Digital Image Fundamentals:

The field of digital image processing refers to processing digital images by means of digital computer. Digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called picture elements, image elements, pels and pixels. Pixel is the term used most widely to denote the elements of digitalimage.

An image is a two-dimensional function that represents a measure of some characteristic such as brightness or color of a viewed scene. An image is a projection of a 3-D scene into a 2D projection plane.

An image may be defined as a two-dimensional function ***f(x,y),*** where x and y are spatial (plane) coordinates, and the amplitude of ***f***at any pair of coordinates **(x,y)** is called the intensity of the image at thatpoint.

Fig 1.1: Fundamentals of Digital Image Processing System

Source: Tutorials point

The term ***gray level*** is used often to refer to the intensity of monochrome images. Color images are formed by a combination of individual 2-D images.

For example: The RGB color system, a color image consists of three (red, green and blue) individual component images. For this reason many of the techniques developed for monochrome images can be extended to color images by processing the three component images individually.

An image may be continuous with respect to the x- and y- coordinates and also in amplitude. Converting such an image to digital form requires that the coordinates, as well as the amplitude, be digitized.

APPLICATIONS OF DIGITAL IMAGE PROCESSING

Since digital image processing has very wide applications and almost all of the technical fields are impacted by DIP, we will just discuss some of the major applications of DIP.

Digital image processing has a broad spectrum of applications, such as

- Remote sensing via satellites and otherspacecrafts
- Image transmission and storage for businessapplications
- Medicalprocessing,
- RADAR (Radio Detection andRanging)
- SONAR(Sound Navigation and Ranging)and
- Acoustic image processing (The study of underwater sound is known as underwater acousticsor hydroacoustics.)
- Robotics and automated inspection of industrial

parts. Images acquired by satellites are useful in trackingof

- Earthresources;
- Geographicalmapping;
- Prediction of agriculturalcrops,
- Urban growth and weathermonitoring
- Flood and fire control and many other

environmentalapplications. Space image applicationsinclude:

- Recognition and analysis of objects contained in images obtained from deep space-probemissions.
- Image transmission and storage applications occur in broadcasttelevision
- Teleconferencing
- Transmission of facsimile images(Printed documents and graphics) for office automation

Communication over computer networks

- Closed-circuit television based security monitoring systems and
- In military

Medicalapplications:

- Processing of chest X-rays
- Cineangiograms
- Projection images of transaxial tomography and
- Medical images that occur in radiology nuclear magnetic resonance(NMR)
- Ultrasonic scanning

IMAGE PROCESSING TOOLBOX (IPT) is a collection of functions that extend the capability of the MATLAB numeric computing environment. These functions, and the

expressiveness of the MATLAB language, make many image-processing operations easy to write in a compact, clear manner, thus providing a ideal software prototyping environment for the solution of image processing problem.

COMPONENTS OF IMAGE PROCESSING SYSTEM:

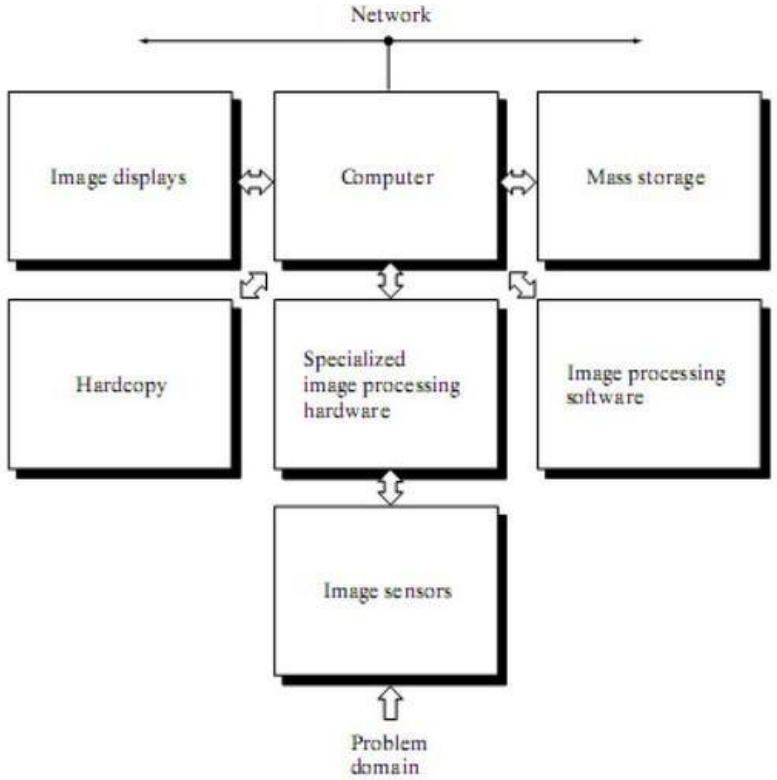

Figure 1.2: Components of Image processing System
Source: Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing', Pearson, Third Edition, 2010.

