A STUDY ON IMAGE QUALITY IN TELEDERMATOLOGY AND TELEPATHOLOGY OF TELEMEDICINE USING A DIGITAL CAMERA

A DISSERTATION SUBMITTED FOR THE PARTIAL FULFILLMENT OF MASTER'S DEGREE OF SCIENCE IN PHYSICS

BY

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RECOMMENDATION

It is certified that Mr. Krishna Bahadur Rai has carried out the dissertation work entitled **"A STUDY ON IMAGE QUALITY IN TELEDERMATOLOGY AND TELEPATHOLOGY OF TELEMEDICINE USING A DIGITAL CAMERA"** under our supervision and guidance. We have checked and verified his observation from time to time so we recommend the dissertation in the partial fulfillment for the requirement of Master's Degree of Science in Physics at Tribhuwan University.

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ABSTRACT

This dissertation entitled “A STUDY ON IMAGE QUALITY IN TELEDERMATOLOGY AND TELEPATHOLOGY OF TELEMEDICINE USING A DIGITAL CAMERA” is based on the rating method in image of patient characteristics that affects whether the disease can be diagnosed or not.

Telemedicine (Teledermatology and Telepathology) are being ever increasing popular and advanced. The use of teledermatology and telepathology for clinical diagnosis are not always without risk because sufficient images quality may not be there in images. To get sufficient diagnostic information, sufficient quality of images must be used and detection display and interpretation should be optimal. An image taken depends upon various factors and specially has an effect on diagnostic of disease. An optimized image procedure is one in which image quality of patient characteristics is properly balanced. In this context, a general study of the image quality of image formation in diagnostic teledermatology and telepathology are the major works performed at Department of dermatology, TUTH, T.U., Kathmandu; Kathmandu Medical College, K.U. Kathmandu and Health Net Maharajgunj, Kathmandu Nepal.

In the test carried out to study the image quality of teledermatology and telepatholgy (telehistology and telecytology), there were found that the gold standard for any specialist referred traditional way in case of pathology viewing through microscope and in case of dermatology face to face consultation remain same with the image of diseased patient used to diagnosis.

Here it was found that the area under the ROC curve for dermatology is 0.922 means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 92% of the time. And for histology and cytology area under ROC curve are 0.909 and 1.000 respectively. These larger area support high diagnostic accuracy through the high image quality. Again the P-value for dermatology, histology and cytology are respectively 0.000, 0.000 and 0.001. Such that P is low i.e. $P < 0.05$ which is statistically significant. Therefore, there is evidence that image has an ability to detect disease.

And we also found that the correct test capacity of expert doctor in the diagnosis of cases through image being high quality. For this, the P-value from SPSS output is 0.000 such that $P<0.005$ which is statistically significant again. So that for high accuracy of diagnostic test supports that the image quality is good.

Finally this research says that the good image quality is necessary for correct diagnosis in teledermatology and telepathology. However, probably most important for the most part of telemedicine is far from being a mature discipline, and much work remains to be done to establish its place in health care delivery.

CONTENTS

Pages

CHAPTER – TWO, GENERAL THEORY AND APPLICATION

CHAPTER – THREE, IMAGE QUALITY OF TELEDERMATOLOGY AND TELEPATHOLOGY

CHAPTER – FOUR, DIGITAL CAMERA

Chapter - One

INTRODUCTION

1.1 General:-

Telemedicine is the delivery of health care and exchange of health care information across distances by the use of electronic communication and information technology. It includes the whole range of medicine including diagnosis treatment and prevention of disease, continuing education of health care providers and consumers, and research and evaluation performed when distance is an issue. The roots of telemedicine can be traced back centuries, when medical care was limited to the radius in which the physician was available. As a result, distance between patient and physician played a large role in driving the costs of health care and the volume of the health care delivery. To deliver treatment, patients and providers had to be co-located. Hence, health care was limited by the need to relocate people and equipment, distances involved and the speed of information transfer. (1)

1.1.1 History of Telemedicine:-

Most telemedicine has clearly occurred in the last 20-30 years, concomitant with advances in information technology. If, however, telemedicine is considered to be any medical activity performed at a distance irrespective of how the information is transmitted, its history is much older. An early example of medicine at a distance be it one of the first public health surveillance networks, was in the middle ages, when information about bubonic plague was transmitted across Europe by such means as bonfires. With developments in national postal services in the mid-19th century, the means by which more personal health-care delivery at a distance could be performed was facilitated, and the practice of

physician providing diagnosis, and the direction for a cure, was established.

In the mid-19th century, telegraphy signaling by wires also began and was quickly deployed by those providing and planning for medical care.

The telephone has been used for delivering health services since its invention in the late 19th century, and for 50 or 80 years remained the mainstay of communication for such purposes. However, it was realized as early as 1910 that the telephone could be used for purposes other than voice communication; amplified sounds from a stethoscope were transmitted through the telephone network and similar devices are still used today. Other uses for the ordinary telephone network have since been released and include the transmission of electrocardiograms (ECGS) and electroencephalograms (EEGS).

The next development of widespread significance was at the end of the 19th century when communication by radio became possible. It was set up in 1935 and in its first 60 years assisted with over 42,000 patients, making it the largest organization in the world to use telemedicine to provide health care to seafarers. Radio medical advice for passengers in long distance air journeys has also been provided more recently. For in-flight medical incidents that require professional assistance. Assistance can be obtained from on-call health-care workers on the ground.

1.1.2 The birth of Modern Telemedicine:-

The recent development of telemedicine has been facilitated on two fronts. First, there are the advances in electronic methods of communication. Initially, analogue methods were used, but now modern digital communication techniques are the mainstay. Second, telemedicine has developed because of the pioneering efforts of a few organizations and individuals. While these were no doubt of great importance in

fostering the development of telemedicine and telecommunications generally, the efforts of a few individuals using readily-available commercial equipment have arguably been just as important for the development of telemedicine. It is interesting to note that in the 40-80 years since these individuals initiated their ventures things have changed relatively little, as far as who are doing research of practical value, and how it is being done.

A major influence on the development of telemedicine was the introduction of television. By the late 1950s, developments in closed-circuit television and video communications were made use by medical personnel, who began to employ them in clinical situations. The system permitted interactive consultations between specialists and general practitioners, and facilitated education and training at the distant site. Early example of television linking doctors and patients was at the Massachusetts General Hospital/Logan International Airport Medical station, which was established in 1967. This used a two-way audiovisual microwave circuit and permitted care to be provided to passengers and airport employees 24 hour a day by nurses, supplemented by physician expertise using the audiovisual look. In an early report of the feasibility of this method of delivering health care, the observations of two episodes were documented. It is note worthy that few reports of telemedicine projects since have contained such numbers of episodes performed. More recently, there has been a major growth in real-time telemedicine with the wide availability of video-conferencing systems. This has been made possible because of improvements in digital communication and the introduction of low-cost computing, many of the video conferencing system, systems now being based on PCs Systems.

The recent developments of mobile pones and satellite communications have allowed mobile telemedicine. [(2)]

Today telemedicine represents the experiences, opinions, perceptions and interests of a vast number of individuals and organizations. Most operational telemedicine services, of which the majority concern diagnosis and clinical management at a distance, are in industrialized countries.

Telemedicine clearly has a role in the case of emergencies in remote environments such as the Antarctic and in ships or aeroplanes, where it may be difficult, if not impossible, to get medical care to the patient in time. In countries with unstable or weak economics, however, where health-care services are often not a priority, telemedicine also permits access to services that would not otherwise be available.

Telemedicine has advantages in remote or rural areas where it improves access to health services, obviating the need for patients and health-care workers to travel. Even in urban areas, however, telemedicine can improve access to health services and to information. Telemedicine has also been shown to improve the consistency and quality of health care. It may sometimes also be cheaper than conventional practice, although as previously mentioned, scientifically sound economic appraisals of telemedicine applications are only just beginning to appear.[2]

Nearly a decade ago, smith described what he termed "the future of health-care systems, where information technology and consumerism will transform health care worldwide. He commented that most sectors of industrialized economics, such as transport, manufacturing and telecommunications, have been transformed in the past 20 years, where as health care has not. He described a view of the future where health care will be provided through both integrated and virtual systems, anywhere, anytime, and where clinicians will focus on long-term relationships with patients, suppliers, founders and insurers, with the patient's role being

much greater and more assertive than at present. Smith predicted in figure 1.1.2.1 that ‘industrial age Medicine' will invert to become 'information age health care', where 'instead of being viewed as the apex of a system of care that hardly recognizes the large amount of self-care that occurs now, professional care will be viewed as a support to a system that emphasizes self-care.[3]

