CHAPETER # I

INTRODUCTION TO IMAGE PROCESSING

1.1 INTRODUCTION

Techniques of digital images processing combined with the elegant capabilities of the digital computers, have produced amazing results. They have replaced various older technique of image processing. The new techniques offer a relative ease and improved accuracy over the conventional techniques. The older techniques were either of analog type or based on the improved visual capabilities of a trained person analysing the image. The present disseration utilizes a small portion the digital image processing concerned with the angiography and in this chapter we attempt to present a panoramic view of the angiographic technique and outline of the dissertation.

1.1.1 Angiography

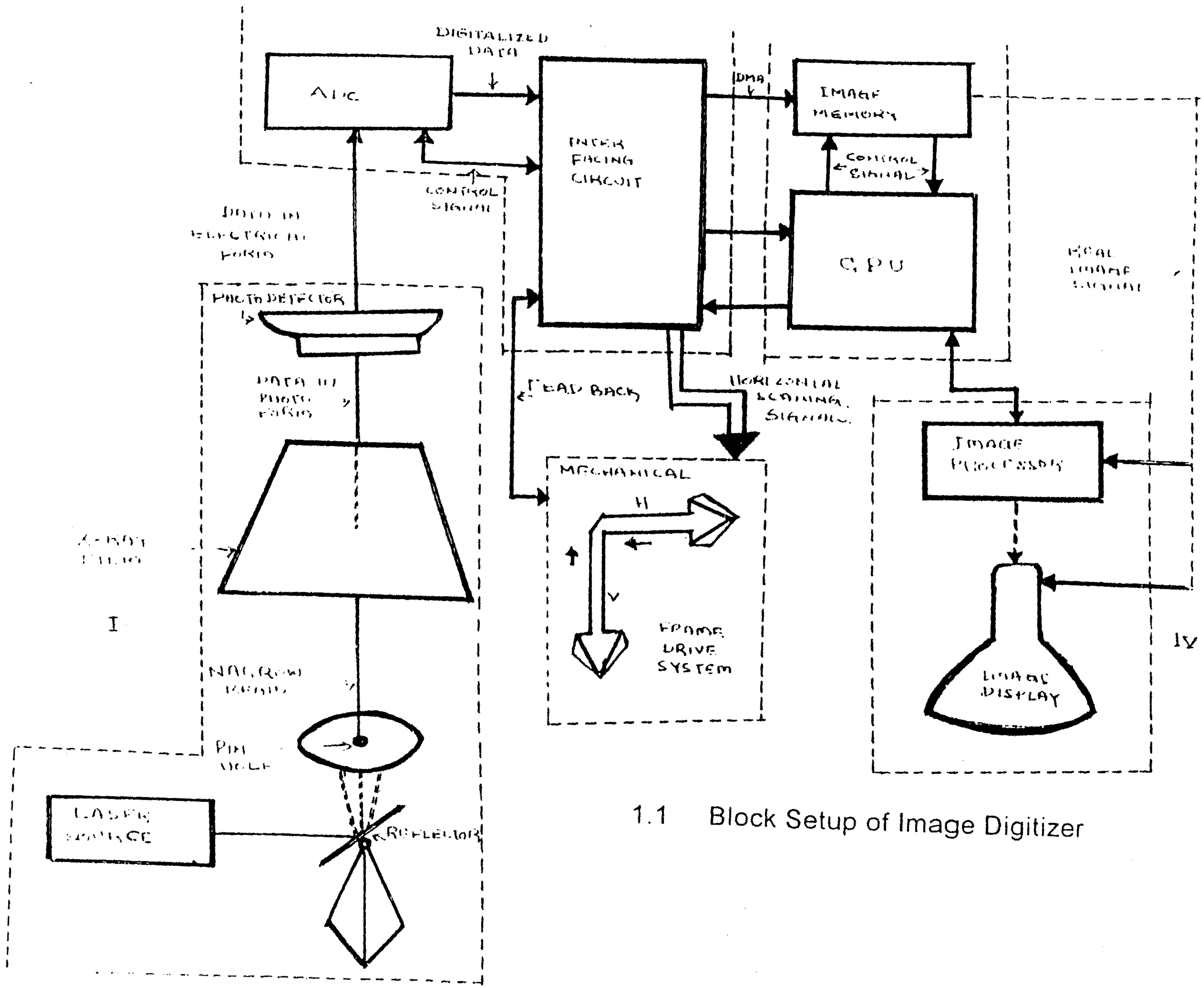
The radiographic study of the blood vessels is known as angiography. A fine catheter is passed through the vessel near the region of the investigation under guidance of a image-intensifier screening machine. After the catheter reaches the correct position a radio opaque die is injected into the vessel and the vessel is pictured with a fast speed x-ray camera or the images of the intensifier are recorded on a video tape for further investigations.

The subtraction techniques are used to image the intra-vessel geometry. Usually the technique of analog subtraction is limited to the use of light box. Therefore the amount of die/contrast required for unambiguous diagonsis is sufficiently high.

