**Quote: A picture is worth more than a thousand words.**

**Objectives:**

This chapter has several objectives: (1) to define the scope of the field that we call image processing.

(2) to give a historical perspectiveof the origins of this field.

(3) to give you an idea of the state of the art in image processing.

(4) to discuss briefly the principal approaches used in digital image processing,

(5) to give an overview of the components contained in a typical general-purpose image processing system.

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

**Digital image:**

When x,y and the intensity values of f are all finite, discrete quantities, we call the image a digital image. A digital image is composed of finite number of elements, each of which has a particular location and value, called as *picture elements, image elements, pels and pixels.*

**Digital Image Processing:**

The field of digital image processing refers to processing digital images by means of a digital computer. Unlike humans who are only able to perceive a tiny part of Electromagnetic (EM) Spectrum, imaging machines cover almost the entire EM spectrum, thus encompassing a wide and varied field of applications.

Interest in digital image processing arises from two main reasons:

1. Improvement of pictorial information for human interpretation

2. Processing of image for tasks such as storage, transmission and extraction of information.

**Computer Vision? Image Analysis? How are they different?**

There is no clear-cut boundary between image processing and other related areas such as image analysis and computer vision. Usually a distinction is made by defining image processing as a discipline in which both input and output of a process are images. But this is limiting and somewhat artificial boundary, because even the trivial task of finding average intensity of a picture, whose output is a single number, will then be out of the scope of the field.

Computer Vision, on the other hand, is a branch of AI whose objective is to emulate human vision, including learning, inferencing and act based on visual inputs.

The area of image analysis (also called image understanding) is in between image processing and computer vision.

One useful paradigm is to consider three types of computerised processes: low-,mid-,high- level processing. A low-level process, whose input and ouput are images, involves primitive operations such as image processing to reduce noise, constrast enhancement, and image sharpening. Mid-level processes include tasks like segmentations (partioning of image into regions or objects), description of these objects to a form suitable for computer processing, and classification (recognition) of individual objects and giving attributes extracted from image (eg edges, contours,etc). Higher-level processes include make inference from recognised objects and eventually performing cognitive functions normally associated with human vision.

So, digital image processing mainly encompasses the low-level to mid-level processes.

**Origins of digital image processing:**

Earliest application of digital image was in newspaper industry, where images were sent by cable in between London and New York and reproduced on telegraph printer with typefaces simulating a halftone pattern.

Then, by the end of 1921, tapes perforated at the telegraph receiving terminal were used for printing, which was capable of printing 5 gray levels. This capability was increased to 15 by the end of 1929.

Although the above involve digital images, they are not considered digital image processing results since digital computer were not used in their creation. The origin of digital image processing, is thus intimately tied with development of digital computers, and supporting technologies such as storage, display and transmission.

The first computers powerful enough to carry out meaningful image processing tasks appeared in the early 1960s. The birth of digital image processing, can be traced back to availability of those machines, and to the onset of space program, wherein the pictures sent by Ranger 7 from moon needed to processed to correct various types of image distortion inherent in the on-board television camera.

In parallel with space applications, digital image processing techniques were used in medical imaging such as invention of *Computerized Axial Tomography* (CAT) and *Computerized Tomography* (CT).

From late 1960s, the field has grown rapidly and is now serving broad range of applications such as in X-rays, biological sciences, geography (studying aerial and satellite images), archeology, physics, astronomy, nuclear medicine, law enforcement, defence and industry.

**Applications of digital image processing:**

There is almost no area of technical endeavor that is not impacted in some way by digital image processing. The areas of application are so varied that some from of organization is desirable in attempting to capture the breadth of this field.

One simple way to visualise the extent of these applications is to categorize images according to their source.

Applications based on different ranges of radiation from EM spectrum and other types of radiation such as acoustic, ultrasonic, and electronic are discussed.

**Gamma-Ray Imaging:**

Major uses of gamma ray imaging include nuclear medicine and astronomical observations. In nuclear medicine, the approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays. (figure 1.6a) shows an image of complete bone scan obtained by using gamma-ray imaging. Images of this sort are used to locate tumours, infections or bone pathology.Positron emission tomography (PET) is another major modality. Similarly, it is used to analyse astronomical objects like constellations and stars.

**X-ray Imaging:**

X-rays are one of the oldest source of EM radiation used for imaging. The best known use is in medical diagnostics but they are also extensively used in industry and other areas like astronomy. X-rays generated from X-ray tube, where accelerated electrons strike positive anode, are passed through patient onto the devices (such as a phosphorous screen). Angiography (area of constrast enhancement radiography used to obtain images of blood vessels),Computerized Axial Tomography (CAT), etc are other applications of X-ray Imaging.

**Ultraviolet Imaging:**

Various applications of Ultraviolet imaging exist like lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations. One of the uses in microscopy is of the field of fluoroscence microscopy, where ultraviolet light is irradiated on a prepared specimen kept on non-fluoroscent background, emits fluorescent light, typically in visible red, which can differentiate it from the background.

**Visible and Infrared Band Imaging:**

As visible light spectrum is the most familiar one, the applications in this area are numerous. The infrared band is often used in conjunction with visual imaging. There are several fields like light microscopy, astronomy, remote sensing, industry and law enforcement.

Light microscopy is used for pharmaceuticals, microinspection, and material characterization, etc.

Remote sensing usually includes several bands in the visual and infrared regions of the spectrum and are used for wide variety of appliations such as monitoring environmental conditions and geography. Even weather observation and prediction is also done.

