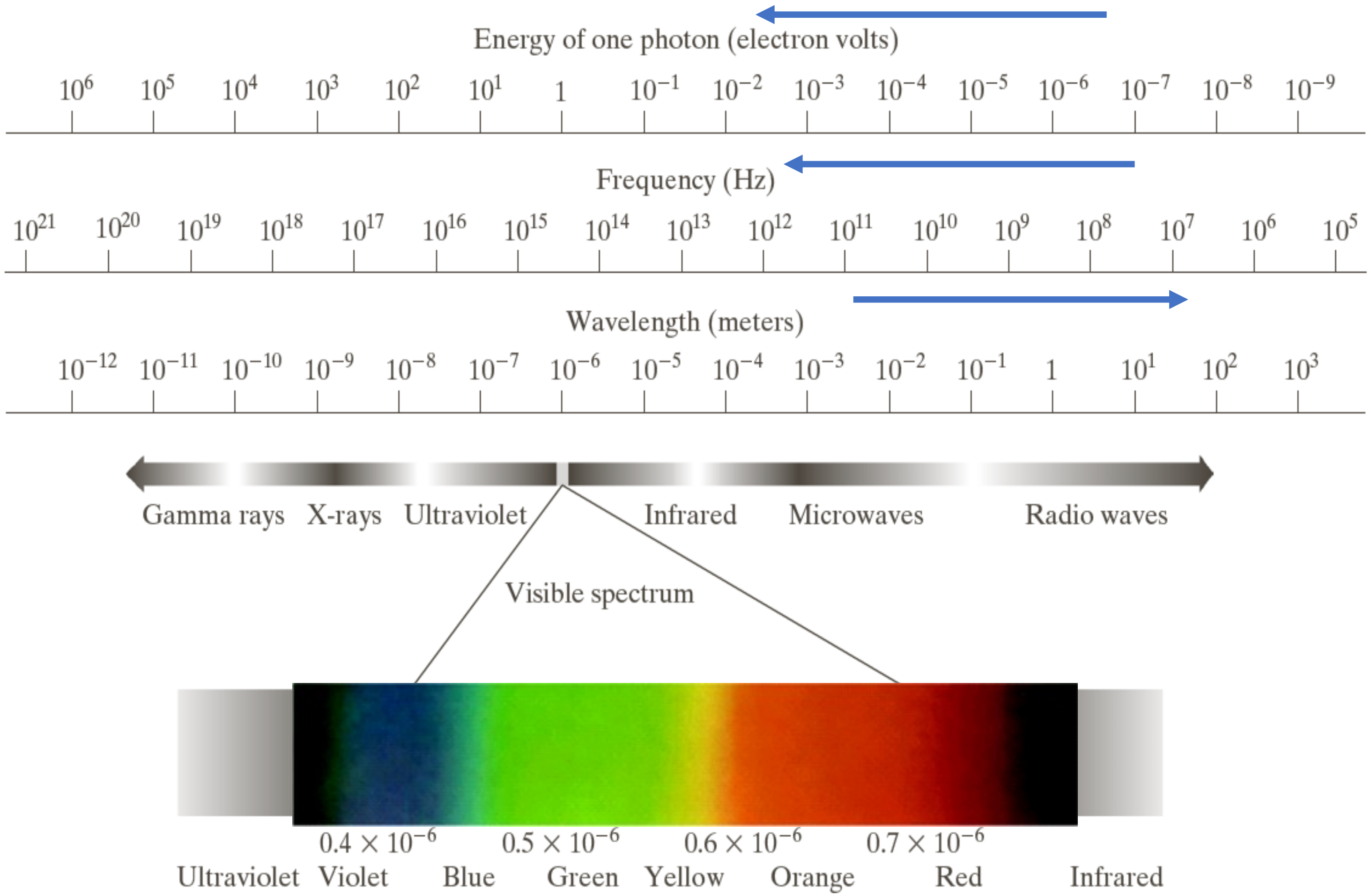
Light and Electromagnetic spectrum

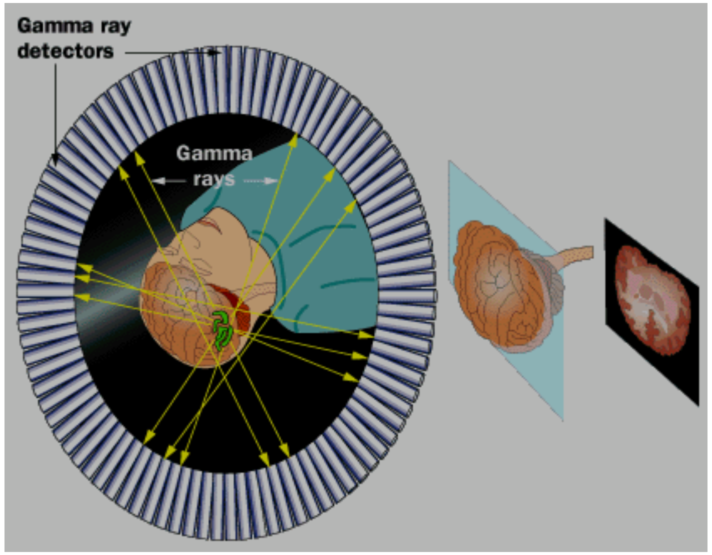


Segments of EM Spectrum

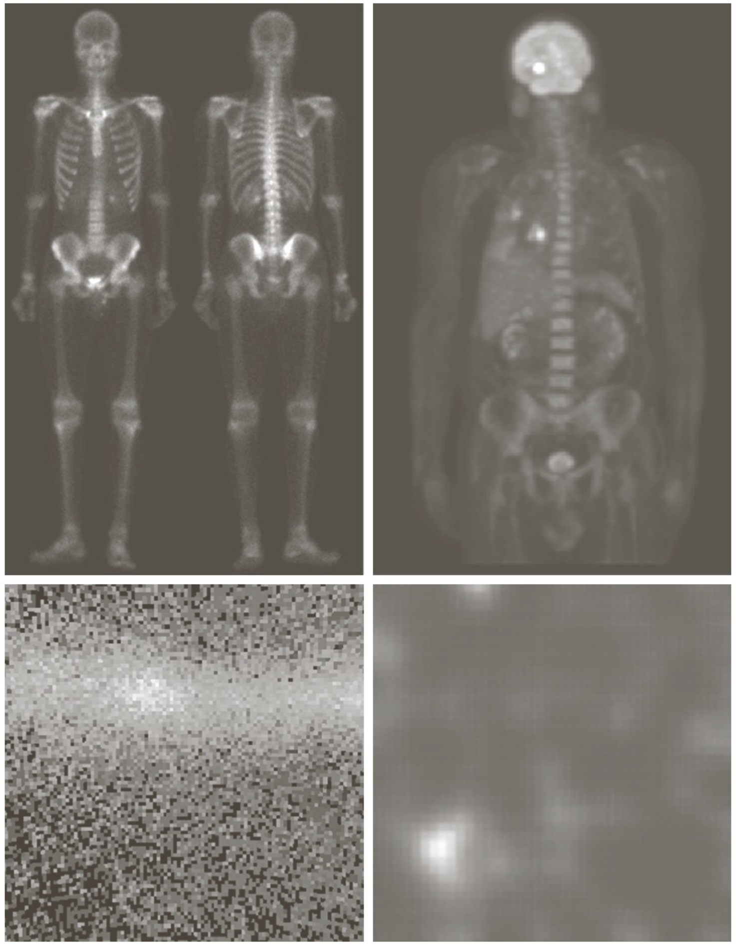
Types of radiation	Frequency range (in Hertz)	Wave length (in cm)	Nature of imaging and its relevance for image processing
Radio waves	10^5–10^{10}	$> 10^9$	AM/FM radio
Microwave	10^{10}–10^{12}	10^9–10^6	Radar imaging
Infrared	10^{12}–10^{14}	10^9–7000	Thermal imaging
Visible light	4–7.5×10^{14}	7000–4000	Optical
Ultraviolet	10^{15}–10^{17}	4000–10	Optical
X-rays	10^{17}–10^{20}	10–0.1	Medical and industrial
Gamma rays	10^{20}–10^{24}	< 0.1	Medical

Gamma-Ray Imaging (10^{20} – 10^{24}) Hz

- Inject a patient with a radio active isotope that emits Gamma rays as it decays.
- Images are produced from the emissions collected by gamma ray detectors.