A way out of the tedious clinical examination schedule is the digital substraction technique. The initial part of the technique is common for both the technique. The blood vessel sites are imaged before and after a small amount die is injected through the catheter and conventional X-ray images (Photographic films or video tape images) are acquesed. The film images are digitized using an 'interface' and the corresponding digital images are stored in the mass storage of a computer. The interface is a versatile device and could be used for many other investigations, where the digitized images of photographs are required.

Coming back to the explanation of digital substraction, the digitized images are first processed by the image processing techniques, described later in chapter #2. After the filtered images are available, a substracted image of the vessel, from images before and after injection of the die, is computed and displayed. It is evident that with this technique one can accurately diagnose a vessel with less amount of contrast injected and with less number of images.

Block schematic of the image digitizer i.e., the 'Interface', is as shown in figure 1.1. The interface shall be described in the forth comming sections in various aspects. At present we shall continue in understanding another use of digital substraction in medical diagnostics.



1.1 Block Setup of Image Digitizer

1.1.2 Dual Energy Imageing

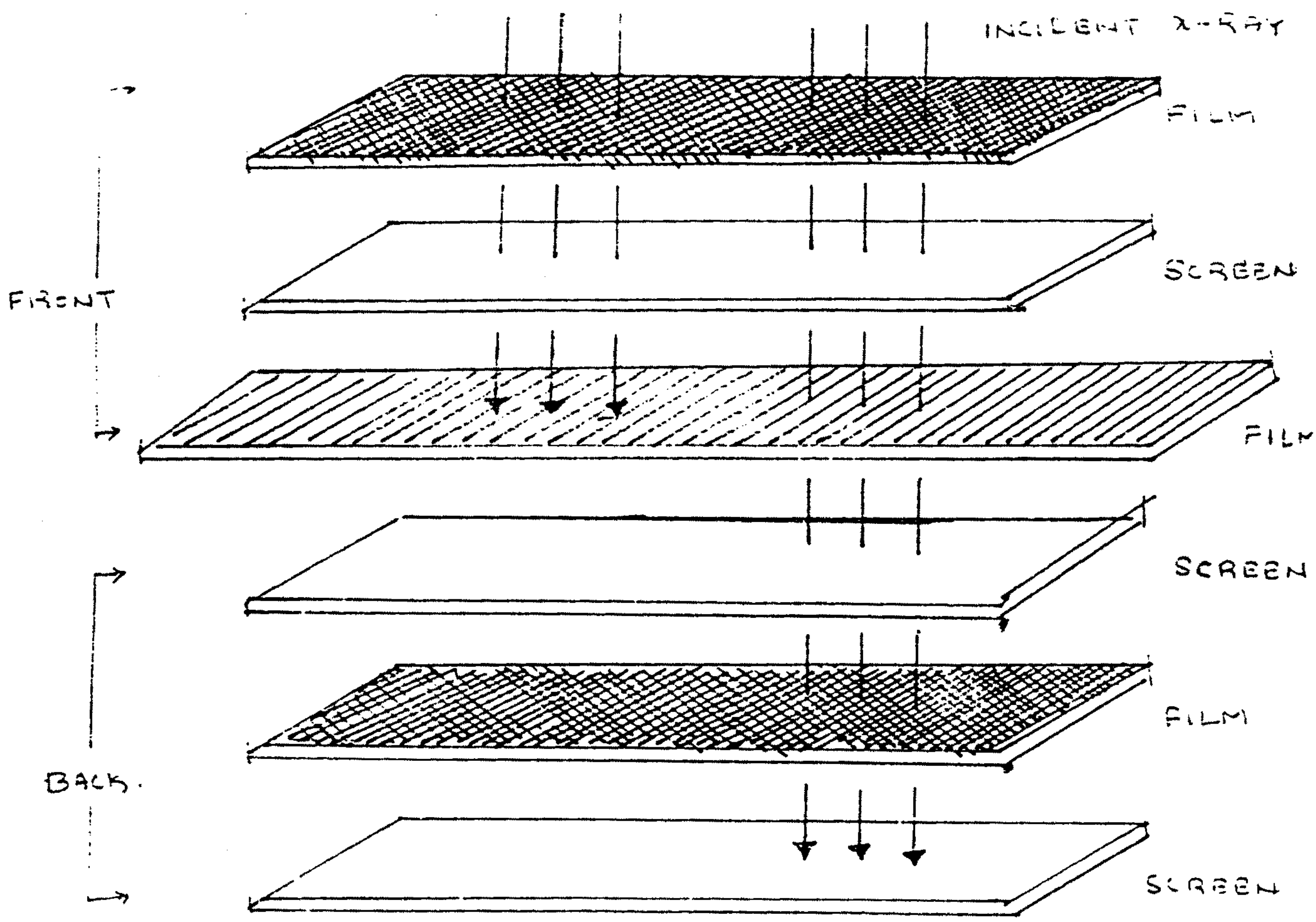
This technique of acquising the x-ray image of the subject is reported by F.Grahman Somner (1), which is similar to the digital subtraction technique. In Dual Energy Imageing, an Unique Energy Selective Cassette is used. The cassette could be divided into two divisions viz., front and back as shown in figure1.2 . The exposure of the two x-ray films with varying energy spectra achieved by single exposure with conventional x-ray equipment. Later the two films are digitized independently and processed.