Image Sensors: With reference to sensing, two elements are required to acquire digital image. The first is a physical device that is sensitive to the energy radiated by the object we wish to image and second is specialized image processing hardware.

Specialize image processing hardware: It consists of the digitizer just mentioned, plus hardware that performs other primitive operations such as an arithmetic logic unit, which performs arithmetic such addition and subtraction and logical operations in parallel on

images.

Computer: It is a general purpose computer and can range from a PC to a supercomputer depending on the application. In dedicated applications, sometimes specially designed computer are used to achieve a required level of performance

Software: It consists of specialized modules that perform specific tasks a well designed package also includes capability for the user to write code, as a minimum,

utilizes the specialized module. More sophisticated software packages allow the integration of these modules.

Mass storage: This capability is a must in image processing applications. An image of size 1024 x1024 pixels, in which the intensity of each pixel is an 8- bit quantity requires one Megabytes of storage space if the image is not compressed .Image processing applications falls into three principal categories of storage

i) Short term storage for use during processing

ii) On line storage for relatively fast retrieval

iii) Archival storage such as magnetic tapes and disks

Image display: Image displays in use today are mainly color TV monitors. These monitors are driven by the outputs of image and graphics displays cards that are an integral part of computer system.

Hardcopy devices: The devices for recording image includes laser printers, film cameras, heat sensitive devices inkjet units and digital units such as optical and CD ROM disk. Films provide the highest possible resolution, but paper is the obvious medium of choice for written applications.

Networking: It is almost a default function in any computer system in use today because of the large amount of data inherent in image processing applications. The key consideration in image transmission bandwidth.

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING:

There are two categories of the steps involved in the image processing –

1. Methods whose outputs are input are images.
2. Methods whose outputs are attributes extracted from those images.

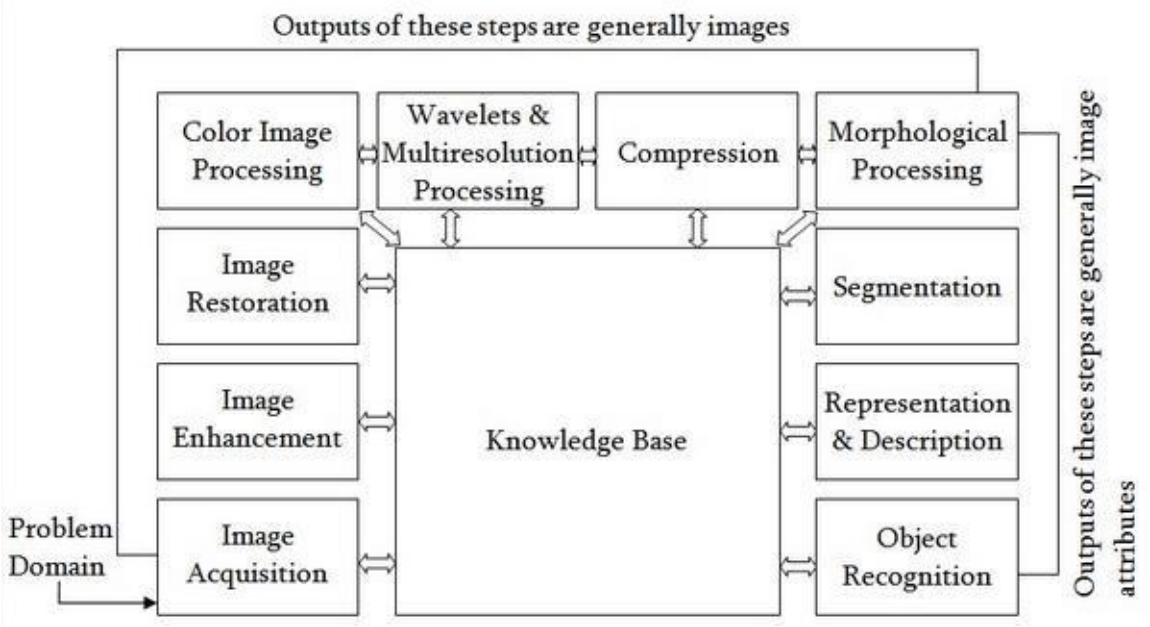

Fig 1.3 : Fundamental Steps in Digital Image Processing
Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010.