Gamma-Ray Imaging (10^{20} – 10^{24}) Hz



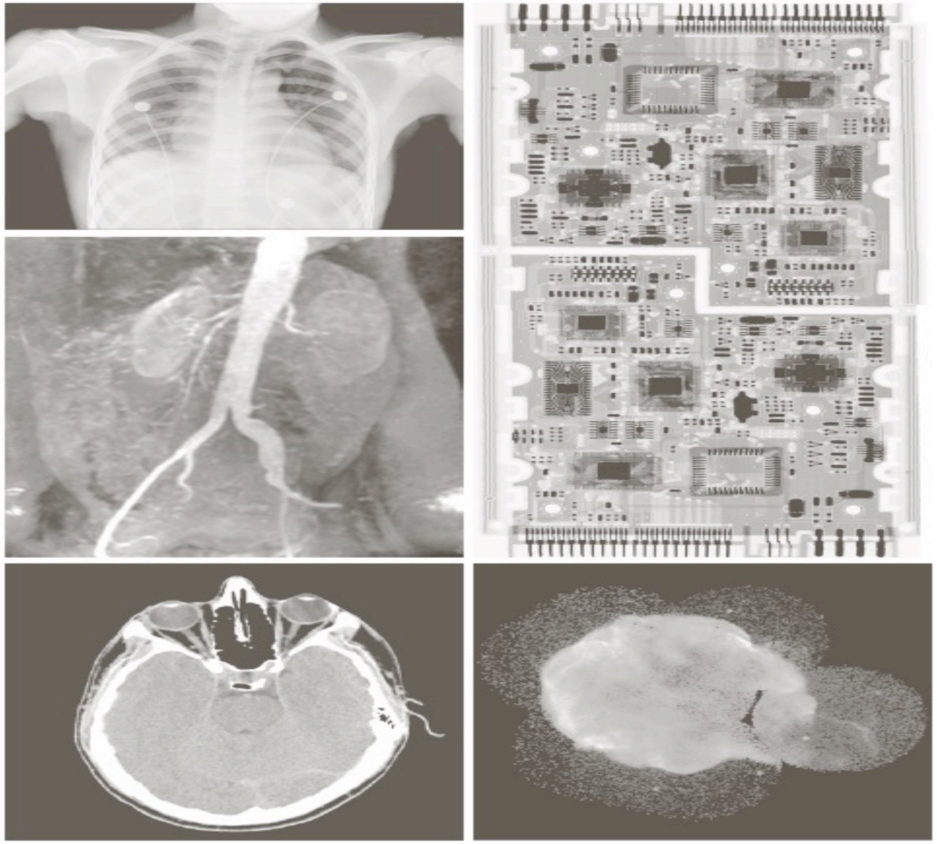
a	b
c	d

FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

X-Ray Imaging (10^{17} – 10^{20}) Hz

- An x-ray source is turned on and x-rays are radiated through the body part of interest and onto a film cassette positioned under or behind the body part.
- As the x-rays pass through, the Bone which is very dense absorbs or attenuates a great deal of the x-rays.
- The soft tissue around the bones is much less dense attenuates or absorbs far less x-ray energy.
- It is these differences in absorption and the corresponding varying exposure level of the film that creates the images which can clearly show broken bones, clogged blood vessels, cancerous tissues and other abnormalities.