The final image is obtained by subtracting one image from the another. In this technique, the dose of x-ray is half compared to the digital subtraction angiography. This technique is used to picture successfully the lung nodules and renal organism during excretory urography.

1.2 BASICS FOR IMAGE DIGITIZER AND PROCESSING SYSTEM

1.2.1 Image

Before we define and analyse the digital image processing system one should have clear understanding of an image, especially a digital image and only then one can fully exploit the topic of digital image processing. According to the Webster's dictionary an image is a representation, likeness or imitation of an object or thing, a vivid or graphic description, something introduced to represent something else. Thus, in general sense, an image is a representation of something else (17). An image contains descriptive information about



1.2 Unique Energy Selective Cassette

the object it represents.

A picture is a restricted type of image viz., a representation made by painting, drawing, or photography. In the vernacular of image processing, however, the word processing is sometimes used as equivalent to the word image.

1.2.2 Digital Image

According to Webster's dictionary, the word digital relates to calculation by numerical methods or by discrete units. And the digital image can be defined to be a numerical representation of an object (which may itself be an image). In a precise way, digital image is a sampled, quantized function of two dimensions which has been generated by optical means, sampled in an equally spaced rectangular grid pattern, and quantized in equal intervals of gray level (17). Thus, a digital image is now a two-dimensional rectangular array of quantized sample values.

1.2.3 Digital Image Processing

A process is a series of actions or operations leading to a desired result. Thus, a series of actions or operations are performed upon an object to alter its form in a desired manner.

Basically it requires a computer, where the image is processed. In addition, the system must have two pieces of special I/P and O/P equipment, viz., (a) an image digitizer and (b) image display device. Since the computers work with numerical rather than pictorial data, an image must be converted to numerical form before processing. This conversion process is called digitization. Further, processing the numerical data by using the computer is readily possible and simple.

Digital image processing usually considers a portion of image, by using the techniques of image manipulation viz., windowing, tonal reversal, subtraction, masking, filtering etc., to enhance desired features of the acquired image for the purpose of analysis (22). The term digital image processing, however, is loosely used to cover both processing and analysis.

The above mentioned operations that can be performed on digital images fall into several classes viz.,

i) Global Operation : Operation technique applied equally throughout the entries digital image.

ii) Point Operation : In which the O/P pixel value depends only on the value of the corresponding I/P pixel.

iii) Local Operation : In which the O/P pixel value depends on the pixel values in a neighbourhood of the corresponding I/P pixel.

1.3 DIGITAL IMAGE PROCESSING SYSTEM

A system which acquiesces the data of an image, especially photographic negative, and converts it into corresponding digital value, corresponding to the respective co-ordinate, and feed it to the digital computer for storage, processing and rebuilding the image onto the CRT, may be said as an image digitizer. Further, hard copies of the stored images could be generated with the same system. The figure 1.1. shows basic components of the Digital Image Processing System. The basic components as appear from the Figure1.1 , are

1. Optical System

2. Image in the form of X-ray Film

3. Quantizer

4. PC and Storage device

5. Display console.

The first component usually an image, in the form of film, is the source of information. The optical sensor acquiesces the image, pixel-by-pixel and converts it into electrical signals. This is called as scanning the image. The magnitude of electrical signal depends upon the density or transmittance of the individual pixel. The electrical signals are feed to the digitizer and digital data is stored either in magnetic tape or hard disk for further processing. The processing is carried out with the help of digital computer. The processed digital data of the image is passed onto the O/P for display on CRT or to the graphic printer for a hard copy. The processed digital data may be stored in the storage device for further processing.

As known, whenever one form of information is transformed into another, possibility of degradation of the actual information is inevitable. As in this case image is transformed from one form to another, while imageing, digitizing, processing and reproducing the image, the possibility for image degradation increases. To minimize this, the entire process should be well designed and properly controlled. Commercial systems are available, which can acquiesce the data of a pixel size of 180 micro meter circular spot (1). These being patented system, the independent design of a similar system with characteristic differences from that of one referred above has been taken up as the present project. In the following subsections, various elements of image digitizer are elaborated.