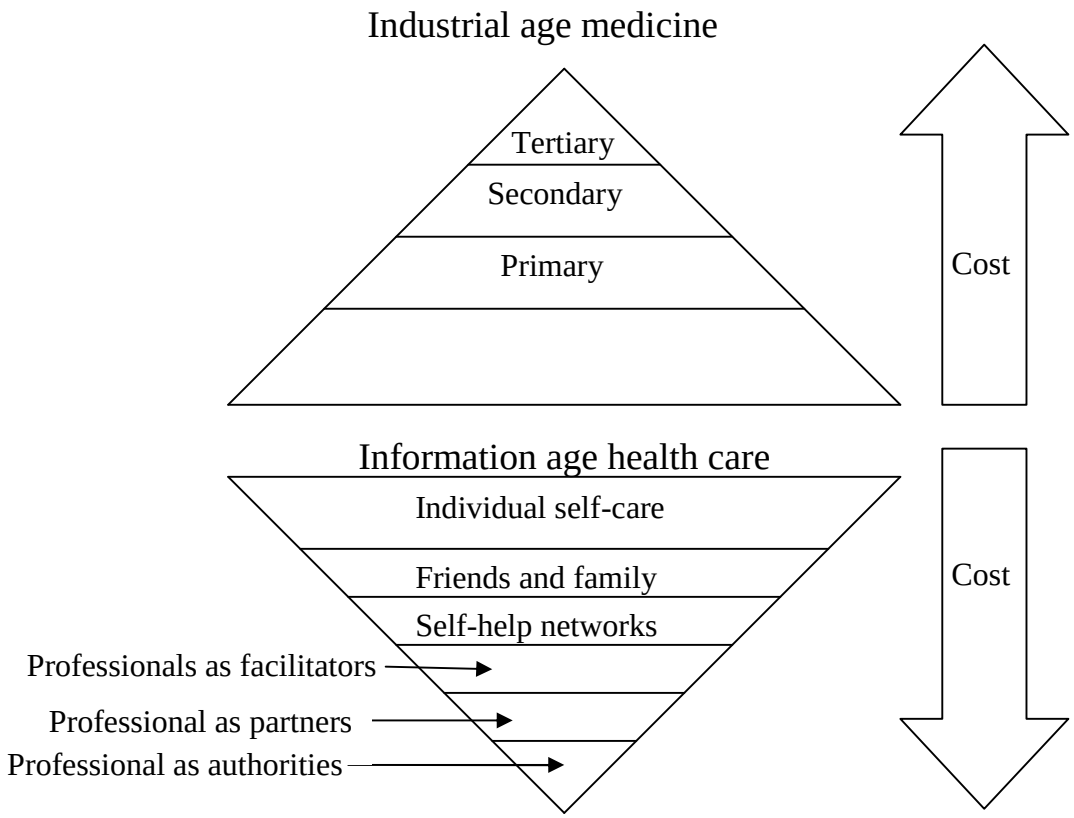


Figure 1.1.2.1: The transformation from industrial age medicine to health care in the information age (based on Smith) [3]

Telemedicine is not a technology or a separate or new branch of medicine or for that matter even new. It is also not the panacea that will cure all of the world's health-related problems or a means by which health-care workers can be replaced. It is also not an activity for antiquarians or Luddites, who range from those who are simply not at ease with the use of electronic machinery, right through to those who feel that telemedicine threatens the very fabric of the practice of medicine,

and as such should be actively opposed. Equally, however, it is not the sole territory of 'computer nerds' or 'technophiles'. In fact, the tendency of these individuals to concentrate on the technical rather than the practical when discussing telemedicine may explain the antipathy of some clinicians towards practicing medicine this way. Sensible, practical presentations by those who have actual experience of telemedicine is not for them, either because it is 'gimmicky', industry-driven and therefore 'less than respectable', or unfathomable.[2] Fig 1.1.2.2 here under shows the telemedicine system.

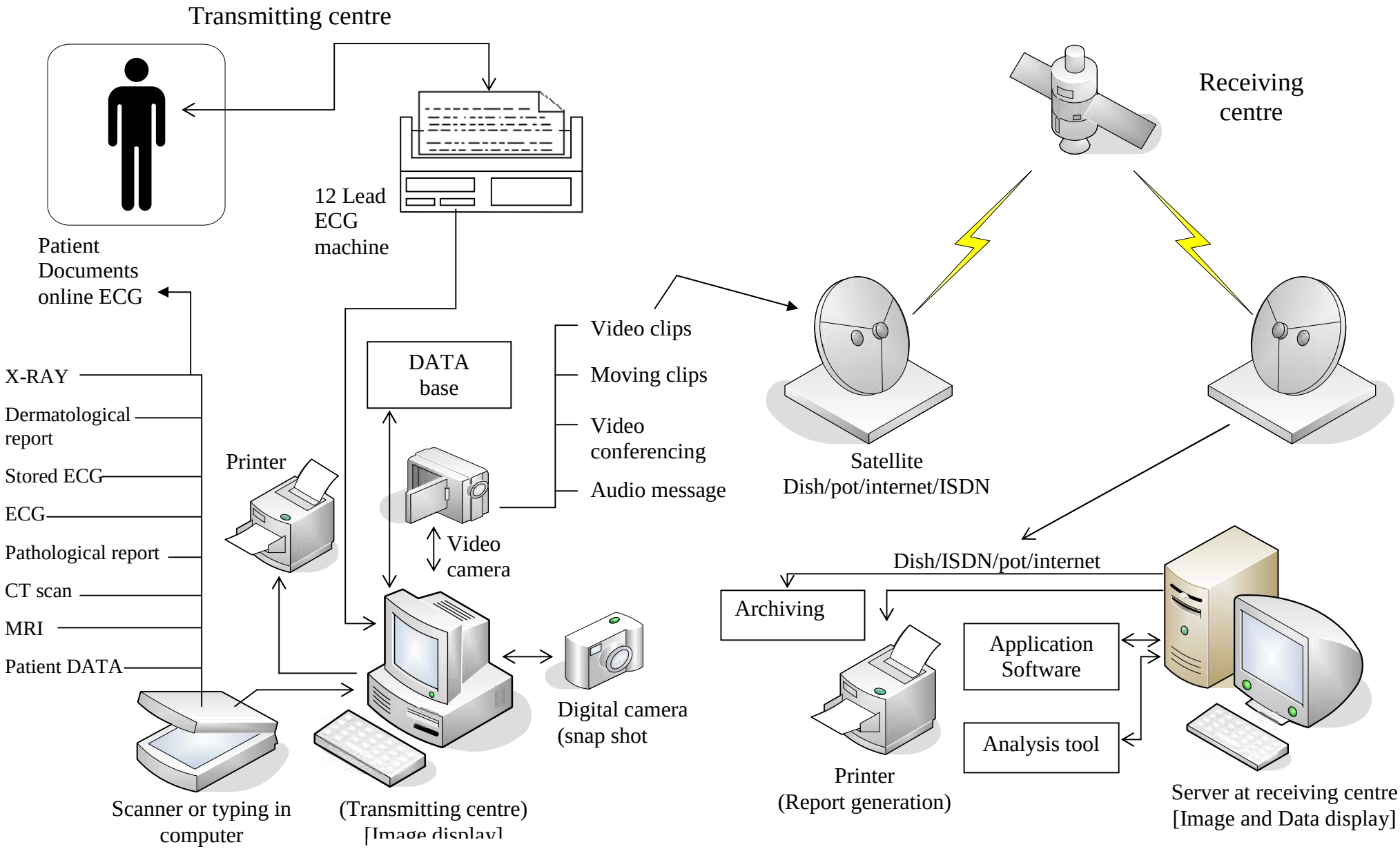


Fig. 1.1.2.2: Block diagram of a telemedicine system[3]

1.2 Scope of Telemedicine:-

Evaluation of new technologies can be time-consuming, aggravating, and expensive. Nevertheless, there are a number of important reasons for critically scrutinizing telemedicine programs. First, healthcare resources are limited. Evaluation provides the data need to compare the relative value of telemedicine systems to alternative uses of medical resources. Second, evaluation is used to document the functional utility of telemedicine as a diagnostic and clinical tool. Without evaluation it is unclear, whether remote consultation is equivalent to, better than, or worse than in-person consultation for many clinical applications. Finally, evaluation over time can provide important clues as to why a telemedicine program is successful or unsuccessful, and how it might be made more efficient.

1.3 Objective of the study:-

The objective of this study is to investigate the image quality of teledermatology and telepathology in telemedicine using a digital camera. The investigation will include

- Identifying the good image quality keeping different setting related to physics in digital camera.
- Finding methods for image acquisition (capturing image) and information transmission (e.g. Image, data etc).
- To approach the similarity in conventionally and remotely (via. telemedicine) observed data, both experimentally and using a non-parametric statistical analysis called a ROC analysis

1.4 Problem statement:-

The problem on quality of teledermatology and telepathology images refer to the visibility of the image. The image visibility is the main thing that determines problem. The image visibility is affected by many parameters such as attenuation, delay distortion, noise, resolution,

patient exposure, uniformity, light on object, instrumented condition, bandwidth of telecommunications, methods of acquisition of image and display system. Further more the light which is the main disturbance of image quality depends on the shutter speed, aperture, focal length, and sensitivity of camera. The other disturbances of image quality are lack of information technology, unavailability and high cost of telecommunications services in rural and some urban communities.

1.5 Significance of the study:-

If high quality medical care is to be provided, the expertise of the care provider is an important factor. This is particularly in dermatology and pathology, where the diagnostic skill of the reviewing dermatologist and pathologist are of paramount importance, and expert dermatology and pathology skills are expensive. Expert dermatology and pathology services are concentrated at larger hospitals and in major metropolitan areas because the maintenance of large dermatology and pathology staffs are not economically feasible at smaller hospitals and clinics.

A potential solution to the problem of providing dermatological and pathological services to areas outside major metropolitan areas is to use technology to provide consulting at a distance.

1.6 Medicine and Telemedicine:-

Increasingly, telemedicine has come to mean collaboration technology used in a medical setting, and work in the areas has typically focused on areas such as training, remote surgery, remote consultations, patient data and file transfers.

The wide-ranging areas of medical practice in existence, the use of telemedicine is generally confined to a few limited domains of application. Despite their undoubted importance, medical work is not limited to networking and training medical personnel, providing information for remote patients, assessing remote patients' needs and

symptoms, and transferring images and notes. Their everyday work is often more mundane, grounded in seeing patients face-to-face, speaking to a range of other specialists and support staff within the hospital, locating and entering patient data, providing treatment regimes and performing surgery. Whilst perhaps not as exciting on first inspection as the areas currently supported by telemedicine, these are the work a day activities that medical professionals are involved in for a large part of their time. These are perhaps the areas in which telemedicine can make the greatest improvement to the quality and provision of medical care, because they take up such a large proportion of medical workers' time; they are also that may require a very different approach to telemedicine technology to those currently being developed.[4]

1.7 Telemedicine services:-

Telemedicine services or telecommunication in medical services can be divided into seven categories. We can also distinguish subgroups of services, each of them usually requiring different technical solutions.