X-Ray Imaging (10^{17} – 10^{20}) Hz



a d
b
c e

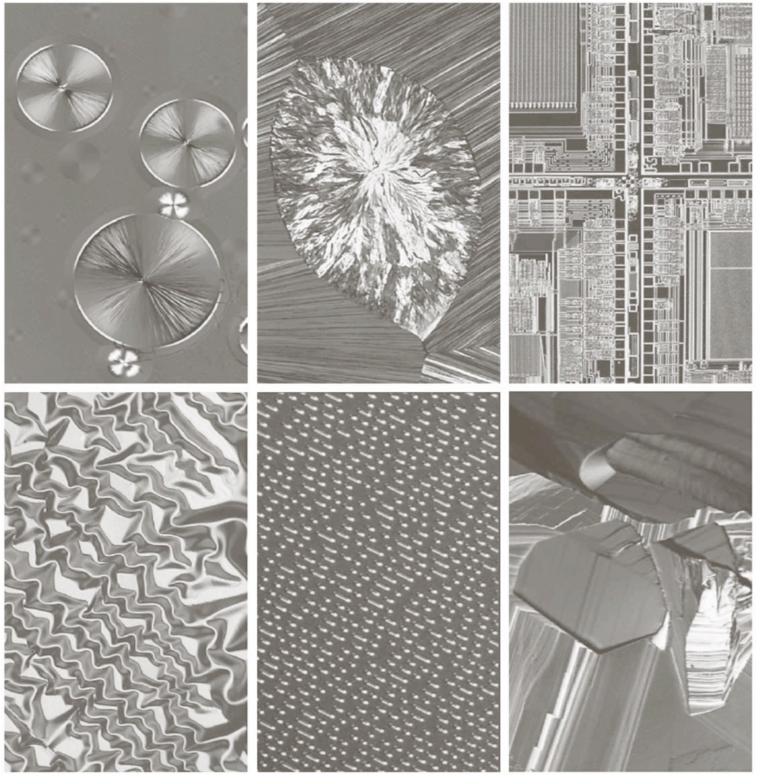
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical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

Imaging in Ultra Violet Band (10^{15} – 10^{17}) Hz

- Ultraviolet light is used in fluorescence microscopy (viewing objects and areas of objects that cannot be seen with the naked eye)

- Ultraviolet light itself is not visible, but when a photon of ultraviolet radiation collides with an electron in an atom of a fluorescence material, it elevates electron to higher energy level, and when the electron relaxes to a lower level it emits light (visible red).

Imaging in Ultra Violet Band (10^{15} – 10^{17}) Hz



a	b	c
d	e	f

FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Visual and Infrared Imaging (10^{12} – 10^{14}) Hz