1.3.1 The Photographic Film

Source of images used for digitization are usually in the form of pictures, mainly in the form of photographic film. Presently designed image digitizer interface also uses photographic film as a source of image. So, it was required to have a detailed information regarding the same. Figure 1.3 shows the structure of modern B/W film. It consists of the following layers .

i) Super coat: The supercoat is of gelatin used for protection against scratches and abrasion marks.

ii) Emulsion layer: The emulsion layer is consisting of minute silver halide crystals.

iii) Substrate layer: The substrate layer, which promotes adhesion of the emulsion to the film base.

iv) Film base : The base is made of cellulose triacetate or a related polymer.

v) Backing layer : To prevent the curling.

a) Transmittance and Density

When an object passes some but not all, of the light incident

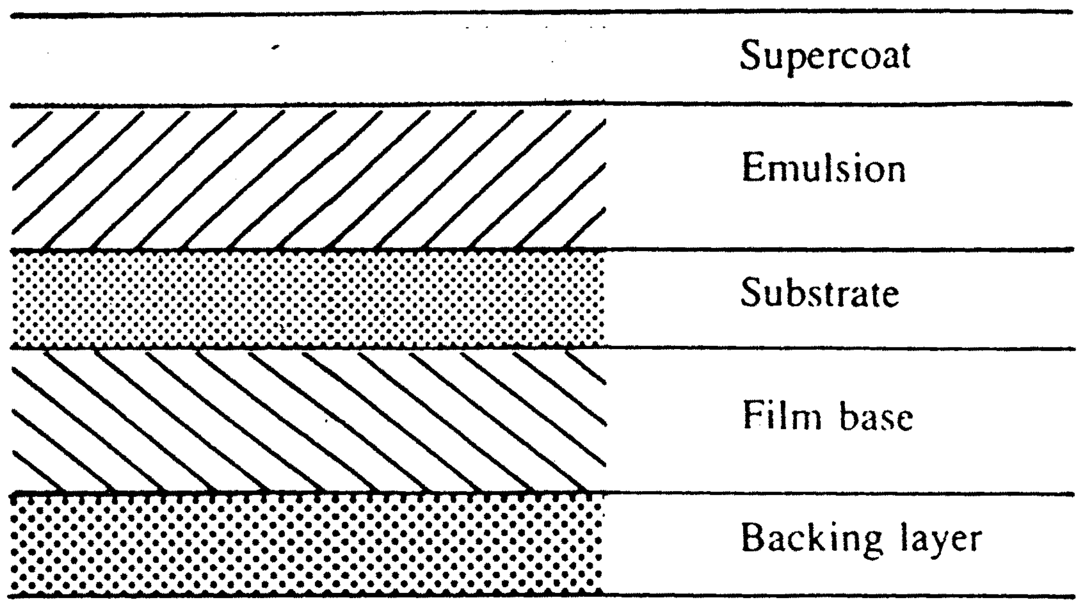
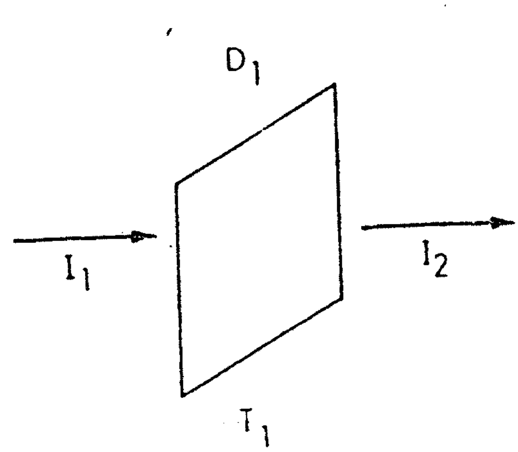


Figure 1.3 Structure of modern black-and-white film.



1.4 Transmittance of Object

upon it, is neither transparent nor opaque. This behaviour may be explained by two measures of this partial light transmitting property, transmittance and optical density. Transmittance of object in Fig. 1.4 is given by the equation-

$$T1 = I2 / I1 \qquad 0 < T1 < 1 \text{ -------- } (1.1)$$

Where I1 - is the Incident photon flux density , I2 - is the Transmitted photon flux density. Transmittance is the factor by which an object attenuates light intensity. Optical density of the object is given by equation

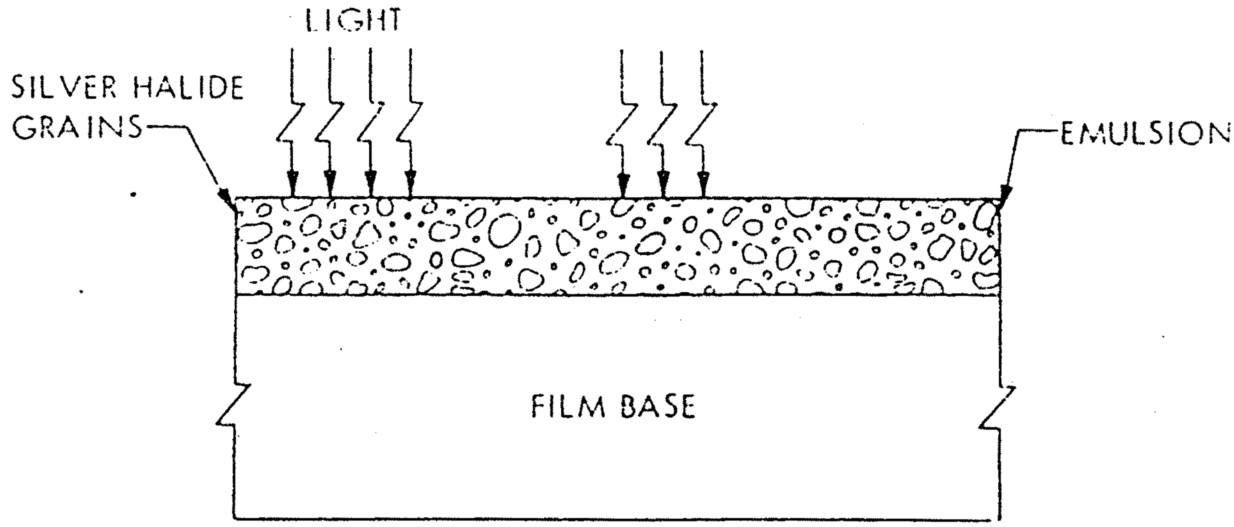
$$D1 = \log I1/I2 = \log 1/T1 = - \log T1 \qquad 0 < D1 <= \text{ -------- } (1.2)$$