1.7.1 Telediagnosis:-

Telediagnosis is basically the performance of any medical diagnostic service at a distance. In practice, this service is initialized by installation of a telecommunication network, or by specific electronic data transfer lines between fixed patterns.

Telediagnosis require different technical solutions. Transfer of patient data is limited to visual information, whereas expert consultations all obviously more efficient when an interactive visual and acoustic data exchange is provided by the information exchange system. Telediagnosis systems can not only be implemented between two partners, but, in addition, several doctors of the same or different specialties can teleconference in order to confirm a final diagnosis, useful in particularly difficult cases or to exchange professional information. Teleconsultation

to a great extent increases the accuracy of diagnosis and substantially contributes to reducing the costs resulting from inadequate diagnosis. Telediagnosis can be applied in any of the medical disciplines involved with diagnostic procedures.

1.7.1.1 Telepathology:-

Telepathology is the performance of pathology at a distance using the available telecommunications links. Telephathology enables pathologists to render diagnosis and to consult remotely.

Basically, the viewing of tissue and cellular specimens by the naked eye or via a microscope is replaced by transfer of the corresponding images to a video monitor. The images are acquired by video cameras or by digital cameras mounted at the place for gross examinations or on a microscope, and transmitted to the examining pathologist. Telecommunication links the place of image acquirement to the workstation for diagnostic examination. Both the sender and receiver need computerized equipment for accurate results.

1.7.1.2 Teleradiology:-

Teleradiology is a method of conducting remote radiological examinations over a telecommunications network. It provides the transmission of X-ray, ultrasound, computer-assisted tomography and magnetic resonance images from locations without a specialist radiologist to big urban (or hub) centers having such a specialist. Again, the small medical centers need to be equipped with adequate hardware and the technical personnel who can perform the necessary examinations. The radiological images obtained are then transmitted for diagnostic evaluation.

1.7.1.3 Teleendoscopy:-

Teleendoscopy is defined as the real-time transmission of compressed video images visualized by an endoscopic examination. This

technology has been developed to provide general practitioners with real-time consultations of experienced endoscopists with the aim of reducing expenses for transportation of patients and repeating examinations. At the site of the examinatory a practitioner must be available who is trained to perform the endoscopic examination of the alimentary trait and who can select any suspicious spots for image transmission. It requires great manual dexterity and experience to minimize the patient's discomfort during the examination and to visualize the important compartments of gastric mucosa for disease classification and tissue examination.

1.7.1.4 Telecardiology:-

Telecardiology is the transmission of electromagnetic data and heart action images for the purpose of specialized assistance in diagnosis, treatment of cardiac diseases and handling of related emergency cases; informing the referring physicians of the result of the examination, training the physicians in cardiology and remote assurance and control of cardian pacemakers.

Functional data and acoustic information such as electrocardiograms and/or valve sounds can be transmitted to the cardiologists or cardiac intensive care centers via the analog public telephone network or other specialized communication lines including ISDN or broad-band networks.

- Frequently, telecardiology is a mixture between diagnostic and therapeutic procedures, specially in emergency cases when the accurate diagnosis implies immediate treatment of the patient.

1.7.1.5 Teledermatology:-

Teledermatology deals with the transmission of macroscopic skin images for expert consultation. Teledermatology has been used for consultation between primary care centers or general practitioners and experienced dermatologists.

Teledermatology not only provides an adequate service to rural areas but, in addition offers new income sources for the experts. Video conferencing systems and high-resolution television cameras permit the transmission of still and live images during the patient's examination for expert consultation. These technical solutions are an excellent solution in the search for improved medical diagnosis by transmission of adequate, non-biased information which can provide the most appropriate diagnostic interpretation and classification.

1.7.2 Teletherapy:-

Teletherapy is the therapeutic practice of a physician at a distance. Depending upon the involved medical discipline, therapy can be performed by information exchange and influence to the patient (psychiatry), by prescription, application, and control of adequate medicine (drugs, injection, etc), by invasive procedures (surgery), or by repeated physician regimes such as physiotherapy, controlled rehabilitation procedures, adequate jogging, etc. Therefore, teletherapy includes the management of living habits, the performance of drug intake and more difficult applications such as telesurgery. Teletherapy is mainly performed in interactive procedures in terms of expert consultation which requires an expert consultation on the receiver's side and an executing general physician at the location of the patient or in terms of telepresence.

1.7.2.1 Telepsychiatry:-

Psychic disorders and emotional disturbances affect a considerable number of humans living in our complex contemporary societies. Many people have difficulty confessing their psychic suffering. Moreover, they often have problems in acquiring professional aid. Others, afraid to reveal the condition of their intimate environment, give up the idea of consulting a doctor. In contrast, emotional support groups offered by many psychologists, psychiatrists and psychotherapists are available to people

suffering from depression or suicidal ideation via the Internet. Consultation via real-time video conferencing between the primary practitioner in a medical center and an expert in psychiatry provides efficient assistance during times of difficult personal circumstances and is an appropriate use of experts.

1.7.2.2 Telesurgery and Telepresence:-

Telesurgery is the discipline in telemedicine which was developed only a few years ago and includes several different techniques used in surgery. It has been applied mainly in surgical disciplines which are highly specialized, is connected with emergency cases, and is relatively rare. Telesurgery includes robotic systems, which will perform the most difficult parts of surgical intervention by remote control or by automated self-learning programs.

Telepresence is an enhanced technique of telesurgery that employs a transparent user interface, permitting the user to work with high effectiveness inaccessible, distant or remote environments. Telepresence systems are designed to improve the surgeons' performance in minimally invasive surgery and microsurgery. They enable the surgeons to operate on patients remotely at greater distances. In microsurgery, this technology can scale down the surgeons' motions, forces, and field of view, allowing them to skillfully operate on microscopic anatomy with relative ease.

1.7.3 Telecare:-

Modern societies are confronted with the problem of the increasing age of their populations and associated need for care of citizens who cannot provide themselves with the needs of daily life. The number of handicapped persons has reached a quite excessive level not only in the developed, but also in the developing countries. Old people need care and supervision in their homes, which is mainly provided by so-called home nursing, i.e. visitations of nurses at the patient's home. According to the

level of the needed care, most of the elderly need only frequent supervision and the possibility of swift and appropriate assistance in critical situations. Visual telecommunication can be used for these purposes accurately and economically. Several trials have demonstrated the practical use and acceptance of this technique by both the elderly and the nurses. In most cases, the arrangement has been as follows: A public video-assisted interactive communication system is installed in the homes of the elderly connecting to a central nursing office. The system permits emergency calls, visualization of both parters, observation of the handicapped person, supervision of simple medical self-treatment, monitoring of daily food intake, etc. patients requiring constant medical care or extended diagnostic examinations. The patient can move freely, and the hospital is enabled to provide immediate assistance in the case of emergency.

1.7.4 Teleeducation:-

Teleeducation is the use of visual and acoustic communication components in teaching, education, and examinations at a distance. The most important factor which influences the change occurring in education has been the installation and development of the Internet and electronic multimedia techniques. Teleeducation is an appropriate technical solution fulfilling the needs of economy and essential application. The speed of exploring new technical, biological or social information is increasingly combined with the task of shortening the gap between the theoretical exploration and practical application. The period of transferring the collected information from specialized centers to interested students has to be shortened, and those countries that can provide their students with the latest science in the shortest time maintain an advantage. The more detailed the education is, the more specialized teachers are needed, and, therefore, the more expensive is the education. Education is closely

associated with results in scientific research. The volume of medical information is constantly growing. As a consequence an increase in the demand for rapid access to the latest results of scientific research, new therapies, and effects of new medicines to be implemented in related education systems is being observed. To solve this problem on a continuous basis, it is appropriate to develop a system of central medical information that would be accessible to students, trainees, or doctors at nay time. Such a system should offer access to various sources of information by means of electronic mail or on-line communication.

1.7.5 Teleresearch:-

Teleresearch has been utilized since the early days of computers. This term includes both the application of electronic information (or data) transfer for research and research in the field of telecommunication.

1.7.6 Telemeasurement:-

Quantitative assessment of non-biased information is the fundament of natural science. The information to be qualified can be measured at its location, or transported to a measurement place.

The assurance of quality of telemeasurements can be performed by control of the resolution and specific performance of the equipment used. An Internet server has been utilized for these purposes providing analysis of the measured data, and information about the quality and constancy of a measurement series.

1.7.7 Teleadministration:-

Electronic administration of patients is a common use in modern hospitals, and electronic registration of patients can be completed prior to admission by the house physician if a convenient teleservice system is available. Referral to the hospitals can then be performed with a precisely defined destination and date of admission, allowing the hospital administration an exact plan for use and occupation of the offered

services. Teleadministrative services, therefore, deal with the storage and transmission of all information connected with administration and personal aspects such as the patient records, patient registration information, personal data, and electronic prescriptions. In addition, medical data from correctional institutions can be immediately transmitted. Administrative data transfer to involved insurance systems and government offices can be provided. [5]

1.8 Goals of Teledermatology and Telepathodogy;-

I. Improving patient care
II. Providing consultative and interpretative dermatological and pathological services in areas of demonstrated need.
III. Making services of dermatologists and pathologists available in medical facilities without on-site dermatologist and pathologist support.
IV. Providing timely availability of dermatological, pathological images and dermatologic, pathologic images interpretation in emergent and non- emergent clinical care area.
V. Facilitating dermatological and pathological interpretations in on-call situations.
VI. Providing specialty dermatological and pathological support as needed.
VII. Enhancing educational opportunities for practicing dermatologists and pathologists.
VIII. Promoting efficiency and quality improvement.
IX. Sending interpreted images to referring providers.