- Sensors are used in Visible and Infrared Bands

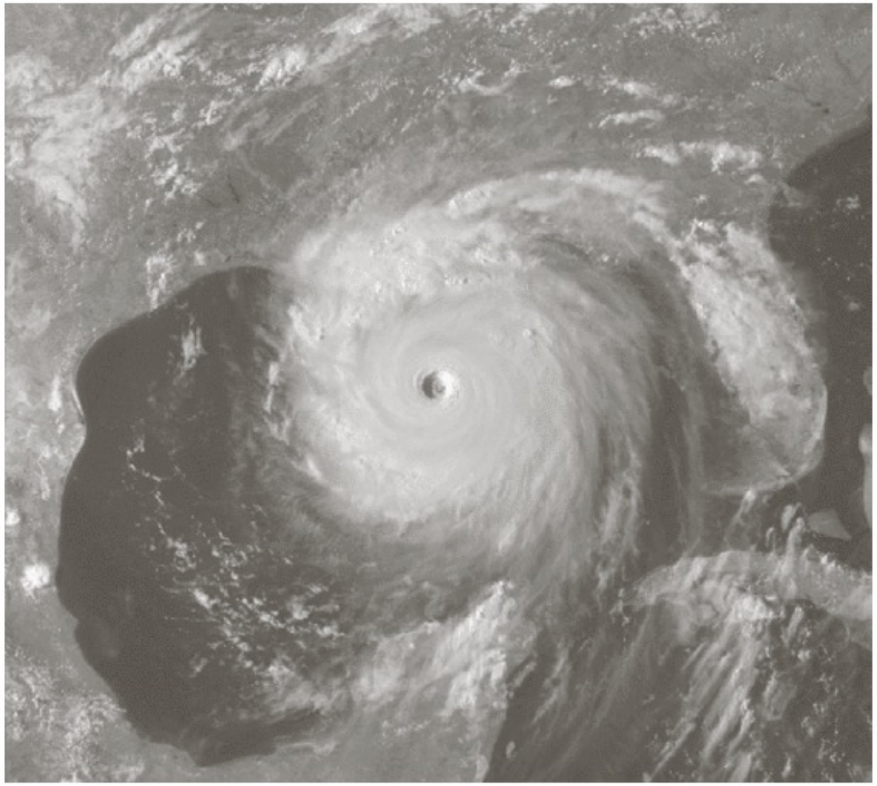


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

Visual and Infrared Imaging (10^{12} – 10^{14}) Hz

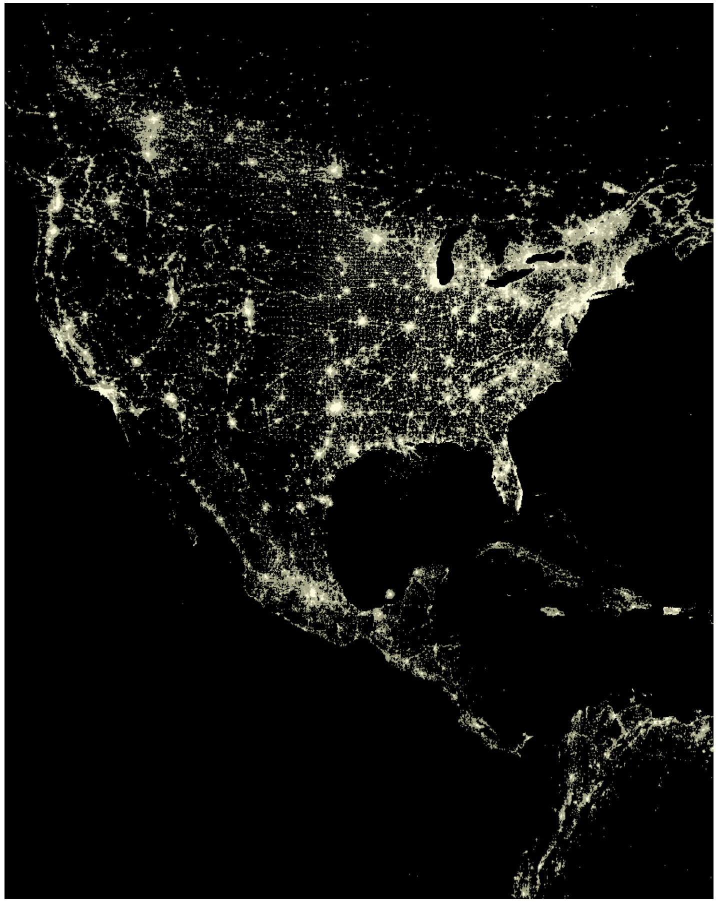


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

These images are Part of the night time Lights of world data set, Which provides a global Inventory of human Settlements.