Optical density is not confined to a convenient range and approaches infinity for opaque objects.

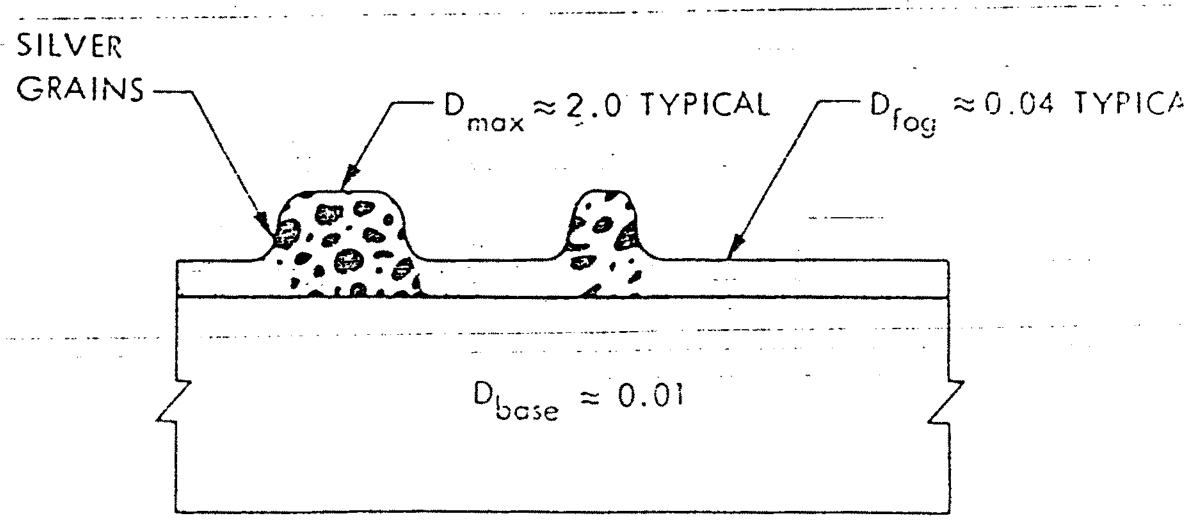
b) Photographic Process

During the manufacture of the film, the silver halide grains are activated to make them photosensitive(2). The figure 1.5 shows the development process of photographic film.

During exposure, different part of emulsion receive light at varying intensities as shown in figure 1.5a. When a silver halide grain absorbs, a photon, one or more molecules are reduced to silver, and the grain becomes "exposed". The development process reduces the silver halide grains to silver; however, the reduction reaction proceeds



1.5(a) Film During Exposure



1.5(b) Film after Exposure

much more rapidly on the exposed grains. After suitable period of time, most of the exposed grains and only a few of the unexposed grains have been reduced. Finally the unreduced grains are washed off the base. Thus, developed film shows a silver coating of varying thicknessas shown in figure 1.5b. In areas that have been heavily exposed, the entire emulsion thickness is maintained, giving a maximum density. In micro meter exposed areas, the silver halide grains are almost completely removed leaving only a "fog level" of approximately 0.04 optical density. Since the silver grains are largely opaque at optical frequencies, an image of gray tone is obtained where the brightness levels are reversed, producing the negative film.

c) Film Characteristics

1) Contrast :

High contrast films reproduce tone difference in the subject as large density differences in the photograph. Low contrast films translate tone differences as small density differences. Exposure depends on the incident intensity I and the duration of the exposure T. This implies that

$$E = I\ T \qquad \text{----------(3)}$$

where as E is energy per unit area at each point on the photo sensitive area.

The most widely used description of the photosensitive properties of photographic film is a plot of the density of the silver deposit on a film versus the logarithm of E. This curve is called characteristic curve, D log E curve (Density Vs. Exposure Curve) or H & D curves (after Hurter & Driffield, who developed the method). The figure 1.6 shows the typical H & D curve for a photographic negative film.