Image acquisition: It could be as simple as being given an image that is already in digital form. Generally the image acquisition stage involves processing such scaling.

Image Enhancement: It is among the simplest and most appealing areas of digital image processing. The idea behind this is to bring out details that are obscured or simply to highlight certain features of interest in image. Image enhancement is a very subjective area of image processing.

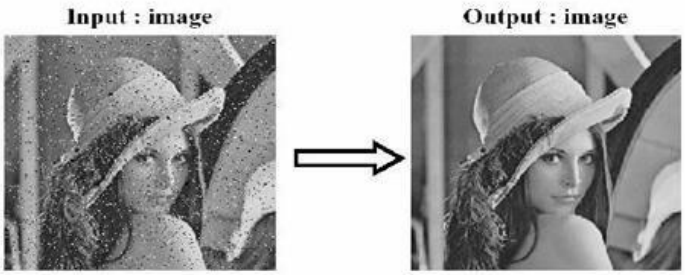

Figure: 1.4 Image Enhancement using Homomorphic Filtering
Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010.

Image Restoration: It deals with improving the appearance of an image. It is an objective approach, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image processing. Enhancement, on the other hand is based on human subjective preferences regarding what constitutes a "good" enhancement result.

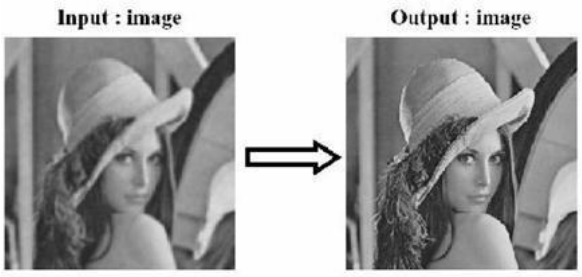

Figure: 1.5 Image Enhancement using Homomorphic Filtering
Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010

Color image processing: It is an area that is been gaining importance because of the use of digital images over the internet. Color image processing deals with basically color models and their implementation in image processing applications.

Wavelets and Multiresolution Processing: These are the foundation for representing image in various degrees of resolution.

Compression: It deals with techniques reducing the storage required to save an image, or the bandwidth required to transmit it over the network. It has to major approaches a) Lossless Compression b) Lossy Compression

Morphological processing: It deals with tools for extracting image components that are useful in the representation and description of shape and boundary of objects. It is majorly used in automated inspection applications.

Representation and Description: It always follows the output of segmentation step that is, raw pixel data, constituting either the boundary of an image or points in the region itself. In either case converting the data to a form suitable for computer processing is necessary.

Recognition: It is the process that assigns label to an object based on its descriptors. It is the last step of image processing which use artificial intelligence of software.

Knowledge base:

Knowledge about a problem domain is coded into an image processing system in the form of a knowledge base. This knowledge may be as simple as detailing regions of an image where the information of the interest in known to be located. Thus limiting search that has to be conducted in seeking the information. The knowledge base also can be quite complex such interrelated list of all major possible defects in a materials inspection problems or an image database containing high resolution satellite images of a region in connection with change detection application.

A Simple Image Model:

An image is denoted by a two dimensional function of the form f{x, y}. The value or amplitude of f at spatial coordinates {x,y} is a positive scalar quantity whose physical meaning is determined by the source of the image. When an image is generated by a physical process, its values are proportional to energy radiated by a physical source. As a consequence, f(x,y) must be nonzero and finite; that is o<f(x,y) <co The function f(x,y) may be characterized by two components- The amount of the source illumination incident on the scene being viewed.

(a) The amount of the source illumination reflected back by the objects in the scene These are called illumination and reflectance components and are denoted by i(x,y) an r (x,y) respectively.

The functions combine as a product to form f(x,y). We call the intensity of a monochrome image at any coordinates (x,y) the gray level (l) of the image at that point l= f (x, y.)

L min ≤ l ≤ Lmax L_{min} is to be positive and

Lmax must be finite

Lmin=iminrmin

Lmax=imaxrmax

The interval [Lmin, Lmax] is called gray scale. Common practice is to shift this interval numerically to the interval [0, L-l] where l=0 is considered black and l= L-1 is considered white on the gray scale. All intermediate values are shades of gray of gray varying from black to white.