References:-

1. Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing", 2/E, Prentice – Hall 2001.
2. Scott E Umbaugh, “Computer Vision and Image Processing”, Prentice – Hall 1998.
3. Nick Efford, “Digital Image Processing – a practical approach using Java”, Pearson Education 2000.
4. John R Jensen, “Introductory Digital Image Processing”, 3/E. Prentice Hall, 2005.

1. Introduction

An image is a picture: a way of recording and presenting information visually. Since vision is the most advanced of our senses, it is not surprising that images play the single most important role in human perception. The information that can be conveyed in images has been known throughout the centuries to be extraordinary - *one picture is worth a thousand words*.

However, unlike human beings, imaging machines can capture and operate on images generated by sources that cannot be seen by humans. These include X-ray, ultrasound, electron microscopy, and computer-generated images. Thus, image processing has become an essential field that encompasses a wide and varied range of applications.

2. Basic definitions

- *Image processing* is a general term for the wide range of techniques that exist for manipulating and modifying images in various ways.
- A *digital image* may be defined as a finite, discrete representation of the original continuous image. A digital image is composed of a finite number of elements called *pixels*, each of which has a particular location and value.

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

3. Digital image processing and other related areas

There is no general agreement regarding where image processing stops and other related areas, such as image analysis and computer vision, start. Sometimes a distinction is made by the following paradigm:

- *Image processing* is a discipline in which both the input and output of a process are images. For example, it involves primitive operations such as image preprocessing to reduce noise and contrast enhancement.
- *Image analysis* (also called image understanding) is in between image processing and computer vision. In this area, the process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects). This area includes tasks such as image segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects.
- Finally, *computer vision* is a field whose ultimate goal is to use computers to emulate human vision, including learning and being able to make inferences of recognized objects and take actions based on visual inputs. This area itself is a branch of artificial intelligence (AI) whose objective is to emulate human intelligence.

4. Types of Imaging Systems

Imaging systems are varying depending on their energy source (e.g. visual, X-ray, and so on). The principal energy source for images in use today is the *electromagnetic (EM) spectrum* illustrated in Figure 1.1. Other important sources of energy include acoustic, ultrasonic, and electronic (in the form of electron beams used in electron microscopy). Synthetic images, used for modeling and visualization, are generated by computer. In this section we discuss briefly how images are generated in these various categories and the areas in which they are applied.

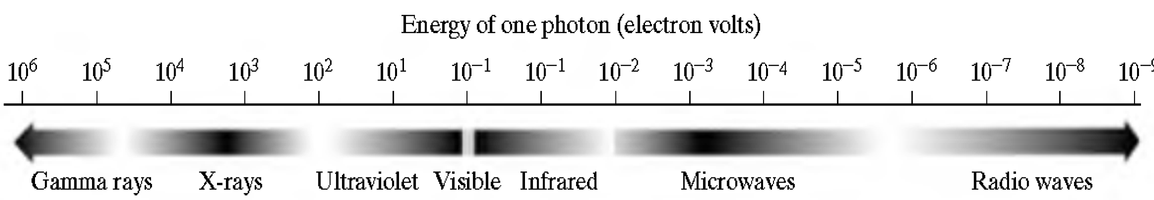
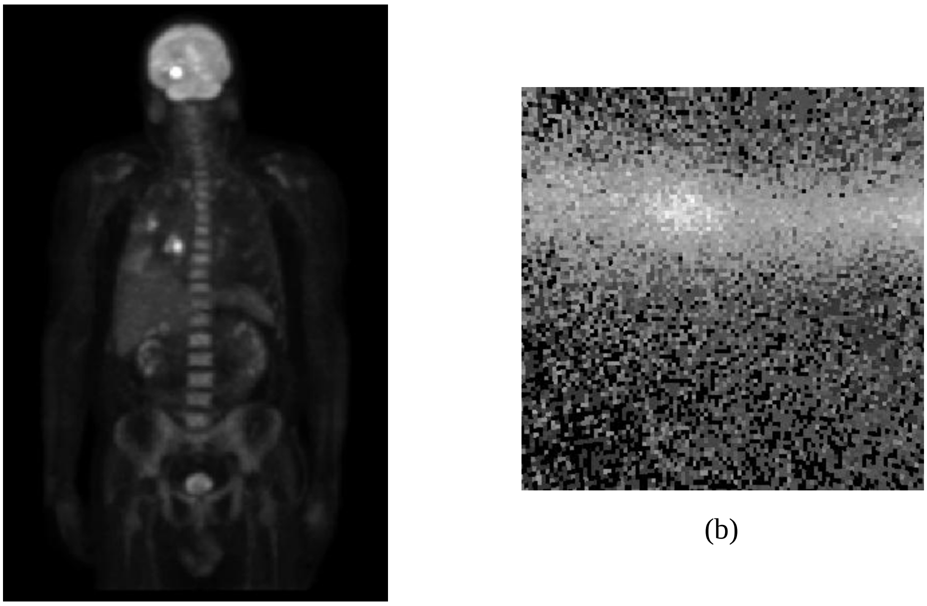


Figure 1.1 the electromagnetic spectrum arranged according to energy per photon.