Imaging in Microwave Band ($10^{10} – 10^{12}$) Hz

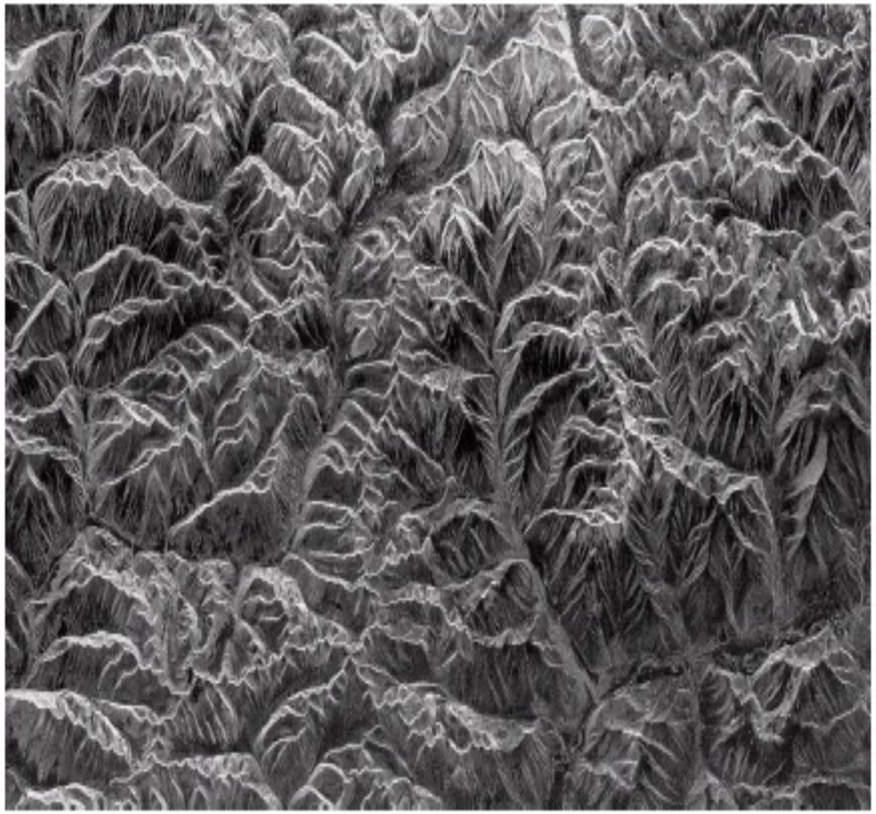
- Application: Radar imaging

- An imaging radar works like a flash camera.
    - It provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot image.
- Instead of a camera lens, a radar uses an antenna and digital computer processing to record its images.
- In a radar image one can see only the microwave energy that was reflected back towards the radar antenna.

- Unique feature of radar imaging is its ability to collect data over any region, at any time, regardless of weather (radar can penetrate clouds) or ambient lighting conditions.

Imaging in Microwave Band (10^{10} – 10^{12}) Hz

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

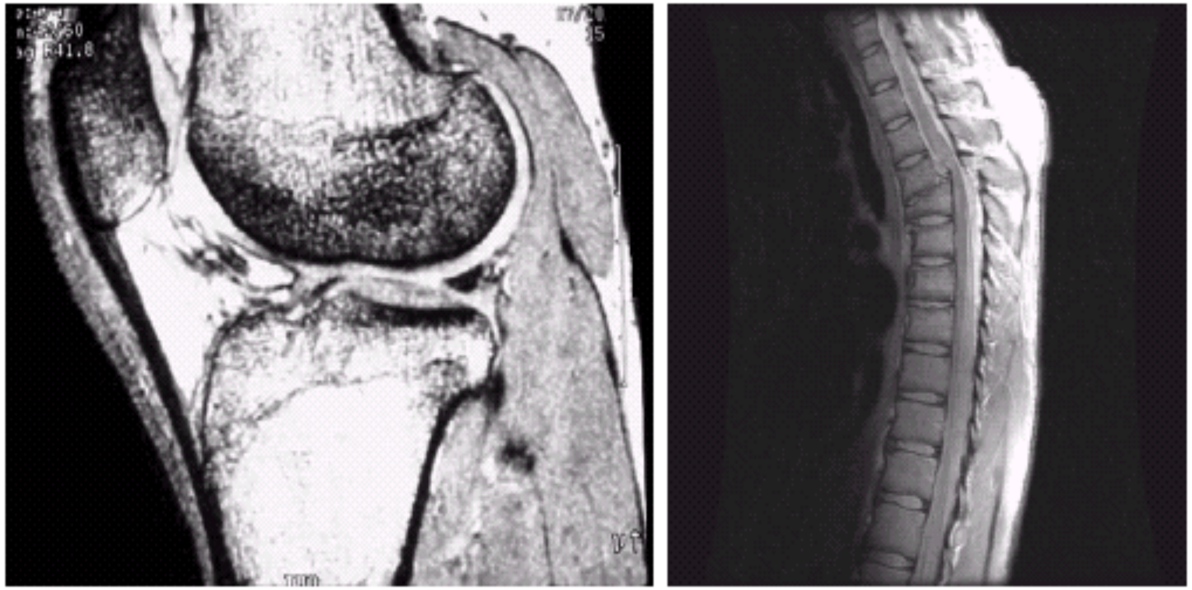


Imaging in Radio Band (10^5 – 10^{10}) Hz

- Application: In medicine (Magnetic Resonance Imaging (MRI)) and astronomy
- MRI technique places a patient in a powerful magnet and passes radio waves through his or her body in short pulses.
- These pulses cause a pulse of radio waves to be emitted by the patient's tissues.
- The location from which these signals originate and their strength are determined by a computer, which produces 2D picture of a section of the patient.

