MEDICAL IMAGE PROCESSING
K.M.M. Rao, V.D.P. Rao

Medical Imaging

Imaging technology in Medicine made the doctors to see the interior portions of the body for easy diagnosis. It also helped doctors to make keyhole surgeries for reaching the interior parts without really opening too much of the body. CT Scanner, Ultrasound and Magnetic Resonance Imaging took over x-ray imaging by making the doctors to look at the body's elusive third dimension. With the CT Scanner, body's interior can be bared with ease and the diseased areas can be identified without causing either discomfort or pain to the patient. MRI picks up signals from the body's magnetic particles spinning to its magnetic tune and with the help of its powerful computer, converts scanner data into revealing pictures of internal organs. Image Processing techniques developed for analyzing remote sensing data may be modified to analyze the outputs of medical imaging systems to get best advantage to analyze symptoms of the patients with ease.

Advantages of Digital Processing for Medical Applications

- Digital data will not change when it is reproduced any number of times and retains the originality of the data.
- Offers a powerful tool to physicians by easing the search for re-presentative images;
- Displaying images immediately after acquiring;
- Enhancement of images to make them easier for the Physician to interpret;
- Quantifying changes over time;
- Providing a set of images for teaching to demonstrate examples of diseases or features in any image;
- Quick comparison of images.

Digital Image Processing Requirements for Medical Applications

- Interfacing Analog outputs of sensors such as microscopes, endoscopes, ultrasound etc., to digitizers and in turn to Digital Image Processing systems.

- Image enhancements.
- Changing density dynamic range of B/W images.
- Color correction in color images.
- Manipulating of colors within an image.
- Contour detection.
- Area calculations of the cells of a biomedical image.
- Display of image line profile.
- Restoration of images.
- Smoothing of images.
- Registration of multiple images and mosaicing.
- Construction of 3-D images from 2-D images.
- Generation of negative images.
- Zooming of images.
- Pseudo coloring.
- Point to point measurements.
- Getting relief effect.
- Removal of artifacts from the image.

Advanced Digital Image Processing Techniques

- Neural Network based Image Processing.
- Statistical approach for texture analysis.
- Segmentation in color and B/W images.
- Expert system based Image Processing.
- Application of object oriented programming techniques in Image Processing environments.
- Shape in machine vision.
- Multispectral classification techniques.
- Auto focussing techniques for MRI images.
- Thresholding technique for finding contours of objects.
- Sequential segmentation technique to find out thin vessels in medical images and hair line cracks in NDT.
- Fractal method for texture classification.
- Data compression techniques using fractals and Descrete Cosine Transformers.
- Image restoration methods using Point Spread functions and Wiener filter etc.

Image Processing Systems for Medical Applications

(a) Endoscopy

In each *endoscope*, there are two fiber bundles. One is used to illuminate the inner structure of object. Other is used to collect the reflected light from that area. The endoscope is a tubular optical instrument to inspect or view the body cavities, which are not visible to the naked eye normally.

For a wider field of view and better image quality, a telescope system is added in the internal part of the endoscope. Gastro-intestinal fiberoscopes and laparoscopes are important endoscopes used in hospitals for examination, treatment of diseases and surgery. Technological advances in computers and semiconductor chips have brought about lot of changes in health care during the last decade. For digestive diseases, this advancement is represented by the incorporation of charge-coupled device (converts optical image to electronic image) into gastrointestinal endoscopy. These *video endoscopes* use xenon arc lamps as light source. Color Imaging is achieved by incorporating RGB filters between Xenon Lamp Supply and the proximal end of the endoscope. The other approach to the generation of color image is to divide the available cells on the CCD among the three primary colors by means of filters. Three images one for each color are then produced simultaneously by the CCD.

Endoscopic pictures are converted to digital images by using CCD cameras and associated image digitizer circuits into a PC/AT. The recorded images can be image processed for better quality.

Stereo Endoscope

Two cameras are mounted on a single laproscope. Images from the cameras are transmitted alternately to a video monitor. Few types of display techniques are used to realise *stereo images* from two-dimensional images recorded from the above cameras. As the cameras transmits images at 60-120 cycles per second a three-dimensional, real time image is perceived. As the images are transmitted at a high frequency, the effect is that of seeing different images simultaneously.