4.1 Gamma-ray Imaging

Gamma rays are emitted as a result of collision of certain radioactive isotopes (a positron and an electron). This occurs naturally around exploding stars, and can be created easily. Images are produced from the emissions collected by gamma ray detectors.

Major uses of gamma ray imaging include nuclear medicine and astronomical observations. In nuclear medicine, a patient is injected with a radioactive isotope that emits gamma rays as it decays. Figure 1.2(a) shows a major modality of nuclear imaging called positron emission tomography (PET) obtained by using gamma-ray imaging. The image in this figure shows a tumor in the brain and one in the lung, easily visible as small white masses.



(a) (b)

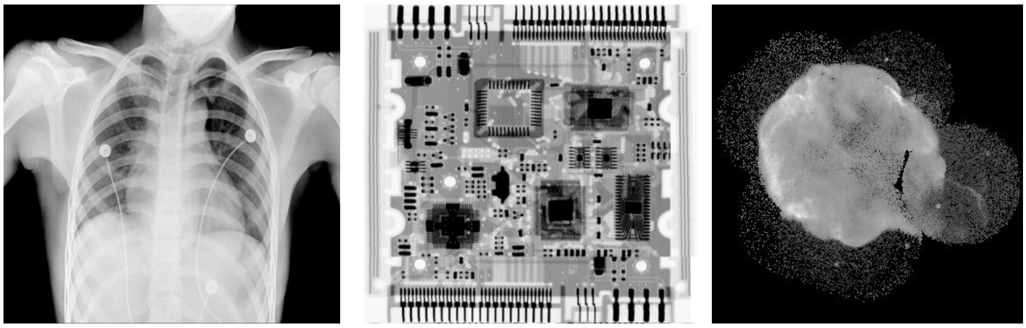
Figure 1.2 Examples of Gamma-Ray imaging a) PET image b) Star explosion 15,000 years ago

Figure 1.2(b) shows a star exploded about 15,000 years ago, imaged in the gamma-ray band. Unlike the previous example shown in Figure 1.2(a) , this image was obtained using the natural radiation of the object being imaged.

4.2 X-ray Imaging

X-rays are generated using an X-ray tube (a vacuum tube with a cathode and anode). The cathode is heated, causing free electrons to be released and flowing at high speed to the positively charged anode. When the electrons strike a nucleus, a modified energy is released in the form of X-ray radiation. Images are either generated by: 1) dropping the resulting energy on a film, then digitizing it or 2) dropping directly onto devices that convert X-rays to light. The light signal in turn is captured by a light-sensitive digitizing system.

X-rays are widely used for imaging in medicine, industry and astronomy. In medicine, chest X-ray, illustrated in Figure 1.3(a), is widely used for medical diagnostics.



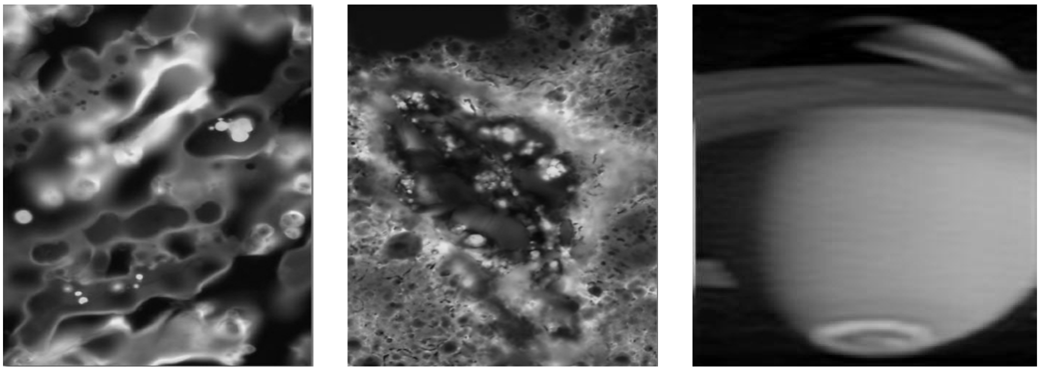
(a) (b) (c)

Figure 1.3 Examples of X-Ray imaging. a) Chest X-ray. b) Circuit board. c) Star explosion

In industrial processes, X-rays are used to examine circuit boards, see Figure 1.3(b), for flaws in manufacturing, such as missing components or broken traces. Figure 1.3(c) shows an example of X-ray imaging in astronomy. This image is the star explosion of Figure 1.2 (b), but imaged this time in the X-ray band.