When a successful teledermatology and telepathology systems have been installed in a health care facility, there are several categories that play a significant role in that system. [6]

1.9 Advantages of Telemedicine:-

All the telemedicine technologies allow health care providers to provide a service that has many advantages. Some important advantages are

- Telemedicine can make specially care more accessible to under-served rural and urban populations, especially in cases where there are skill shortages.
- Video consultations from a rural clinic to a specialist can alleviate travel and associated costs for patients.
- Video conferencing opens up new possibilities for continuing education or training for isolated or rural health practitioners who may not be able to have rural practice or take part in meetings or educational opportunities.

The development of telemedicine has been marvelous to the health care sector. But if health care services want to enjoy the full benefits of telemedicine, there are some barriers in telemedicine that has to be overcome. [6]

1.10 Barriers to Telemedicine:-

There are still several barriers to the telemedicine.

i. Regular telephone lines don't have the adequate bandwidth for most telemedicine applications.
ii. Rural areas don't have capable wiring or other high bandwidth telecommunications required for sophisticated uses, so those who could most benefit from telemedicine may not have access to it.

In areas where the information infrastructure is under-developed, unreliable, or non-existent, the cost of upgrading the infrastructure can be prohibitive. Yet these rural areas would most likely benefit the most from telemedicine services. Rural areas in particular have the least access to high quality capacity modern telecommunications infrastructure.

Another area that is a barrier in security. If consumers are scared of sending their banking details over the Internet, their health information is even more private. Unauthorized viewing of medical information that is held in health care facilities must be prevented for telemedicine to be a success, this security barrier must be overcome.[6]

1.11 Essential components of a Telemedicine System:-

Successful telemedicine requires appropriate equipment and some kind of telecommunications medium. However, successful telemedicine requires more than just technology. The three essential components are

1.11.1 Personnel:-

For any telemedicine system to work in practice-in a real clinical situation-suitable, committed personnel are essential. People with the necessary skills to undertake the clinical components are required at both ends of any telemedicine link. This means that there must be trained staff at the referring end of the link who are able to handle the patient contact required. They must be comfortable with this mode of care delivery and they will probably need prior training, since telemedicine will represent a clinical situation that they are not normally exposed to. Unless this is planned in advance, the technology may be under used (or even ignored entirely) by staff who may be uncomfortable with the new processes.

At the specialist, or consulting, end of a telemedicine link, the two most important factors are the reliability of the equipment and the availability of the appropriate personnel.

1.11.2 Technology:-

The technology is in many ways the most straight forward part of a telemedicine system and, once a working link has been established, it can largely be ignored. Much of the equipment required may already be available for other functions, and can be shared if planned properly. Reliability is a requirement for all medical equipment and telemedicine

equipment is no exception. For telemedicine, all the equipment needs to function properly, since any malfunction will break the chain required for a successful link. Although modern computers and operating systems are fairly reliable, the integration of components still require close attention to ensure reliability and ease of use. Unreliable technology is likely to cause the system to be under used or even ignored.

1.11.3 Perseverance:-

Finally, it is important to mention one crucial component, without which a telemedicine system will not function. That is at least one dedicated and committed individual is needed with the perseverance to overcome the inertia inherent in all established clinical routines, and the commitment to champion the new system until it can demonstrate its usefulness. This mentor or champion of the system will help to drive the implementation and to deal with problems as they arise. [7]

1.12 Requirements of Telemedicine:-

The techonolgy required for a telemedicine links can be divided into three categories:

a) Equipment to capture the clinical information at each site.
b) The telecommunications link needed to transmit this information between the sites.
c) Equipment to display the information at each site.

Before the technology can be selected, it is necessary to consider the nature of the information to be transmitted between the sites because this will determine the choice of equipment and the telecommunications network. Factors to be considered include:

1.12.1 Types of information to be transmitted:-

Different clinical situations generate very different types of clinical information (Table -1). Hence, there are many possible sources of data

that can be used in telemedicine application, where as in others more qualitative and subtle information is needed as in psychiatric assessments, where observations of posture, speech and mental state are required. Not all information will be needed at every site:

Information Source	Type
Electronic stethoscope	Audio
ECG recording	Data
Dermatology, Pathology, Chest X-ray	Still image
Fetal ultrasound recording	Moving images

Table -1: Examples of clinical information.

For example, a telepsychiatry application will probably require ordinary commercial video conferencing equipment instead of very high-quality audio or video signals and a telemonitoring service will require only data and text transfer, without audio and video.

1.12.2 Quantity of information transferred:-

The units in which the quantity of digital information is measured are the bit and the Byte. Here are some examples of quantity of information transferred. (Table - 2)

Information Source	Typical file size
Electronic Stethoscope	100 Kbytes
ECG recording	100 Kbytes
Dermatology image	3.9 Mbytes
Pathology microscope image	1.44 Mbytes
Chest X-ray	1 Mbyte
Fetal ultrasound recording	10 Mbyte

Table – 2: Examples of quantity of information.

A careful assessment of the above needs will determine the quantity of information that must be transmitted between the project sites, and the time frame over which it must be sent to achieve the desired clinical goals. [8]

1.13 Types of Telemedicine:-

The common thread for all telemedicine applications is that a client of some kind (e.g. patient or health care worker) obtains an opinion from someone with more expertise in the relevant field, when the parties are separated in space, in time or both. Telemedicine episodes may be classified on the basis of:

- The interaction between the client and the expert and
- The type of information being transmitted.

The type of interaction is usually classified as either prerecorded (also called store-and-forward or asynchronous) or real-time (also called synchronous). In the former, information is acquired and stored in some format, before being sent, by an appropriate means, for expert interpretation at some later time.[2] This method is generally cheaper and more convenient. The main advantage of this form of telemedicine is that the recipient of the information can examine the material their convenience [8]. In contrast, in real-time interactions, there is no appreciable delay between the information being collected, transmitted and displayed. Interactive communication between individuals at the sites is therefore possible, although it requires more expensive equipment. The advantage of real-time telemedicine is that decisions may be made immediately at the time of the session, and if additional information is required the clinician can request it immediately.[8]

The information transmitted between the two sites can take many forms, including data and text, audio, still images and video pictures. Combining the type of interaction and the type of information to be transmitted allows telemedicine episodes to be classified as in Table 3. [2]

	Information transmitted		
Interaction		Still images	Moving images
	Real-time		e.g. telepsychiartry
	Pre-recorded	e.g. teledermatology, teleradiology	

Table 3: Types of telemedicine [2]

1.14 Store and forward (Prerecorded) Telemedicine: -

Now a days prerecorded telemedicine can be performed in many more ways. Diagnosis and clinical management are the principal applications of prerecorded telemedicine, although quality control and education are increasingly being performed using prerecorded telemedicine.

Prerecorded telemedicine is not appropriate for emergency consultations, since by definition there will be a delay before a response is received. Prerecorded telemedicine should be used only for non-urgent work. [9]

1.15 Type of Store and Forward (Prerecorded) Telemedicine:-

The types of information transferred i.e. audio, data and text, still images and moving images (i.e. video) may be used to categorize the different kinds of prerecorded telemedicine. They are

- Transfer of prerecorded audio
- Transfer of prerecorded data and text.
- Transfer of prerecorded still images.
- Transfer of prerecorded moving image (video).

So far most work in prerecorded telemedicine has been done with data and text, and with still images. Video is increasingly being transmitted for telemedicine. [9]

1.16 Technical aspects of Store and Forward (Prerecorded) Telemedicine:-

In prerecorded telemedicine systems the following steps can be distinguished:

- The acquisition of diagnostic information at the remote site;
- Its storage, which can be at either site, or at both;
- Its delivery to the expert site through an appropriate connection;
- Its display at the expert site.

These steps are outlined in fig. 1.16(a) After analysis of the information, the prerecorded telemedicine process may be reversed by transmitting the results of any episode back to the remote site. (9)

Figure 1.16: Steps in a prerecorded telemedicine system. (9)

1.17 Effects of Telemedicine:-

In broad terms, telemedicine can be expected to improve equity of access to health care, the quality of that care and the efficiency by which it is delivered, by enhancing communication up and down the health-care pyramid fig1.17.1. Widespread adoption of telemedicine would permit decentralization; work previously done in the secondary sector, could be performed in primary care and work previously done in the primary care sector could be developed to the community level. Such changes, if implemented in the developing world, could potentially have the greatest effect, allowing underserved people to benefit from a greatly improved standard of health care. In all remote or rural areas, however, telemedicine could have a great impact, permitting among other opportunities, better diagnostic and therapeutic services, faster and easier access to medical knowledge, and enhanced communication between

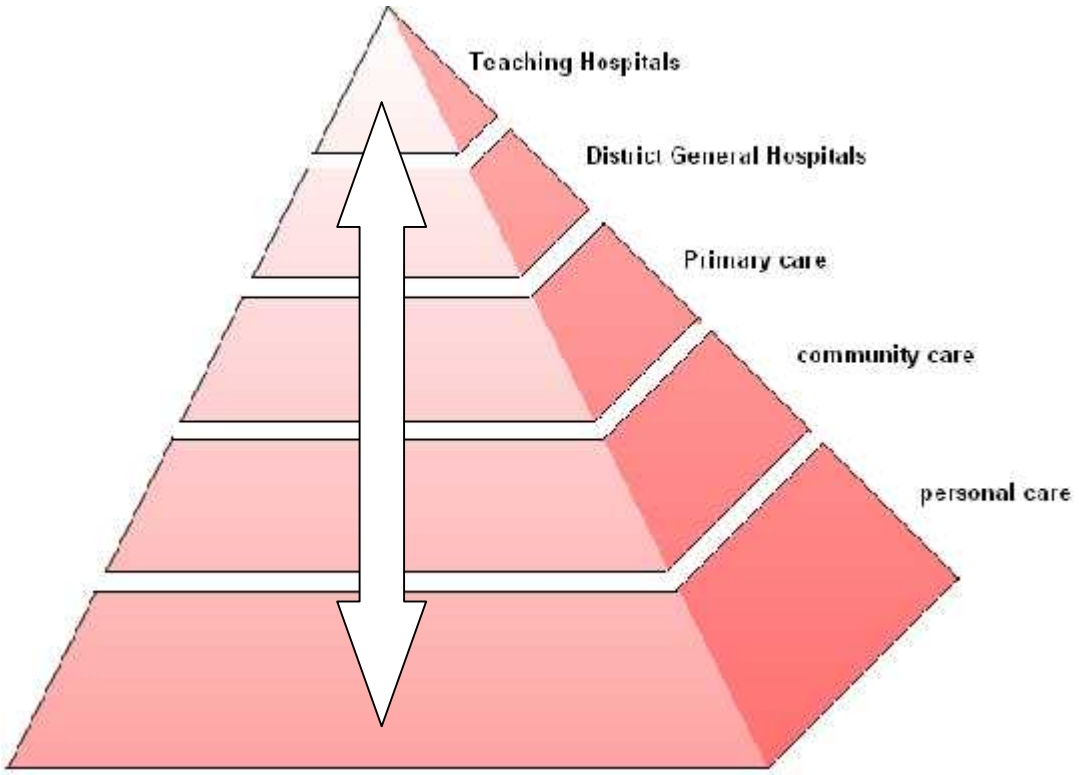


Fig.1.17.1: Telemedicine as a means for improving communication up and down the health-care pyramid.[2]

health care workers. [2]