(b) *Computer* Tomography (Ct)

Computerised Axial Tomography or computer transmission tomography or computer tomography is a method of forming images from X-rays. Measurements are taken from X-rays transmitted through the body. These contain information on the constituents of the body in the path of the X-ray beam. By using multidirectional scanning of the object, multiple data is collected.

An image of a cross-section of the body is produced by measuring the total attenuation along rows and columns of a matrix and then computing the attenuation of the matrix elements at the intersections of the rows and columns. The number of mathematical operations necessary to yield clinically applicable and accurate images is so large that a computer is essential to do them. The information obtained from these computations can be presented in a conventional raster form resulting in a two dimensional picture.

The timing, anode voltage and beam current are controlled by a computer through a control bus. The high voltage d.c. power supply drives an X-ray tube that can be mechanically rotated along the circumference of a gantry. The patient lies in a tube through the center of the gantry. The X-rays pass through the patient and are partially absorbed. The remaining X-ray photons impinge upon several radiation detectors fixed around the circumference of the gantry.

The detector response is directly related to the number of photons impinging on it and hence to the tissue density. When they strike the detector, the X-ray photons are converted to scintillations. The computer senses the position of the X-ray tube and samples the output of the detector along a diameter line opposite to the X-ray tube. A calculation based on data obtained from a complete scan is made by the computer. The output unit then produces a visual image of a transverse plane cross-section of the patient on the cathode ray tube. These images are also stored into computer for image processing.

(c) Ultrasonic Imaging System

Ultrasonography is a technique by which ultrasonic energy is used to detect the state of the internal body organs. Bursts of ultrasonic energy are transmitted from a piezo-electric or magnetostrictive transducer through the skin and into the internal anatomy. When this energy strikes an interface between two tissues of different acoustical impedance, reflections (echoes) are returned to the transducer. The transducer converts these reflections to an electric signal proportional to the depth of the interface, which is amplified and displayed on an oscilloscope. An image of the interior structure is constructed based on the total wave travelling time, the average sound speed and the energy intensity of the reflected waves. The echoes from the patient body surface are collected by the receiver circuit. Proper Depth Gain Compensation (DGC) is given by DGC circuit. The received signals are converted into digital signals and stored in memory. The scan converter control receives signals of transducer position and TV synchronous pulses. It generates X & Y address information and feeds to the digital memory. The stored digital image signals are processed and given to digital-to-analog converter. Then they are fed to the TV monitor. These signals are converted to digital form using frame grabber and can be stored onto PC/AT disk. Wherever the images lack in contrast and brightness, Image Processing techniques may be used to get full details from Ultrasound images. Figure 1 shows Ultrasound Imaging System.
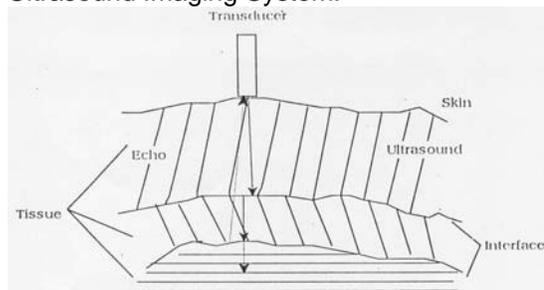

Fig 1. Ultrasound Imaging System

Magnetic Resonance Imaging (MRI)

Superconducting magnets are used in *MRI* systems to provide strong uniform, steady magnetic fields. The superconducting magnetic coils are cooled to liquid helium temperature and can produce very high magnetic fields. Hence the signal to noise ratio of the received signals and image quality are better than the conventional magnets used in the MRI systems.

Different gradient coil systems produce a time varying, controlled spatial non-uniform magnetic fields in different directions. The patient is kept in this gradient field space. There are also transmitter and receiving RF coils surrounding the site on which the image is to be constructed. There is a superposition of a linear magnetic field gradient on to the uniform magnetic field applied to the patient. When this superposition takes place, the resonance frequencies of the processing nucleii will depend on the positions along the direction of the magnetic field gradient. This produces a one- dimensional projection of the structure of the three dimensional object. By taking a series of these projections at different gradient orientations using X, Y and Z gradient coils a two or three-dimensional image can be obtained. The slice of the image depends upon the gradient magnetic field. The gradient magnetic field is controlled by computer and that field can be positioned in three time invarient planes (X, Y and Z). The transmitter provides the RF signal pulses. The received nuclear magnetic resonance signal is picked up by the receiver coil and is fed into the receiver for signal processing. By two-dimensional Fourier Transformation, the images are constructed by the computer and analysed using image processing techniques.