4.3 Ultraviolet Imaging

Applications of ultraviolet "light" are varied. They include industrial inspection, fluorescence microscopy, lasers, biological imaging, and astronomical observations. For example, Figure 1.4(a) shows a fluorescence microscope image of normal corn, and Figure 1.4(b) shows corn infected by "smut," a disease of corn. Figure 1.4(c) shows the entire "oval" of the auroral emissions at Saturn's South Pole captured with Cassini's ultraviolet imaging spectrograph.

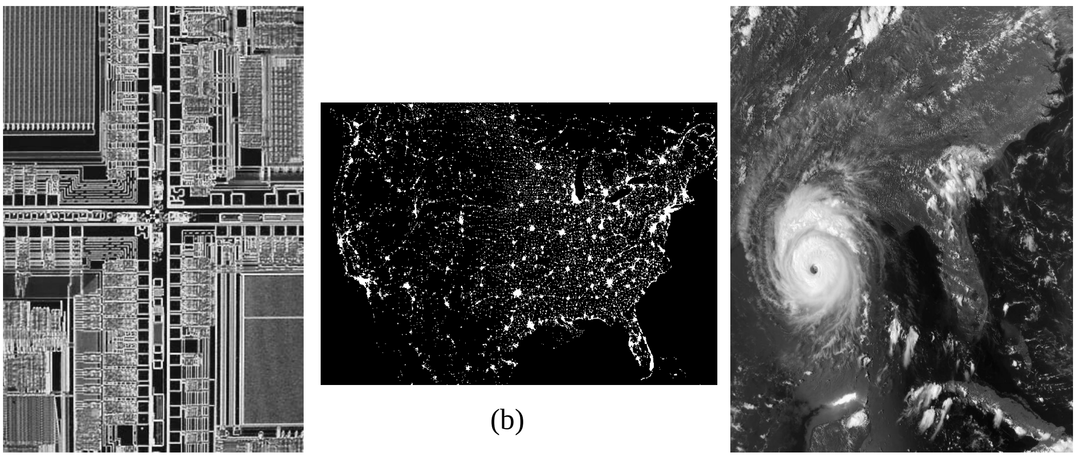


(a) (b) (c)

Figure 1.4 Examples of ultraviolet imaging (a) Normal corn (b) Smut corn (c) Emissions at Saturn's South Pole

4.4 Imaging in the Visible and Infrared bands

The visual band of the EM spectrum is the most familiar in all activities and has the widest scope of application. The infrared band often is used in conjunction with visual imaging (Multispectral Imaging). Applications include light microscopy, astronomy, remote sensing, industry, and law enforcement. Figure 1.5(a) shows a microprocessor image magnified 60 times with a light microscope, and Figure 1.5(b) illustrates infrared satellite image of the Americas. Figure 1.5(c) shows a multispectral image of a hurricane taken by a weather satellite.



(b)

(a) (c)

Figure 1.5 Examples of visible and infrared imaging. a) Microprocessor magnified 60 times. b) Infrared satellite image of the US. c) Multispectral image of Hurricane

4.5 Imaging in the Microwave band

The dominant application of imaging in the microwave band is radar. Imaging radar works like a flash camera in that it provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot image. Instead of a camera lens, 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 toward the radar antenna. Figure 1.6 shows a radar image covering a rugged mountainous area.