1.18 Drawbacks of Telemedicine: -

Although telemedicine clearly has a wide range of potential benefits, it also has some disadvantages. The main drawbacks of telemedicine that can be envisaged are [10]

- Breakdown in the relationship between health professional and patient
- Breakdown in the relationship between health professionals
- Issues concerning the quality of health information
- Organizational and bureaucratic difficulties

Chapter – Two

GENERAL THEORY AND APPLICATION

2.1 Introduction

The use of advanced telecommunications and information technologies has been investigated for more than 40 years in an effort to improve health care. In particular, the focus has been centered on telemedicine, which is also referred to as telehealth in some arenas. Telemedicine compromises information and communication technologies to provide and support health care when distance separates the participants.[11] So telemedicine is the fusion of three dynamic and complex industries, medicine and health care, information and telecommunication given in fig.2.1.1.

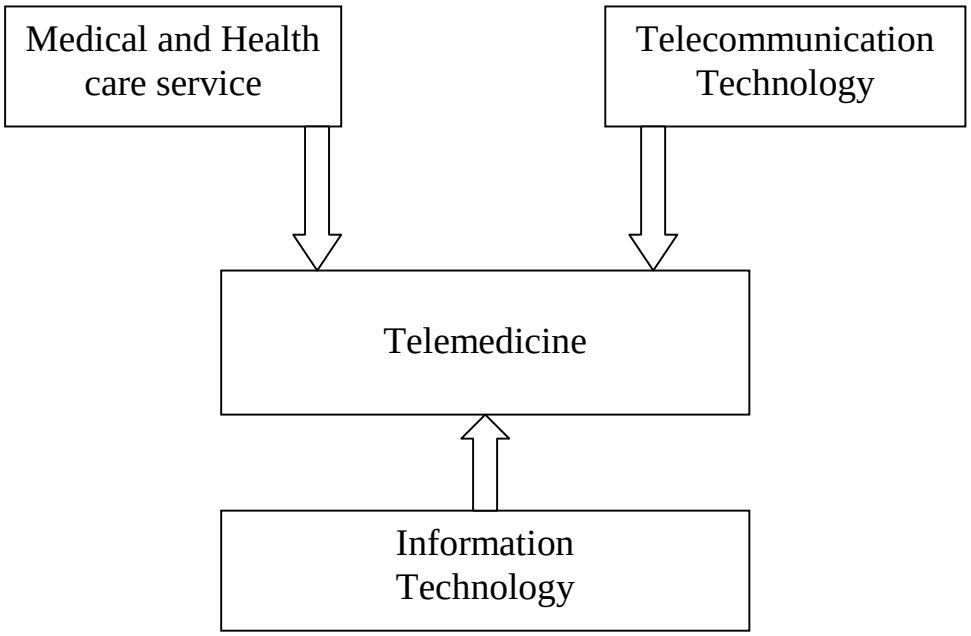


Fig. 2.1.1: Telemedicine and related areas [11]

Technology has been a driving force in defining the practice of modern medicine. Technology also receives brunt of criticism regarding escalating health-care costs. And each telecommunications innovation from telegraph, teletype, telephone, radio, television and recently satellite

and wireless technology could have been a vehicle for some form of communicating health information from one geographic area to another. Any of these transmission systems mentioned could convey a crude mechanism of telemedicine. [12]

The fundamental concepts of telemedicine technology include basic principles of telecommunications and Internet-working of computer systems, use of communications software, and forms of telecommunications. With continuing advances in information technology, the applications of computers in medicine are increasing rapidly. Modern information technology affects the delivery of health care. Since the 1990s, technologic developments in high bandwidth telecommunications systems and digitizing devices have led to a surge of interest in telemedicine. In recent years, internet with its powerful penetration and scalability has become increasing popular medical information and resource and a new platform for telemedicine.

Telemedicine encompasses a wide variety of technologies ranging from the telephone to high technology equipment that enables health care professionals (including physicians, nurse, and other health professionals) to provide health care thousands of miles away from the point of service. It includes interactive video equipment, fax machines, and computers along with satellites and fiber optics.

Telemedicine is not a new concept. Health care professionals have been using the telephone to carry out their services for years. In addition, research efforts have begun utilizing more of the telecommunication repertoire, including speech, text, data, picture, and video communication. The use of telecommunications and information technology is central in providing health services, regardless of locations. The investigation, monitoring and management of patients, and the education of patients and staff is done using systems which allow ready

access to expert advice and patient information, no matter where the patient or relevant information is located. The application of telecommunication technology to health care requires integration of technology, tools and training with medical care practices and problems. However, it is not necessary to be an expert in all these components to effectively use a telemedicine system. Telemedicine achieves its potential to improve delivery of health care in rural or remote areas only through cooperation among health professionals, computer system developers, telecommunication providers, and educators.

The fundamental concepts of telemedicine technology include

- Basic principles of telecommunications and Internet-working of computer systems
- Use of communications software, including electronic mail and browsers for the world wide web, and
- Forms of telecommuniations, including videoconferencing, remote data monitoring and file transfer, applicable to medical care in remote or rural environments.

In the last few years, information and communication technologies have seen enormous growth, and have been introduced by various degrees into the medical environment. Each year, computers are getting faster, smaller, and cheaper. The extra processing power and facilities open up the scope for much more powerful processing and networking of medical applications. Communication networks are becoming increasingly large in size and heterogeneous in nature. Recent advantages in communication technologies have contributed to an explosion of new products and services directed at the medical environment. An abstract mapping between medical applications and network evolution is given in fig. 2.1.2.

The general goal of using communication technologies in medical environments is to improve the overall quality of Health care at the

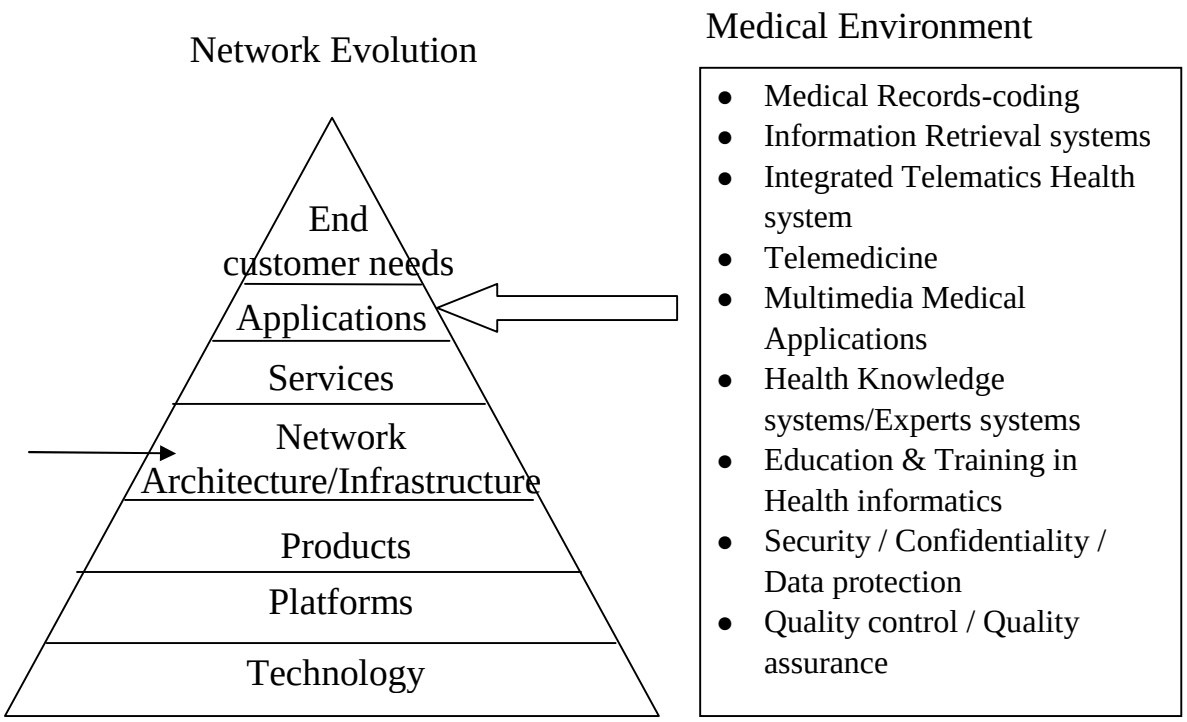


Fig. 2.1.2: An abstract mapping of medical applications to network evolution.[(11)]

affordable cost. This requires close interaction between health care practitioners and information technologies to ensure that the proposed technologies satisfy current user's needs and anticipate future ones. Appropriate application of information technology in primarily health care will extend traditional diagnosis and patient management beyond the doctor's clinic into the everyday living environment.