Multispectral tissue classification of Magnetic Resonance Imaging (MRI)

- MRI data consists of multiple channels of independent but geometrically registered medically significant data, it analogous to multispectral remote sensing data.

- Multispectral analysis of proton MR images may provide tissue characteristic information encoded therein.

- Using well-established methods for computer processing of multispectral images, tissue characterization signatures are sought; using supervised or unsupervised classification methods.

The principal advantages of Multispectral analysis of MRI include:

∗ It is a quantitative means of analyzing multidimensional image data, such as MRI.

∗ In other applications, multispectral methods have been useful in identifying subtleties that would otherwise be overlooked.

∗ MR images are intrinsically multispectral. The data in a set of MR images is highly redundant, both geometrically and radiometrically.

∗ Multispectral methods are well developed, have been implemented on computers, for which software is readily available that can process MR image data efficiently, and can adapt to existing MR scanners.

Associated Problems With X-Ray Imaging

X-ray films have large dynamic range to accommodate maximum possible details of X-ray image (as shown in Fig.2). Details in the darker portion and brighter portion get saturated and are not possible to interpret easily. X-ray images can be converted into digital form using X-ray flouroscopy technique or by digitising X-ray film using scanners. By applying Image Processing techniques, the digital images can be manipulated for easy interpretation. Using these techniques, additional X-ray exposures can be reduced to the patient.
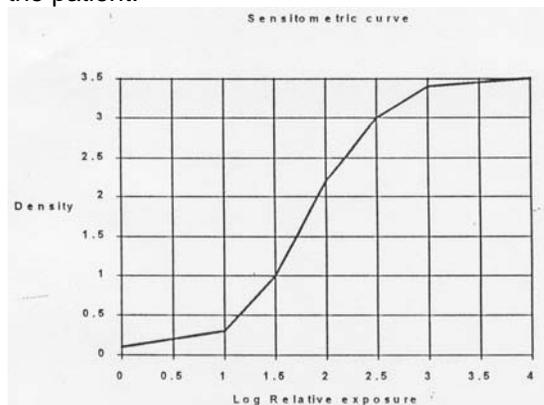

Fig2. Sensitometric curve of X-ray image

Medical Imaging System (MIS)

During the next years, profound changes are expected in computer and communication technologies that will offer the *medical imaging systems* industry a challenge to develop advanced telemedicine applications of high performance. Medical industry, vendors, and specialists need to agree on a universal MIS structure that will provide a stack of functions, protocols and interfaces suitable for coordination and management of high-level image consults, reports and review activities.

Most hospital imaging departments have to computerise information systems in which patient images and reports are to be stored. The stored information can be handled by two major types of medical applications, the *integrated Report and Review* applications. The former is performed by experts (eg. radiologists) in four steps :

1. Retrieving and viewing images;
2. Processing, interpretation and annotation of the diagnosis;
3. Composition of final diagnostic multimedia report; and
4. Permanent storing in the database.

The latter allows many simultaneous users (authorized patient-care personnel) to view, read, and listen to the diagnostic report; these users do not alter the handled data.

However, recent advances in high-speed networking technology have opened to hospitals the possibility to obtain applications enhanced with conferencing services, referred to as *Consult* applications, to geophysically distributed users. For example, physicians located in rural health care centres could consult one or more experts located in the regional hospital of an urban area and gain access to patient images and other information through parallel interfacing with the database of the hospital's imaging department.

The implementation of such applications requires an appropriate infrastructure with high-speed networking and image manipulation facilities. The Consult application is achieved by accessing picture archiving and communication systems (PACS).

Picture Archiving And Communication Systems (PACS)

• In application domains such as remote sensing, astronomy, cartography,

meteorology and medical imaging, images comprise the vast majority of acquired, processed and archived data.