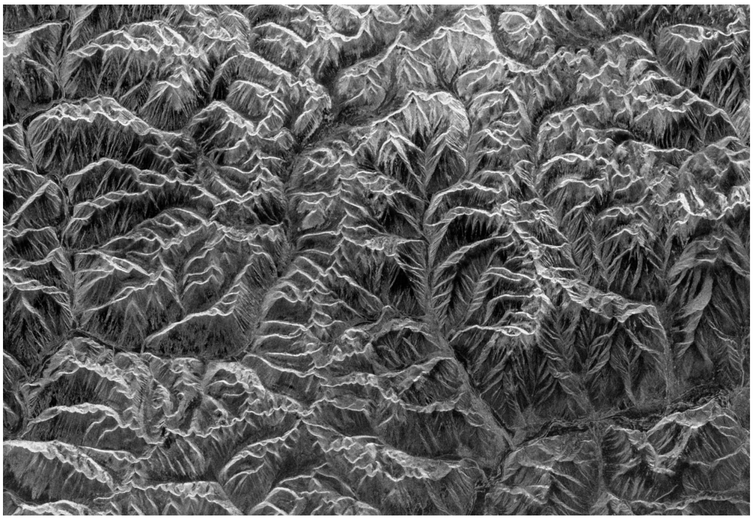
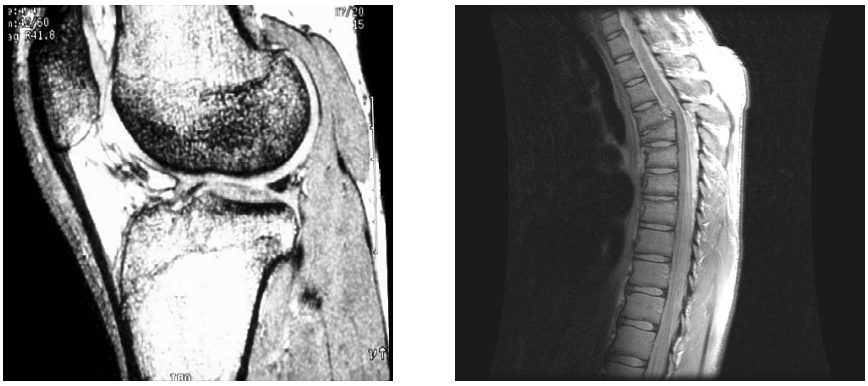


Figure 1.6 Radar image of mountainous region

4.6 Imaging in the Radio band

The major applications of imaging in the radio band are in medicine and astronomy. In medicine radio waves are used in magnetic resonance imaging (MRI). For MRI, a powerful magnet passes radio waves through the patient body in short pulses. Patient's tissues respond by emitting pulses of radio waves. The location and strength of these signals are determined by a computer, which produces a 2D picture of a section of the patient. Figure 1.7 shows MRI images of a human knee and spine.



(a) (b)

Figure 1.7 MRI images of a human (a) knee, and (b) spine.

4.7Other Imaging Modalities

There are a number of other imaging modalities that also are important. Examples include acoustic imaging, electron microscopy, and synthetic (computer-generated) imaging.

Imaging using "sound waves" finds application in medicine, industry and geological exploration. In medicine, ultrasound imaging is used in obstetrics where unborn babies are imaged to determine the health of their development. A byproduct of this examination is determining the sex of the baby. Figure 1.8 shows examples of ultrasound imaging.

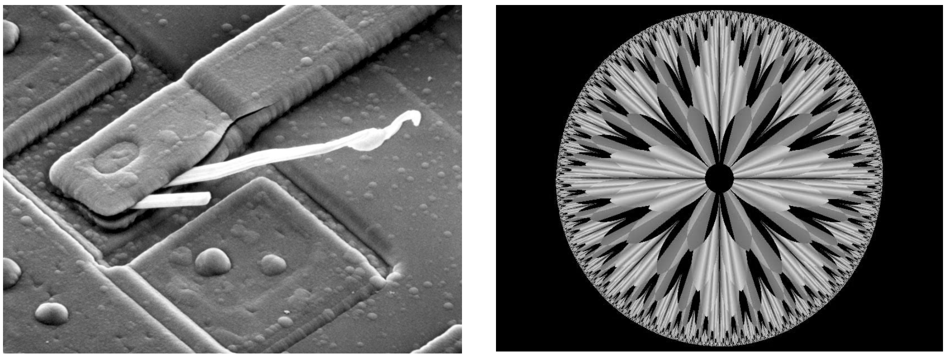
The procedure of generating ultrasound images is as follows:

1. The ultrasound system (a computer, ultrasound probe consisting of a source and receiver, and a display) transmits high-frequency (1 to 5 MHz) sound pulses into the body.
2. The sound waves travel into the body and hit a boundary between tissues. Then, they are reflected back and picked up by the probe and relayed to the computer.
3. The computer calculates the distance from the probe to the tissue or organ boundaries, and then it displays the distances and intensities of the echoes on the screen, forming a two-dimensional image.

(a) (b)

Figure 1.8 Examples of ultrasound imaging. a) Baby b) another view of baby

Finally, Figure 1.9(a) shows an image of damaged integrated circuit magnified 2500 times using an electron microscope. Figure 1.9(b) shows a fractal image generated by a computer.