When the concept of the integrated information management system was jointly endorsed, telemedicine has been a system that would be integrate all aspects of medical informatics. Remote consultation would be integrated with patient care records, clinical decision tools, pharmacy and other treatment services, professional and patient education, appointment, filling, and other administrative services. In this scenario, health care would be available where it is needed and when it is

needed. As telemedicine is ideally configured, it would require networks capable of delivering voice, video, images, and data. [11]

2.2 Information technology and information capture:-

2.2.1 Information technology:-

The internet, being directly within reach for a major proportion of our societies, was revolutionary, not only because of its accessibility, but also because it offer access to virtually unlimited amounts of information and in addition, more rapid means of communication.

The personal computer is thus now the center of a global electronic network of appliances and systems, interacting to offer unprecedented possibilities for the collection, processing and communication of information. So as the new information technology and its networks advance and become more pervasive, telemedicine operations and activity in general are becoming increasingly knowledge-based and directed by information. [13]

2.2.1.1 Computes Networks:-

Computer systems are often connected to a local area network-LAN, which permits an open access to various network resources such as printers, modems, user programs, databases, etc. Local area network in a larger or smaller area can be easily connected with large public network-MANS (Metropolitan Area Network). The MAN can in turn be connected with still larger wide area networks, for example, the WAN (Wide Area Network). Connections of wide area networks create a global network hospital or wide area networks can be completely secured and dedicated for medical purposes only, or they can be connected to the Internet network. For safety reasons these communications are complicated and require at least a switch computer to construct a firewall, for example, via the TCP/IP protocols as shown in figure 2.2.1.1.1.[5]

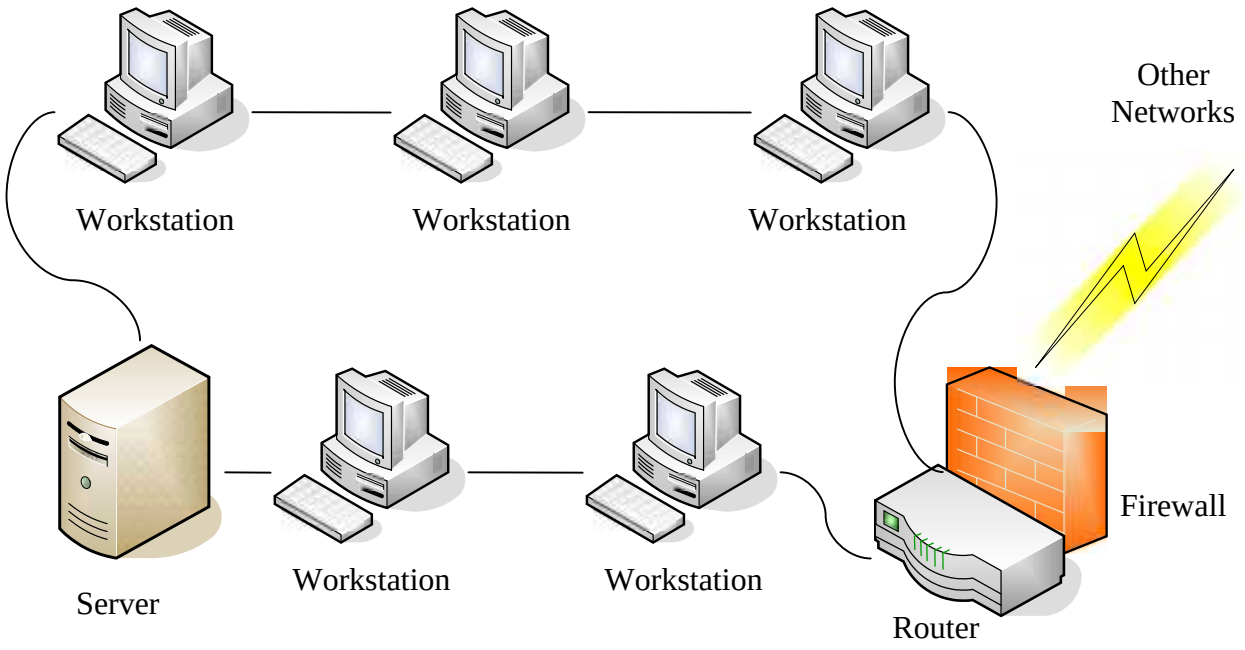


Fig. 2.2.1.1.1: Scheme of a local area Network (LAN) [5]

2.2.1.2 Data communication:-

When we communicate, we are sharing information. This sharing can be local or remote. Between individuals, local communication usually occurs face-to-face, while remote communication takes place over distance.

The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.

Data communication is the exchange of data between two devices via some form of transmission medium such as wire cable. For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (program). The effectiveness of a data communications system depends on the fundamental characteristics delivery, accuracy, and timeliness.

2.2.1.3 Components of data communication:-

A data communication system has five components given in figure 2.2.1.3.1.

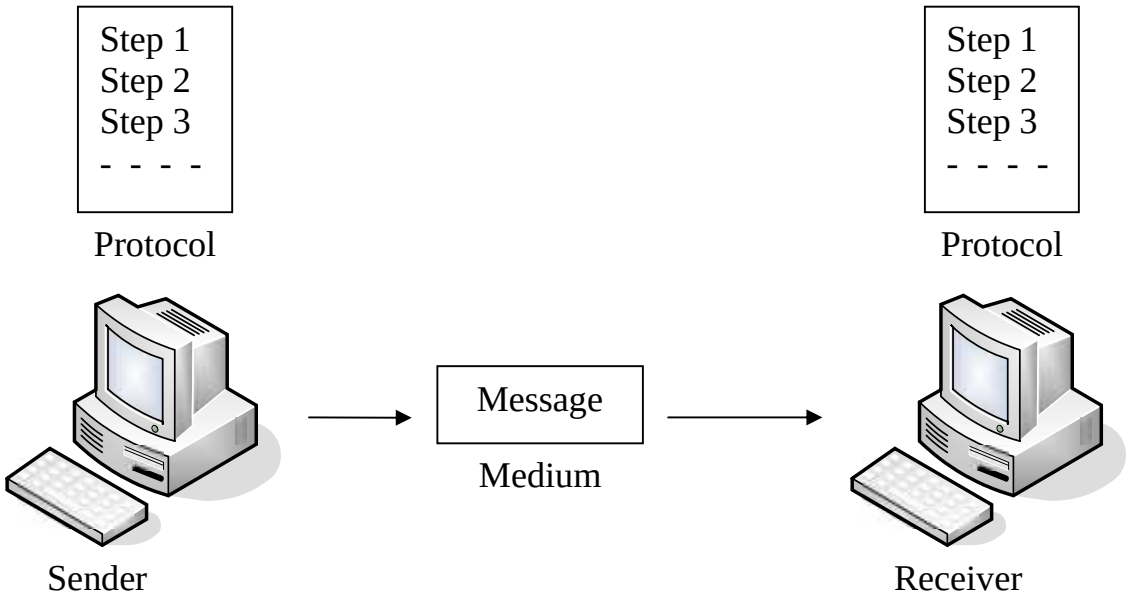


Fig. 2.2.1.3: Five components of data communication[14]

a) Message: - The message is the information (data) to be communicated. It can consist of text, numbers, pictures, sound, or video-or any combination of these.
b) Sender: -The sender is the device that sends the data message. It can be a computer, work station, telephone handset, video camera, and so on.
c) Receiver: -The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television and so on.
d) Medium: - The transmission medium is the physical Path by which a message travels from sender to receiver. It would be a twisted –pair wire, co-axial cable, fiber-optic cable, or radio waves (terrestrial or satellite microwave).
e) Protocol: - A protocol is a set of rules that governs data communication. It represents an agreement between the communicating devices. Without protocol, two devices may be connected but not communicating.

2.2.1.4 Data representation:-

Information today comes in different form such as text, numbers, audio and video.

(a) Text:-

In data communications, text is represented as a bit pattern, a sequence of bits (os or 1s). The numbers of bits in a pattern depends on the number of symbols in the language.

Different sets of bit patterns have been designed to represent text symbols. Each set is called a code, and process of representing symbols is called coding.

(b) Numbers:-

Numbers are also represented by using bit patterns. However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number. The reason is to simplify mathematical operations on numbers.

(c) Images:-

Images today are also represented by bit patterns. However, the mechanism is different. In its simpler form, an image is divided into a matrix of pixels (picture elements), where each pixel is a small dot. The size of the pixel depends on what is called resolution. An image divided into more number of pixels has the better resolution, but more memory is needed to store the image.

After an image is divided into pixels, each pixel is assigned a bit pattern. The size and the value of the pattern depend on the image. For an image made of only black-and-white dots (e.g. a chess board), a 1-bit pattern is enough to represent a pixel.

If an image is not made of pure white and pure black pixels. We can increase the size of the bit pattern to include gray scale. To show four levels of gray scale, we can use 2-bit patterns. A black pixel can be represented by 00, a dark gray pixel by 01, a light gray pixel by 10 and white by 11 to represent color image each colored pixel is decomposed

into three primary colors red, green, and blue (RBG). Then the intensity of each color is measured, and a bit pattern (usually 8 bits) is assigned to it. In other word, each pixel has three bit pattern: one to represent the intensity of red color one to represent the intensity of the green color, and one to represent the intensity of the blue color.

(d) Audio:-

Audio is a representation of sound. Audio is by nature different from text, numbers, or images. It is continuous, not discrete. Even when we use a microphone to change voice or music to an electric signal, we create a continuous signal.

(e) Video:-

Video can be produced either as a continuous entity (e.g. by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

2.2.1.5 Direction of Data flow:-

Communication between two devices can be simplex, half-duplex, or full-duplex.