Imaging in Radio Band (10^5 – 10^{10}) Hz

Imaging in Radio Band ($10^5 - 10^{10}$) Hz



a b

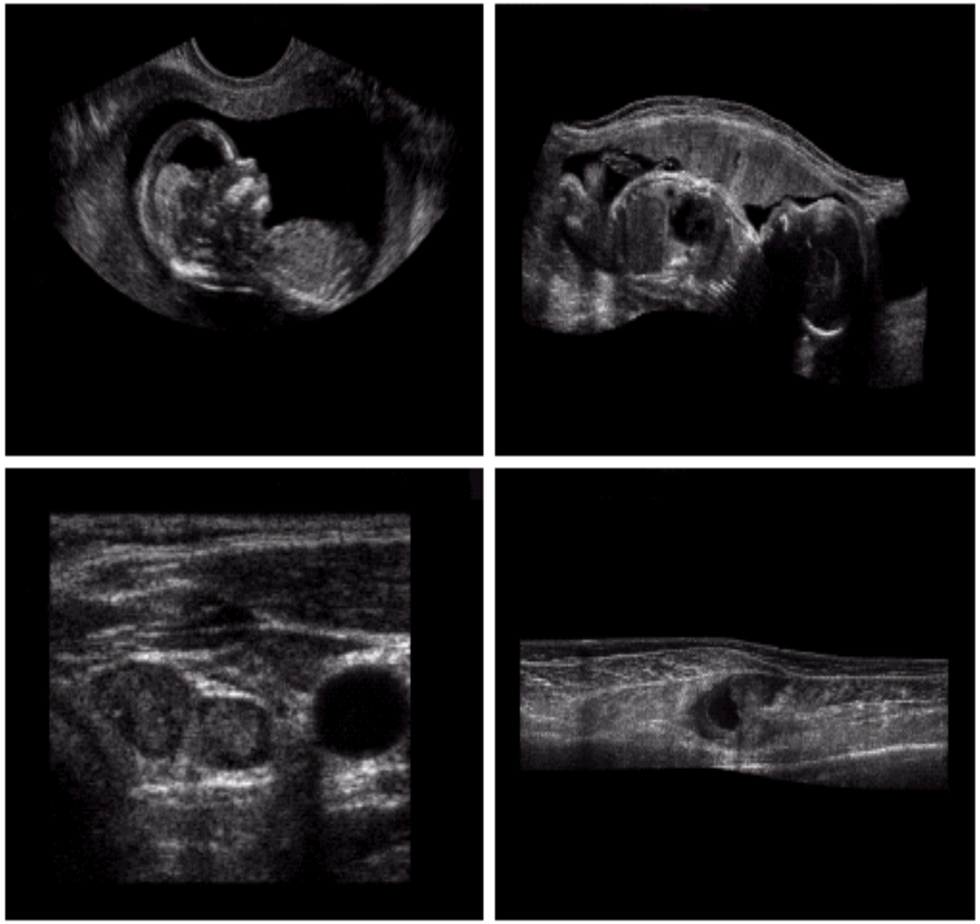
FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Ultrasound Imaging (1 – 5) MHz

Application: in medicine

- The ultrasound system transmits high frequency (1 to 5 MHz) sound pulses into body
- The sound waves travel into the body and hit a boundary(tissue, bones).
- Reflected waves are picked up by probe
- Some of the sound waves are reflected back to the probe, while some travel further until they reach another boundary & get reflected.
- Machine calculates and displays the distances and intensities of the echoes on the screen forming a two dimensional image.