- The medical imaging field in particular, has grown substantially in recent years, and has generated additional interest in methods and tools for the management, analysis and communication of medical image data.

- PACS are currently used in many medical centres to manage the image data.

- Important considerations in the design and implementation of Image Database (IDB) systems are:

    * Image feature extraction;
    * Image content representation and organization of stored information;
    * Search and retrieval strategies;
    * User interface design

- Recent proposals regarding the design of IDB systems and the management of image data are influenced by the 'object-oriented' approach.

- This approach offers a framework within which different types of entities (eg. different kinds of image data) and operations (eg. image processing functions, image access mechanisms, etc.) may be uniformly represented as 'objects'.

- Objects are grouped into 'classes', which can also be objects. Object classes are organised into hierarchies, thus taking advantage of the property of 'inheritance'.

- Image retrieval using color, shape and texture.

- Content based image retrieval for image databases.

- Region detection in medical images. Eg. locate endocardium boundaries of the left and right ventricles from gradient - echo MR images.

Current research activities are interested in the implementation of smaller and more flexible systems than PACS, called *miniPACS.*

Digital Image Processing For Ophthalmology

- To analyse retina, optic nerve, pigment epithelium and choroid in the ocular fundus.

- Color slides have a resolution of 4000 x 3000 pixels.

- Fluorescein Angiograms have a resolution of 1800 x 1350 pixels.

- Common standard digital cameras have resolution of 512 x 480, which may be sufficient for obtaining relevant information of blood vessels etc. (Present day technology: 2048 x 2048 element resolution cameras).

- 8-bit resolution (indicative of contrast) is sufficient for most of the Opthalmology images.

Indo Cyanine Green (Icg) Imaging

- *ICG Angiography* is basically similar to that of fluorescein angiography.

- Differences are :

    * Spectral characteristics and,
    * Permeability from choroidal capillaries.

- Sodium fluorescein dye used in fluorescein angiography has a maximum absorption at 485nm and peak emission at 520nm.

    * The largest portion of excitation and emission energy of this visible light is absorbed by the retinal pigment epithelium and macular xanthopyll.
    * As a result, it is difficult to obtain sufficient fluorescence from the deeper layers of choroidal vessels.

- In blood, about 20% to 40% of injected sodium fluorescein remains unbound to

serum albumin. This unbound fluorescein leaks rapidly from the highly fenestrated choriocapillaries into the choroidal anatomy. Because of this, details of the choroidal vascular pattern are obscured. For these two reasons, fluorescein angiography cannot provide useful information on choroidal circulation.

- In ICG angiography, the maximum absorption and peak fluorescence of Indocyanine dye is in the spectrum at 805nm and 835nm respectively. This near infrared light can penetrate the retinal pigment epithelium much more effectively than visible light, allowing uninterrupted examination of the choroidal vascular network. In addition, since approximately 98% of ICG dye in blood is bound to serum proteins, it leaks very slowly from the choroidal capillaries.

Corneal Image Analyzer

Corneal Image Analyzer (CIA) is software developed at NRSA for analyzing Endothelial images of cornea. The corneal image consists of a set of hexagonal shaped cells of different sizes. The aim of this software is to compute the statistics of the cornea endothelial such as the cell density, minimum, maximum & mean cell sizes, their standard deviation, co-variance etc. This data is useful for various studies such as dystrophy and degeneration, intraocular lens implantation, corneal transplantation, drug toxicity, glaucoma, etc.

The cornea of the patient is scanned by special devices and these images can be analyzed using computers at greater speed and precision. Requirements such as endothelial cell analysis and cell area measurement are currently done manually.

The images of endothelium can be filmed with a 35mm still camera attached to the specular microscope.

The images can be fed to the computers as input by scanning the films/prints or by capturing the images directly from the patient's eye through high resolution and high sensitive CCD camera whose video output is connected to a Frame grabber board on a PC-AT. The analysis is done on a high resolution monitor. The quantitative measurements can be done on computers using image processing techniques. Prints of these images are used for diagnosis.

The software gives a printout of the cell density, minimum, maximum and mean cell sizes, standard deviation and coefficient of variance of the cell sizes, histogram of cell sizes and distribution of cell areas. Several reports of a patient at various dates are combined to give a combined report.