(a) (b)

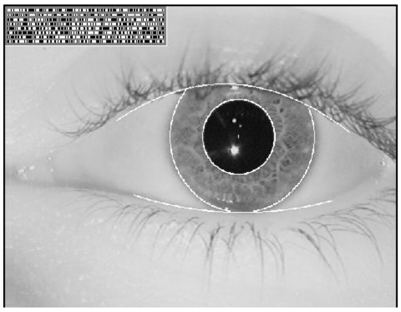
Figure 1.9 (a) image of damaged integrated circuit magnified 2500 times (b) fractal image

5. Digital image processing applications

Image processing is used in a wide range of applications for example:

- Security (e.g. face, fingerprint and iris recognition)

(a)



(b) (c)

Figure 1.10 (a) Face recognition system for PDA (b) Iris recognition (c) Fingerprint recognition

- Surveillance (e.g. car number plate recognition)

Figure 1.11 Car number plate recognition

- Medical applications as shown in the previous sections

6. Components of digital image processing system

The basic model of a digital image processing system assumes the existence of a source of energy, a sensor devise to detect the emitted/reflected energy, a coding system for the range of measurements, and a display device. However, a modern DIP system requires powerful computing hardware, specialized software, large storage systems and communication devices. Figure 1.12 shows the basic components comprising a typical general-purpose system used for digital image processing.

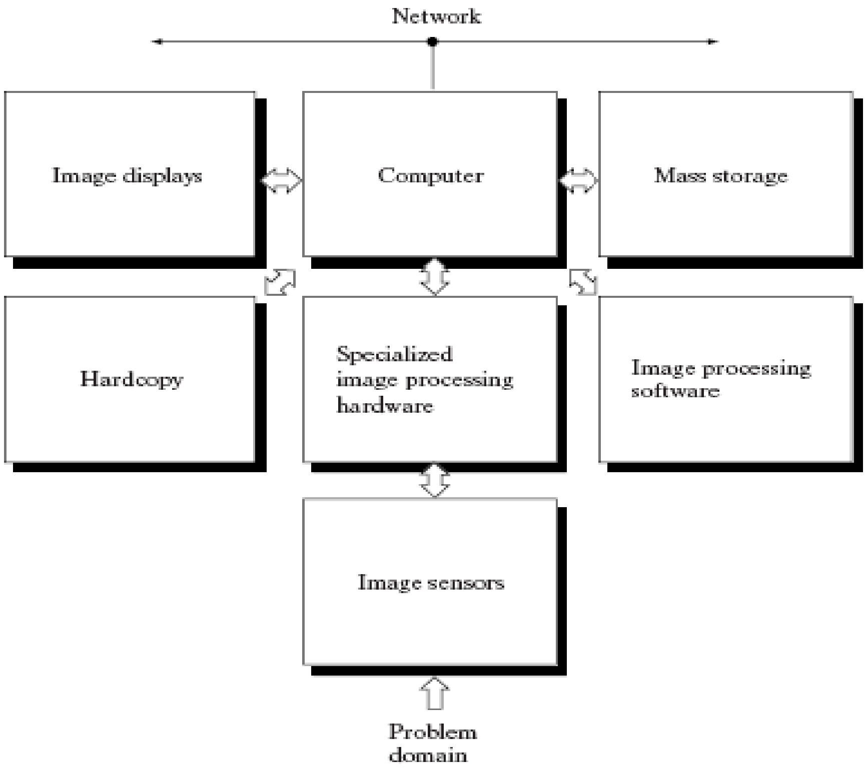


Figure 1.12 Components of a general-purpose image processing system

7. Fundamental tasks in digital image processing

Image applications require a variety of techniques that can be divided into two main categories: *image processing techniques* whose input and output are images, and *image analysis techniques* whose inputs are images, but whose outputs are attributes extracted from those images.

1. Image processing techniques include:

§ *Image Enhancement*: brings out detail that is obscured, or simply highlights certain features of interest in an image. A familiar example of enhancement is increasing the contrast of an image.

§ *Image Restoration*: attempts to reconstruct or recover an image that has been degraded by using a priori knowledge of the degradation phenomenon.

§ *Image Compression*: deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.

2. Image Analysis tasks include:

§ *Image Segmentation*: is concerned with procedures that partition an image into its constituent parts or objects.

§ *Image Representation and Description*: Image representation converts the output of a segmentation stage to a form suitable for computer processing. This form could be either the boundary of a region or the whole region itself. Image description, also called *feature selection*, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

§ *Image Recognition:* is the process that assigns a label (e.g., "vehicle") to an object based on its descriptors.