Ultrasound Imaging (1 – 5) MHz

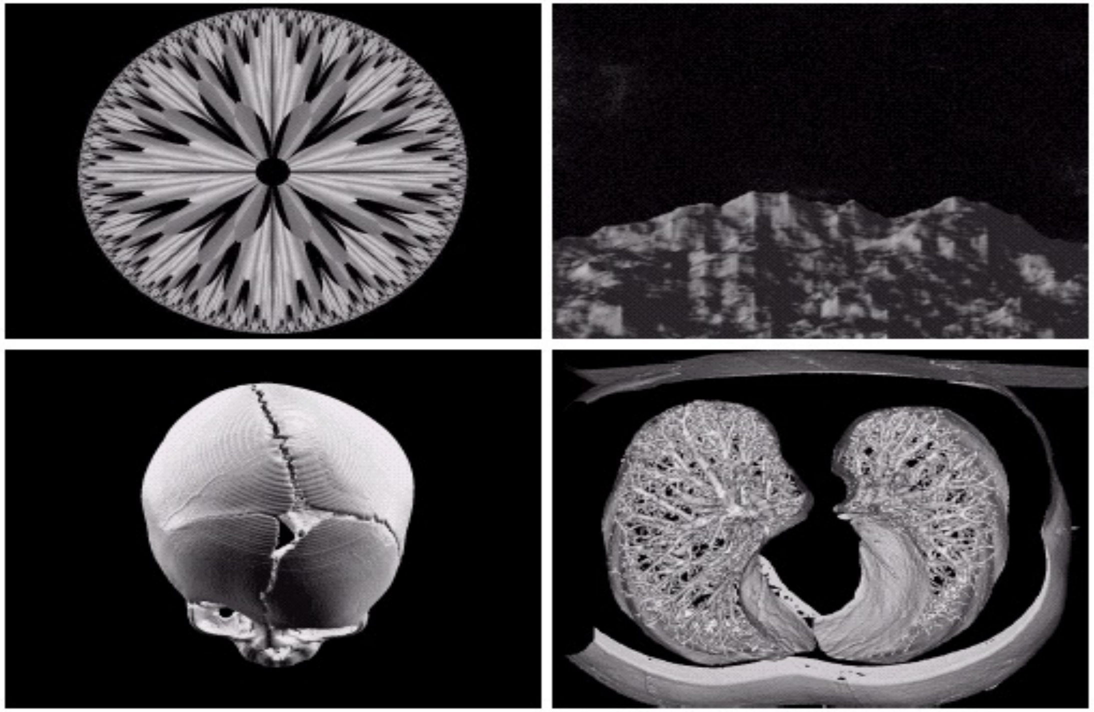


a b
c d

FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Fractal Images

- Computer generated images: Iterative reproduction of a basic pattern according to some mathematical rules.



a b
c d

FIGURE 1.22 (a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

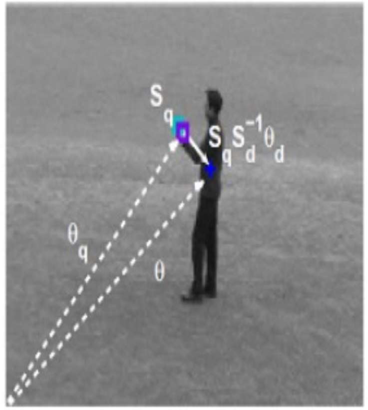
DIGITAL IMAGE PROCESSING-1

Applications

Currency Detection, Signature Recognition, Bio-Metrics, Face / Emotion Recognition

Courtesy: github.com, parascript.com, nice.com, biometricupdate.com, pcmag.com

Applications



Object/Human Tracking/ Human Activity Recognition

Courtesy: Kintronics.com, Learnopencv.com, Ibug.com.ic.ac.uk

Applications

- Remote sensing
- Medical Applications-CT scan, ultrasonograph, MR,PET etc.
- Satellite Image –city planning, terrain mapping
- Weather forecasting
- Atmospheric study- ozone holes etc.
- Machine vision applications for product assembly and inspection
- Target detection and tracking
- Night surveillance
- Finger print Recognition
- Satellite Image processing
- Automated Bottling
- Boundary Information
- Background separation-segmentation
- Structural defects-dimension, angle/corners
- Surface –uniform / non uniform-texture
- IC manufacturing defects-broken /missing leads

And many more…….

Next Session

- Fundamental Steps in DIP
- Components of an Image processing System
- Visual perception
- Image formation model

THANK YOU

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