(a) Simplex:-

In simplex mode, the communication is unidirectional, as on a one-way street in figure 2.2.1.5.1. Only one of the two devices on a link can transmit; the other can only receive. Keyboards and traditional monitors

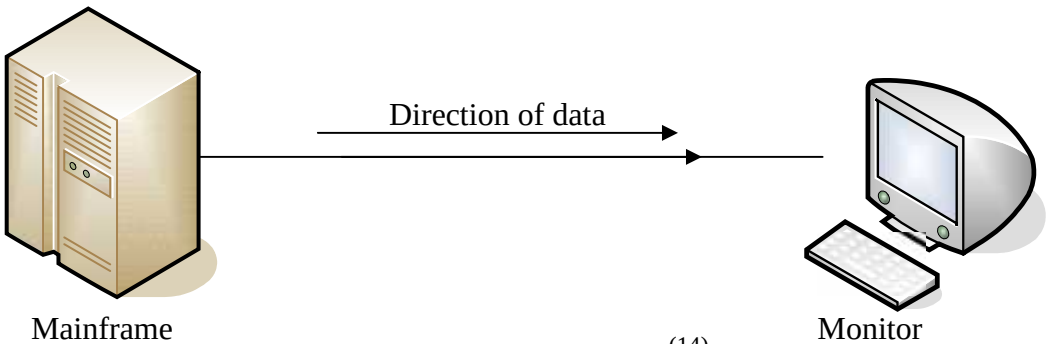


Fig. 2.2.1.5.1: Simplex [14]

are both examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output.

(b) Half-duplex:-

In half-duplex mode, each station can both transmit and receive, but not at the same time in figure 2.2.1.5.2. When one device is sending, the other can only receive and vice versa.

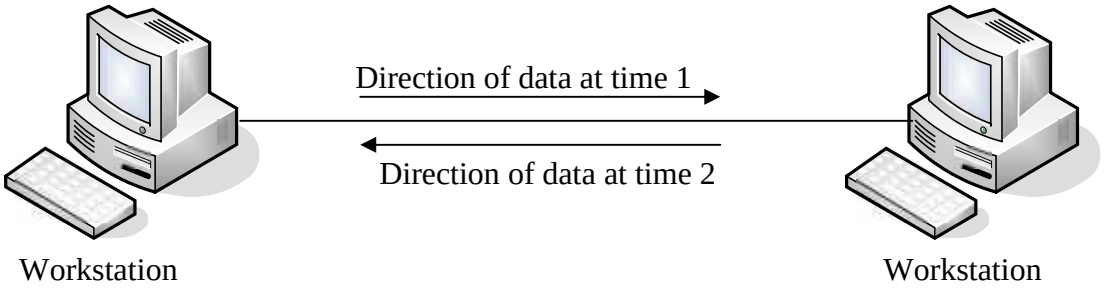


Fig. 2.2.1.5.2: Half – duplex [14]

The half-duplex mode is like a one lane road with two directional traffic, while cars are traveling one direction, cars going the other way must wait. In a half-duplex transmission, the entire capacity of a channel is taken over by which ever of the two devices is transmitting at the time. Walkie-talkie is a half-duplex system.

(c) Full-Duplex:-

In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously like in figure 2.2.1.5.3. The full-duplex mode is

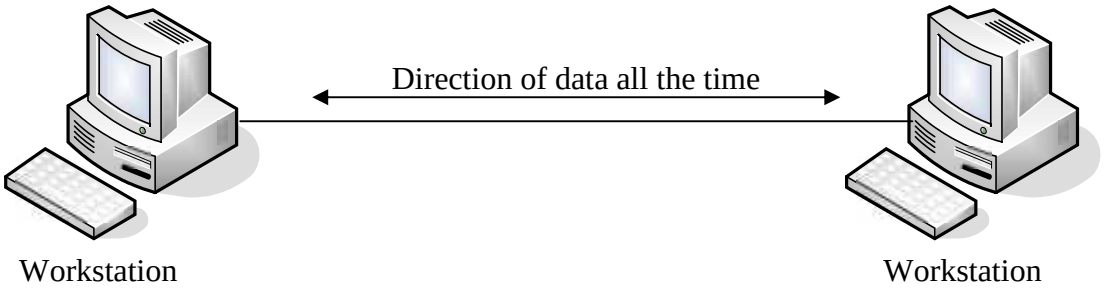


Fig. 2.2.1.5.3: Full – duplex [14]

like a two-way street with traffic flowing in both directions at the same time. In full-duplex mode, signals going in either direction share the

capacity of the link. This sharing can occur in two ways: either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals traveling in both directions.

The telephone network is a full-duplex communication. When two people are communicating by a telephone line, both can talk and listen at the same time.

Full-duplex mode is used for telemedicine system: - (14)

2.2.2 Information capture:-

The types of information that are relevant to telemedicine can be divided into five broad categories.

(a) Documents:-

Documentary information (e.g. primary patient data; patient history; clinical information; investigation; data and reports) can be transmitted in digital form, if the information already exists as a computer text file. Alternatively, paper documents can be digitized using a flatbed scanner or a document camera, and then transmitted as still images note, however, that , for non-urgent cases, copies of written records can be posted to the consultant end of the link in advance, or paper documents can be faxed before or during a telemedicine session, even in the age of digital telemedicine the use of the postal service can represent a very cost effective way of transferring large quantities of information from one place to another; the disadvantages involves the delay and the human interaction required.

(b) Electronic medical records:-

Traditional paper-based records are gradually being replaced by electronic medical records (EMRs). At present, the EMR is a hodge-podeg of heterogeneous, proprietary systems that rarely interoperate successfully. Efforts are underway to create a highly interoperable EMR

system, where data can flow across the health-care continuous seamlessly. EMRs will allow instant access to a patient's record.

(c) Still images:-

The major classes of image are important in telemedicine - those of unspecified quality and those where the diagnostic needs (and hence legal consequences) dictate a particular image quality. The difference can best be appreciated by considering the difference between photocopies of images and the originals – a photocopy may be perfectly legible and acceptable for many purposes, but fine detail present in the original may have been lost.

For many telemedicine purposes, a simple photographic image may be sufficient. A digital camera now provide very good imaging quality and may be adequate to capture an image of a skin lesion for teledermatology or a view down a microscope for telepathology.

(d) Audio:-

At its simplest, voice transmitted by telephone or radio can be used for some remote diagnosis. Although the telephone system has been designed for voice transmission, it is not necessarily idea for all types of medical sound transmission. Telephones use analogue transmission, which therefore susceptible to noise and loss of quality, particularly over long distances. Digital signal transmission offers many advantages, particularly since digital signals can be transmitted over networks for long distances without degradation. It is also possible to process a digital signal in various ways, including compressing it so that a live or recorded voice requires less data to be transmitted than the original signal.

Most modern PCs are equipped with a sound card that is suitable for capturing audio for telemedicine purposes. No special equipment is required other than a suitable microphone.

(e) Video:-

A common view of telemedicine is that it only involves real-time video images transmitted between remote sites for the purposes of consultation between a doctor and a patient. This is certainly one form of telemedicine, although it is by no means the only one. In cases where video transmission is considered appropriate, the issue arises of what video quality is required, since unsurprisingly the higher the quality, the higher the cost of the equipment and the transmission. In the majority of applications, commercial videoconferencing units provide the most straightforward solution to the problem of transmitting video pictures for telemedicine. [8]

2.3 Telecommunication technology and information transmission:-

2.3.1 Telecommunication technology:-

In telecommunications generally, convergence is taking place between video, voice and data networks. Now, telephone companies offers Internet services in addition to voice, and Internet service providers (ISPs) are offering digital voice services. Convergence of the various technologies used for health care at a distance can also be expected to occur.

Telemedicine networks employed dedicated telecommunications circuits. The underlying communications medium is some form of public digital lines typically Public Switched Telephone Network (PSTN). Integrated Service Digital Network (ISDN) or T-1 lines can also be used. These special lines are required because the transmission capacity of an ordinary telephone line is not adequate for most telemedicine applications.

2.3.1.1 From circuits to packets:-

Digital lines, such as T-1 or ISDN lines, are circuit-switched telecommunication. The sender and receiver are connected by a private

circuit. More recently, the Internet has become widely available for general use, including telemedicine. Data transmission via the Internet is packet-switching i.e. it takes place in a fundamentally different way from transmission in circuit-switched networks.

The Internet protocol (IP) is a standard that segments all data, voice and video into a series of variable-sized chunks of information called packets. Each packet has the destination address as a header. In the Internet itself, devices called routers read the address on a data packet and forward it in the general direction of the final destination. Ultimately, after passing through several routers, an individual packet will reach its destination. Packets from multiple locations become interspersed as they flow along the Internet, something like a conveyor belt that is being fed packages from many delivery trucks at the same time.

Some packets are sent with delivery guaranteed, and some are not. Information sent along a circuit remains in order and travels along the path defined by that circuit; in contrast, consecutive IP packets may or may not take the same route to reach a destination, and they may also arrive in any order. All these delivery details occur invisibly to the use. This IP engineering allows the Internet to be used by millions of people simultaneously for multiple purposes such as email, web browsing, watching videos, telephone and videoconferencing activities to and from any other Internet-connected location. The routers can reconfigure themselves to avoid network paths that may have become blocked due to damage or equipment failure, this improves the resilience of the Internet. (15)

2.3.1.2 Synchronous and asynchronous communication:-

The telecommunication technology system spans the globe with satellite, telephone (copper wire), fiber-optic, and cable networks (switches, lines, and software).

Synchronous connections are also known as real-time or live. Data, audio, and video synchronous file transmissions are available to the recipient almost immediately. Synchronous interactions allow simultaneous review and discussion of a file, situation, condition, or patient. Examples of interactions using synchronous technology include a standard telephone conversation, the walkie-talkie like interaction prevalent in Internet chat rooms (commonly referred to as near real-time), and an interactive video-consultation from a specialist in an urban area to a patient in a rural area.