Fundus Image Analyzer

Many diseases of the human visual system and of the whole body can have a dramatic impact on the 3-dimensional geometry of the ocular fundus. Glaucoma is probably the most important disease in this category. It increases the cupping of the optic nerve head at an early stage of the disease, in many cases before a reliable diagnosis can be made and visual field losses occur. The early diagnosis of glaucoma is a major issue in general public health care. Quantitative assessment of fundus geometry is expected to be helpful for this purpose.

The ocular fundus consists of several layers of highly transparent tissue, each having individual physical properties, reflectivity, absorption and scatter. 2-dimensional geometry normally specifies sub-structures such as the vessel pattern or the area of pallor delineated by contrast or color variations. It is less important how deep they are located within the fundus. Depth is commonly associated with the topography of the interior limiting surface of compact retina and optic disc tissue.

A system for ocular fundus analysis consists of two parts, the image acquisition and the analysis software. The image is normally obtained using a telecentric fundus camera (Ex. Ziess-30 degree fundus camera). The image is captured onto a slide film. The film is scanned using a slide film scanner and transcribed to a Personal Computer. Alternatively the image can be directly acquired from the camera by interfacing it to the Personal Computer using a frame grabber card. Fundus Image Analyzer (FIA) is the optic disc analysis software developed at NRSA. The present version operates on 2-D images only and does not support

depth/volume calculation. Figure 3 shows the Fundus Image Analysis System.

Fig 3. Image Acquisition and processing of endothelial cells of cornea

The following is the list of parameters calculated using this software:

Disc diameter: Specifies the horizontal/vertical diameter of the selected disc edge.
*Cup diameter:* Specifies the horizontal/vertical diameter of the selected cup edge.
Disc Area: Specifies the area within the selected disc edge.
Cup Area: Specifies the area within the selected cup edge
Rim Area: Specifies the area between the selected disc edge and the calculated cup edge.
Cup-to-Disc Ratio: Specifies the ratio of the cup size to disc size.

Quantitative measurements of fundus image are shown in Figure 4.
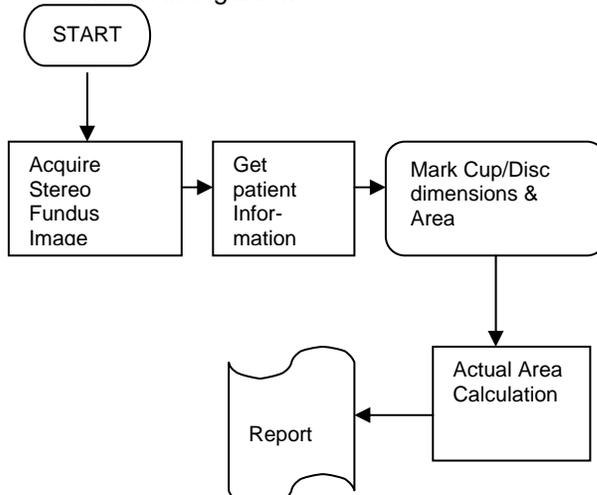
This package is useful for quantitative measurements of the optic nerve. If the depth information is derived from the stereo pair, then volume calculations & profile generations can also be done.

Automatic Classification of Cancerous Cells from a Digitized Picture of a Microscope Section

Mathematical morphology is used to remove the background noise from the image and the nuclei of the cells are segmented. These nuclei are analysed for the shape and size. The texture of the nuclei is evaluated by using *KOHONEN NEURAL NETWORK*; automatic classification of the image is done.

Structure-Sensitive Adaptive Contrast Enhancement Methods

- For medical images the overall goal of display is the detection, localization and qualitative characterization of anatomical objects represented by the intensity variations in the recorded data.

- *Global histogram equalization* is justified by the argument that for noise-free images, it maximally transmits information as to scene intensity values.

- *Adoptive Histogram Equalization* has demonstrated its effectiveness in the display of images from a wide range of imaging modalities, including CT, MRI and Radiotherapy portal films.

- *Gordon's technique* is another method for contrast-based enhancement for the detection of edges within the contextual region.

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