* **Gross Fog :** When the exposure is below certain level, the density in independent of exposure and equal to a maximum value called the gross fog.

* **Toe :** Point of curve where the density begins to increase with increasing exposure.

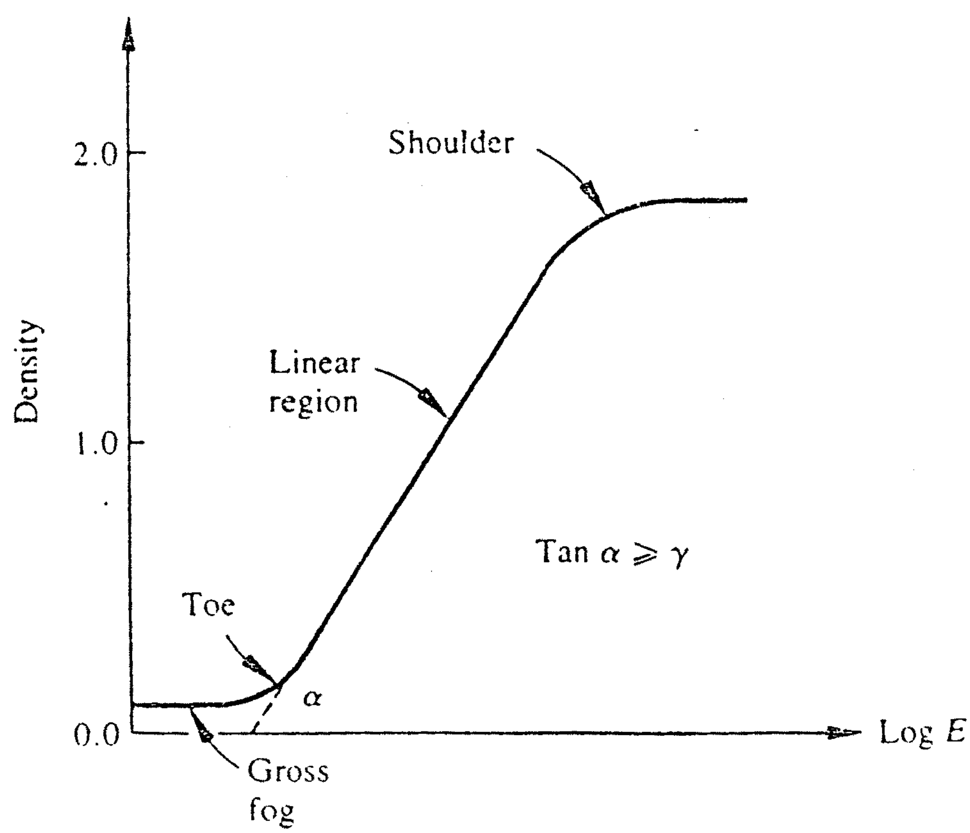
* **Linear Region :** Region of curve in which density linearly proportional to logarithmic exposure.

* **γ (Gamma) :** The slope of this curve is referred to as the film gamma (r). It is a measure of film contrast . The steeper the slope, the higher the contrast rendered. General purpose, medium contrast films have gamma in the range of 0.7 to 1.0, while high contrast films have gamma on the order of 1.5 to 10.

* **Shoulder :** Region of curve where it saturates is called shoulder.

2) Speed :

It determines how much light is needed to produce a given amount of silver on development. The lower the speed, the longer is


Shoulder
2.0
Density
Linear
region
1.0
Tan $\alpha \geqslant \gamma$
Toe
α
0.0
Log E
Gross
fog

1.6 H & D Curve

the exposure needed.

3) Graininess :

The image derived from the silver halide crystal is discontinuous in structure. This gives an appearance of graininess in figure enlargements. The effect is most prominent in fast films, which have comparatively large crystals. Slower, fine-grain emulsions are therefore preferable in applications where fine detail is desired.

4) Resolving power :

The fineness of detail that a film can resolve depends not only on its graininess, but also on the light scattering properties of the emulsion and on the contrast with which the film reproduces finer details. Fine-grain films with thin emulsion yield the highest resolving power.

Regardless of the type of the film, proper camera settings are also essential in obtaining acceptable picture. The principle settings are the lens diagpharm and shutter speed. As far as the present project is concerned, the details regarding the film are importent when the digitized image is to be preprocessed.

1.3.2 Image Digitizer

As per figure 1.1 the second component of the digital image processing system is image digitizer. Images, in the form in which they occur, are not directly amenable to computer analysis. Since computers work with numerical rather than pictorial data, an image must be converted to numerical form before processing.

A image digitizer must be able to divide an picture elements and address each individually, measure the gray level of the image at each pixel, quantize the data to produce an integer, and write out the array of integers on a data storage device. To accomplish this a digitizer must follow the (a) Philosophy of image acquization and (b) should have five elements (2).

a) Philosophy of Digitizing

The two important digitizing philosophies are viz., scan in and scan out, digitizing. In scan out system, the entire object is illuminated continuously, and sampling aperture allows the sensor to 'see' only on one pixel at a time. Figure 1.7.a

In scan-in system, only small spot of object is illuminated, all the transmitted light is collected by sensor. Figure.1.7b

By combining the above two principles a "Scan-in/Scan-out" a third system is also possible where the object is illuminated by a moving spot and sampled through a moving aperture that follows the spot (2).