A major area of imaging in the visible spectrum is in automated visual inspection of manufactured goods, wherein product is inspected to spot deformities, missing parts, etc.

Even, images of thumbprints are routinely processed by a computer, either to enhance them or to find features that aid in the automated search of a database for potential matches, used in law enforcement etc. Also imaging is used to inspect and count currency notes, read the serial numbers for the purpose of tracking and identifying currency bills. Automated license place reading is another example.

**Imaging in the microwave band:**

The principal application of imaging in microwave band is radar. The unique feature of radar is its ability to collect data over virtually any region at any time, regardless of weather, or ambient light conditions. Figure shows a spaceborne radar image covering a rugged mountaineous area of southeast Tibet. Note the absence of clouds and other atmospheric interferences normally encountered in imaging in visual band.

**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). In astronomy, they are used to monitor celestial bodies activity. Also, background radiation (usually consisting of radio waves) is essential in the theory of expanding universe.

**Other Imaging Modalities:**

There are a number of imaging modalities other than that of EM spectrum, such as acoustic imaging, electron microscopy and synthetic (computer-generated) imaging. Acoustic imaging, wherein sound is employed, is used in geological exploration (oil exploration, sea bed imaging), medicine (ultrasound images to observe fetuses), electron microscopes, etc.

**Fundamental Steps In Digital Image Processing:**

The usual processes that are done in digital image processing are given in the picture. The diagram does not imply that every process is applied to an image but rather it is a sketch encompassing various processes that can be applied to images for different purposes.

*Image acquisiton* is the first process in the figure. Acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling.

*Image enhancement* is the process of manipulating an image so the result is more suitable than the original for a **specific** application. The word specific is emphasized to signify that enhancement techniques are usually problem-oriented and thus, for example, a method quite useful to enhance X-ray images may not be the best approach for enhancing satellite images taken in Infrared region. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is when we increase the contrast of an image because “it looks better”. It is important to keep in mind that enhancement is a very subjective area of image processing.

*Image restoration* is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a “good” enhancement result.

*Color image processing* ,an area that deals with processing color and related features in an image, has been gaining in importance because of the significant increase in the use of digital images over the Internet.

*Wavelets* are the foundation for representing images in various degrees of resolution. We use it for image data compression, pyramidal representation (images are subdivided successively into smaller regions), and transformations.

*Compression*, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it. Although storage technology has improved significantly over the past decade, the same cannot be said for transmission capacity. This is true particularly in uses of the Internet, which are characterized by significant pictorial content. Image compression is familiar (perhaps inadvertently) to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG (Joint Photographic Experts Group) image compression standard.

*Morphological processing* deals with tools for extracting image components that are useful in the representation and description of shape.

*Segmentation* procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. In general, the more accurate the segmentation, the more likely recognition is to succeed.

*Feature extraction* almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself. Feature extraction consists of feature detection and feature description. *Feature detection* refers to finding the features in an image, region or boundary. *Feature description* assigns quantitative attributes to the detected features. For example, we might detect corners in a region, and describe those corners by their orientation and location; both of these are quantitative descriptors.

*Image pattern classification* is the process that assigns a label (eg., “person”) to an object based on its feature descriptors.

*Knowlegde* about a problem is coded into an image processing system in the form of knowledge database. This knowledge maybe as simple as detailing regions of an image where the interest is known to be located, thus limiting the search that has to be conducted in seeking that information.

**Components of an image processing system:**

Figure shows the basic components comprising a typical general-purpose system used for digital image processing.

We require two subsystems for acquiring digital images; one being physical *sensor* that responds to energy radiated by the object we wish to image and the other being the device called *digitizer* that converts the output of the physical sensing device into digital form. For instance, in a digital video camera, the sensors (CCD chips) produce an electrical output proportional to light intensity and the digitizer converts these ouputs to digital data. Specialised image processing hardware consists of the digitizer and some other harware such as ALU that performs arithmetic and logic operations in parallel on entire images, for instance in averaging images quickly as they are digitized to reduce noise reduction, etc. This type of hardware is called *front-end subsytem* and is usually very quick, and can contain one or more GPUs.

The *computer* in an image processing system is a general-purpose computer and can range form a PC to a supercomputer. It is for performing the processing on the images.

*Software* for image processing consists of specific modules that perform specific tasks. More sophisticated modules also includes the capabilities for the user to write code that utilizes the specialized modules. One such example is MATLAB Image Processing Toolbox.

*Mass Storage* is used for storing the images and various computations, intermediate results, etc. Digital storage for image processing appliations falls into three pricipal categories: (1) short-term storage for use during processing (computer memory/ frame memory); (2) on-line storage for relatively fast recall (Magnetic disks/ optical-media storage); and (3) archival storage, characterized by infrequent access (Magnetic tapes and optical disks). Storage is measure in bytes, Kbytes, Mbytes, Gbytes, etc.

*Image displays* are for displaying the images/ information and usually consist of color, flat screen monitors.

*Hardcopy*  devices for recording images include laser printers, film cameras, heat-senstitive devices like ink-jet units, and digital units, such as optical and CR-ROM disks.

*Networking and cloud communication* are for sending/receiving image and other data. Because of the large amount of data inherent in image processing applications, the key consideration in image transmission is bandwidth. In dedicated networks, this typically is not a problem, but communications with remote sites via the Internet are not always as efficient. Fortunately, this situation is improving quickly as a result of optical fiber and other broadband technologies.