The fourth philosophy of image digitizer is frame capturing in which the entire image is captured in a single frame using either a digitizing camera e.g. television camera or even two dimensional array of photosensitive solid state devices. In this technique the image is

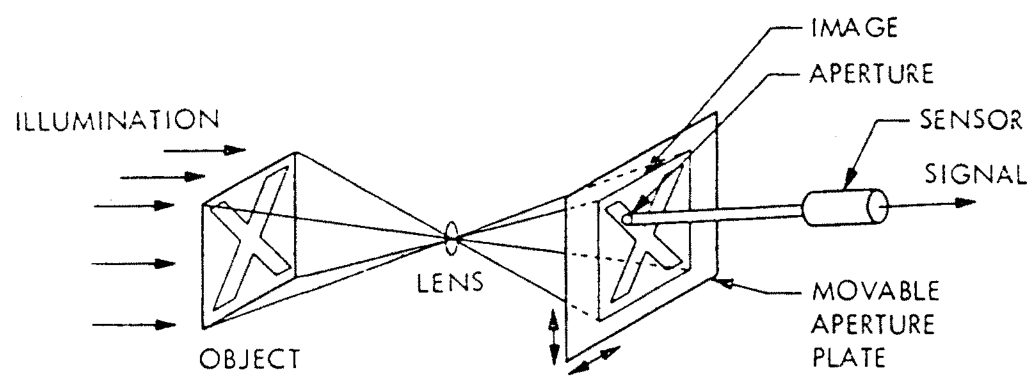
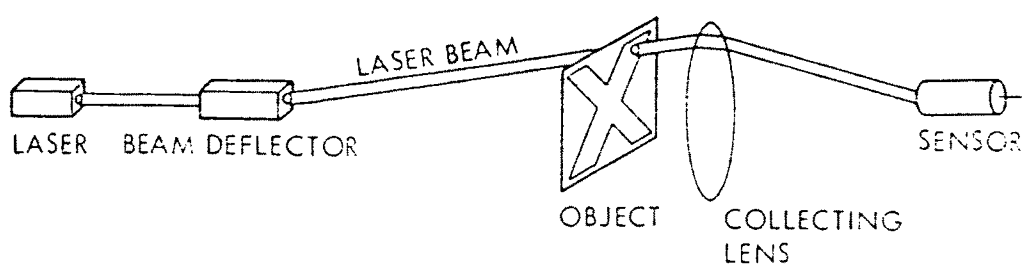


Figure1.7(a)A scan-out digitizer



1.7(b) Scan-In Digitizer

uniformly illuminated from the view side and the reflected rays from the object are the source of the information.

b) Elements of Digitizer

i) Sampling Aperture :

Sampling aperture allows the digitizer to accesses picture elements individually while ignoring the remainder of the image. Further more either the light source or the light sensor, or both must be behind a sampling aperture. Various types of light sources and light sensors used usually in Digital Imaging System are described below.

SOURCES :

* **Incandescent Bulb :** It is convenient for general illumination of the object or image being digitized for scan-out system. For scan-in and scan-in/scan-out work, the filament of a small bulb can be imaged with a lens and pinhole to form a bright spot.

* **Laser :** The laser generates a narrow, intense, coherent beam of light. May be useful for Scan-in and Scan-in/Scan-out system.

* **LED's :** Solid-state light-emitting diodes form compact and convenient light source, may find useful in Scan-in and Scan-in/Scan-out system.

* **CRT :** The brightness of the light spot produced by the electron

beam on the plane of phosphor coated glass plate illuminates the spot. If all the pixels/spots of the screen are focused by the fast moving electron beam, the entire screen gets illuminated, finding useful source of light in scan out digitizer system.

ii) Mechanism for Scanning the Image

Scanning allows the sampling aperture to address pixels in order, one at a time. For scanning the images, different mechanism are proposed, some of them are :

* Moving-Mirror Scanning mechanism
* Mechanical Scanning Devices.
* Electron Beam Scanning (vidicon Camera Tube).
* Image Dissector.
* The dual moving mirror image plane scanner. etc.

iii) Sensor

The sensor which can measure the brightness of the image at each pixel through the sampling aperture. It is commonly a transducer that converts light intensity into an electrical quantity. The sensor produce an electrical signal proportional to the intensity of light falling upon it. Three physical phenomena give rise to three types of light sensors.

* **Photoemissive Devices :** Photoemissive substances emit electrons

when irradiated with light. E.g.. Photo Tube and photo Multiplier Tubes.

* **Photovoltaic Cells :** Photovoltaic substances, such as silicon and selinium solar cells, generate an electrical potential when exposed to light. Photovoltaic cells are useful for solar power applications, but their show response makes them undesirable for image digitizing application.

* **Photoconductive Devices :** Conductors made up of sulphide and cadmium selenide, show a drop in their electrical resistance when exposed to light. E.g. Photo Resistors.

* **Semiconductor devices :** Devices constructed using P & N junction, change their junction characteristic under the influence of light.
E.g. Photo Diodes and Photo Transistors.

* **CCD's :** The promising new type of image sensor is the self scanning array of charge coupled devices. The charge developed in each sensor is shifted as a "Packet" down a series of internal capacitor until it reaches an external terminal with the continued development in the submatter, a compact and rugged CCD cameras has been developed and is available commercially.

The CCD's are fast and readily driven by the on chip electronics. These have become the photosensitive "retina" of video, still video and digital cameras. One of the major drawback of CCD is its relatively expensive manufacturing cost - particularly when designed for the high-resolution imageing.

*** New Semiconductor Photo Sensor :** As per the recent report a totally new sensor technology has been devoloped (23). It is reported that C MOS-chip performing as a sensor and it is [illegible] cheaper and consumes extremely less power compared to conventional devices. It is predicted that C MOS sensors will replace the traditional CCD Imageing chips.The C MOS sensors can transfer images to camera memory cards more quickly than CCD's may produce cleaner images, and do not require seperate ADC's.

iv) Quantizer

Quantizer converts the continuous O/P of the sensor into an integer value. Typically, the quantizer is an electronic circuit called Analog to Digital Converter. This unit produces a number that is proportional to the I/P voltage or current. These are available as Industry standard components .

v) Output Device

The gray level values produced by the quantizer must be stored in an appropriate format for subsequent computer storage devices in the computers are available, especially the hard disk.

Remaining two elements of digitizer are processing, storage and display of the image.The specifically required component of this category are elaborated in subsequent chapters.

1.4 SCOPE OF THE DISSERTATION

The foregoing discussion is aimed at depicting uses of digital image processing for the purpose of medical diagnostics. Also an attempt is made to provide in depth the preliminary information about the digital image processing system. In fact the subject in the context specific manner i.e., the digital image acquisition and processing as required for the medical diagnostics.

Hence it is important to note that the digital subtraction angiography is a very involved technique and the commercial angiographic systems have inbuilt image digitization capabilities. Nevertheless, there exist a wide range of radio logical imageing, where stand alone image digitizers may provide various added advantages over the existing methods of image interpretation.

The modern radiological laboratories are equipped with a versatile X- ray machines with a dedicated image intensifier. The radiologist views the region under investigation via the image intensifier and the X-ray graphs are imaged, the conventional X-ray negatives film. It has been observed that the direct digitization and real time image analysis is not a routine requirement for the radiologists. Nevertheless, if we adopt the technique like dual energy imageing (1), coupled with the digital image analysis, we can access a few structures, which are otherwise hidden in the conventional radiographic methods. To be more precise, the technique of the digital dual energy imageing may access low contrast structures which are masked by the high contrast material like bones. We want to emphasis that the digital image processing has very generalised application not limited only to the dual energy imageing.

Few other important applications of the image digitizer are enumerated below.

* The X-ray images could be processed by application of high pass filtering algorithm to improve the sharpness of image (3).
* The histogram equalization could also be employed for further enhancement of the image characteristic.
* In addition to the X-ray images, the images aquised by the remote sensing satellite could also be digitized using the setup design and presented in this dissertation.

This paragraph attempts to define precisely the activity taken up as a part of this dissertation. Realising the need of image digitizer for the images in the form of negatives, mechanical stage has been designed to move the film for a scan-in digitizer. The scanning mechanism selected is based on PM-DC motor (7) for the X-axis movement and stepper motor for the Y-axis movement. As both these mechanisms are included, the design becomes most versatile. The DC and stepper motor control system are designed to be PC Add-on.

Within the limited laboratory and workshop available at our parent institute, the Shivaji University Centre for P. G. Studies, the testing of the proposed hardware has been carried out at the laboratory of Department of Material Science, Indira Gandhi Centre for Atomic Research, Kalpakkam, Chennai. For the testing purpose the PC interfacable mechanical stage was available at the IGCAR, Kalpakkam. We had to modify this assembly for the purpose of testing. Another important component for the testing is Densitometer. The densitometer is also made available to us by the IGCAR. We acknowledge with thanks the laboratory facility made available to us by IGCAR. Also we acknowledge the help received during the course of testing by Prof. B. Purnaih and Prof. K.Govindraj.

The software as required for the present image digitizer is also developed at the laboratory of IGCAR. The chapter #2 of dissertation provides the background information regarding the image digitizer and the methods to design and interface the custom hardware to IBM-PC.

The chapter #3 describes the design of the mechanical assembly and concerned hardware which synchronizes the mechanical movements with data acquisition by the computer. The chapter #4 describes the testing procedure adopted. Also few sample listings of the interface software and printout of the digitized image is included in this chapter.