The most common type of synchronous equipment is the telephone, which is often neglected when discussing technology, despite the many advantages it already offers to both patients and practitioners. Internet audio services have also become popular modes of synchronous communication technology.

Interactive televideoconferencing (ITV) is the traditional form of synchronous communication for telehealth programs. Using ITV, two or more parties are physically present in front of video equipment. They can thus see and hear each other and even share documents in real time. Of course, the quality of these interactions varies with the type of technology and the type of bandwidth connecting the technology.

Asynchronous communication through store-and-forward (S & F) technology provide great flexibility, as it does not depend on the simultaneous presence of parties at the sending and receiving ends. S & F services compile health information and send it to another party, who can retrieve it whenever convenient. Any disadvantages of S & F technology may be more than offset by the convenience of avoiding the need to schedule a same-time meeting of sender and receiver. Common health care applications of this technology include e-mail; the transmission of teleradiological, telepathological and teledermatological images, and

distance learning material used in professional continuing education, research, and administration.

S & F information is rarely time sensitive, it usually requires lower bandwidths than real-time exchanges. If used for emergency diagnoses, for which rapid turn around is essential, more bandwidth would be required. S & F technology typically uses existing phone lines to transmit data, which translates into lower telecommunication costs.[16]

2.3.2 Information transmission:-

In terms of network coverage, the conventional telephone is now widely available. More sophisticated digital telecommunications, such as ISDN, have more restricted coverage and higher costs, through they have major advantages over conventional telephony in terms of reliability and bandwidth.

An important factor in telemedicine is the time frame in which the information is required. For some applications rapid information transfer is needed, when telemedicine is being performed for emergency management. However, in less urgent cases information can be stored and transmitted at a slower rate, for late examination.

Bandwidth is the data-carrying capacity of the communication medium used. It is measured in bits per second (bit/s, often abbreviated to bps). Successful telemedicine has been carried out using a wide range of bandwidths.

The clinical information to be transmitted will dictate the minimum network bandwidth that can be used. How the bandwidth is obtained between the sites involved in the study depends on a variety of different factors. The main questions will be what infrastructure is already in place at each site, and what communications are possible between the sites (both physically and through local telecommunications companies).

Generally speaking, the problems of network reliability (in the

sense of communications being possible or not), exemplified by the traditional telephone network with electromechanical switching, have been solved by the more to digital telecommunications.

The choice of transmission method for any telemedicine application is a compromise between what would like and what one can afford. [8]

There are two means by which data are transmitted: dial-up (or dial-on-demand) services and dedicated connections. Dial-up services use standard telephony, integrated services digital networks (ISDNs), cellular services (mobile phones), and some satellite connections. Dedicated connections, in contrast, are those that provide a permanent connection between specific locations. These include ceased lines; digital subscriber lines (DSLs), cable, microwave links and satellite.

Providers have a variety of choices when selecting a information transmission channel. The first factor to consider is the type of information needing transmission text, audio, still images, or video. Each type of information requires a specific form of transmission. Text-based information may require only a plain telephone connection, where as surgical training may require the transmission of video information over more sophisticated technology.

Other considerations for choosing transmission technology include the required access and flexibility, the reliability of the telecommunication technology, and the quality of service available from the telecommunication provider. The lower the bandwidth, the less capable the system is of delivering high-quality resolution or motion. The higher the bandwidth selected, the higher the quality.

2.3.3 Transmission Channels:-

2.3.3.1 Plain Old Telephone Service (POTS):-

This is a low-bandwidth medium with maximum transmission rates approaching 56 kbps. It is quite adequate for audio and data transmission.

It is the most widely available medium for home health care. Once a connection is made, the line does not have to be shared with other users.[16]

2.3.3.2 Public Switched Telephone Network (PSTN):-

PSTN is used for transmitting the human voice in a more or less recognizable form. Their suitability for use in computer- computer communication is often marginal at best. It has data transfer rate of 33.6-56Kbit/s end ubiquitous coverage. It is also used for data (e.g. text reports) transmission; which is inexpensive available everywhere but slow and limited to simple data. [17]

2.3.3.3 Integrated Services Digital Network (ISDN):-

The digital counterpart of the PSTN is ISDN. It is completely different from the PSTN and offers end-to-end digital connectivity. This has two main advantages: greater reliability due to the digital nature of data traffic and higher bandwidth per line. Two standard types of ISDN connection are available: a basic-rate line and primary-rate line.

The basic-rate ISDN is also called basic rate interface (BRI) ISDN. A basic rate ISDN line offers the user a bandwidth of 128 Kbit/s in two separate 64 Kbit/s data channels. All information is digitally transmitted over the public switched network.

Primary-rate ISDN is also called broadband ISDN (B-ISDN)and is much faster form of the traditional ISDN that uses ATM switching networks. Primary-rate ISDN lines offer the user a bandwidth of up to 2 Mbit/s, thus allowing very high-quality video pictures to be transmitted. [8]

2.3.3.4 Switched 56:-

Switched 56 is a low-bandwidth switched data service with a two-channel call option. It can transmit at speeds of 56 or 64 kbps per channel over the public switched telephone network. Applications for switched 56

include videoconferencing, data transfer, and digital audio broadcasting. This method uses the same physical infrastructure as ISDN. However, it is an older technology with decreasing relevance. – [16]

2.3.3.5 Asynchronous Transfer Mode (ATM):-

This is a data-encoding, packet-based technology that typically transmits over higher bandwidths, at speeds from 45 Mbps to 622 Mbps. It is a low-delay switching and multiplexing technology. Its primary use is in backbone networks. [16]

2.3.3.6 Digital Subscriber Line (DSL):-

DSL technology, which is often referred to as 'broadband', provides an IP connection to the user. DSL connections come in a variety of types, such as symmetric and asymmetric.[8] The most common current DSL deployment is asymmetric DSL(ADSL).ASDL converts regular copper twisted pair phone lines into high-speed communication channels without interrupting the voice traffic on theses lines. It allows transmission speeds of up to 9 Mbps. ADSL usually provides more downstream bandwidth (i.e. to the user) than upstream. This is fine for downloading data, but is not necessarily suitable for real-time videoconferencing. ADSL operates through a special switching and line-conditioning service at the phone company central office, and is "always on" – in other words, it is a dedicated, rather than switched, service. Very high speed ADSL (VHSADSL) is a faster version of basic DSL. [16]

2.3.3.7 Cable Modems:-

These devices are becoming widely available and complete directly with DSL services. Cable modems, which are simply modems designed for use on a TV coaxial cable line, provide Internet uplink and downlink services. This means that one could download and watch a health-related video clip off the Internet with minimum loading or delay time. Because coaxial cable is used with cable modems, the speed is significantly faster

than traditional POTS or ISDN. The transmission speed is at least ten times faster than traditional dial-up modems. However, users must share the band-width on it, which means that the more people subscribe to cable modems, the slower the link for all people sharing the cable in a region. [16]

2.3.3.8 T – 1:-

This is dedicated (non switched) digital transmission link with a capacity of 1.544 Mbps. A T – 1 line can normally handle the equivalent of twenty-four voice conversations, each of which is digitized at 64 Kbps. T – 1 can be broken down into smaller transmission units (referred to as fractional T – 1). Many telemedicine programs have found that fractional T – 1 is adequate for their teleconsultation needs. [16]

2.3.3.9 Microwave:-

Microwave is a type of wireless technology. It employs electromagnetic waves in the radio frequency spectrum above 890 MHz. Microwave is common means of transmitting video, audio and data conversations by common carriers as well as private networks. Microwave is commonly the frequency used to communicate to and from satellites. In essence, satellites are microwave receivers, repeaters and regenerators that orbit above the earth. Currently, transmission is provided via geostationary units. However, low earth orbit (LEO) satellites are currently in production and may eventually be an alternative to the traditional geostationary satellites.[16] The disadvantage is that a microwave link connects just two locations, point to point. [8]

2.4 Transmission Impairments:-

Analog signaling consists of varying a voltage with time to represent an information stream. If transmission media were perfect, the receiver would receive exactly the same signal that the transistor sent. Unfortunately, media are not perfect, so the receiving signal is not the

same as the transmitted signal. For digital data, this difference can lead to errors.

Transmission lines suffer from three major problems, attenuation, delay distortion and noise. Attenuation is the loss of energy as the signal propagates outward. On guided media (e.g. wires and optical fibers), the signal falls off logarithmically with the distance. The loss is expressed in decibels per kilometer. The amount of energy lost depends on the frequency. To see the effect of this frequency dependence, imagine a signal not as a simple waveform, but as a series of Fourier components. Each component is attenuated by a different amount, which results in different Fourier spectrum at the receiver, and hence a different signal.

If the attenuation is too much, the receiver may not be able to detect the signal at all or the signal may fall below the noise level. In many cases, the attenuation properties of a medium are known, so amplifiers can be put into try to compensate for frequency-dependent attenuation. The approach helps but can never restore the signal exactly back to its original shape.

The second transmission impairment is delay distortion. It is caused by the fact that different Fourier components travel at different speeds. For digital data, fast components from bit may catch up and overtake slow components from the bit ahead, mixing the two bits and increasing the probability of incorrect reception.

The third impairment is noise, which is unwanted energy from sources other than the transmitter. Thermal noise is caused by the random motion of the electrons in a wire and is unavoidable. Cross talk is caused by inductive coupling between two wires that are close to each other. Sometimes when talking on the telephone, you can hear another conversation in the background. That is cross talk. Finally, there is

impulse noise, caused by spikes on the power line or other causes. For digital data, impulse noise can wipe out one or more bits. [17]

2.5 Medical and Health care services; Information display:-

From time immemorial man has been interested in trying to control disease. The medicine man, the priest, the herbalist and the magician, all undertook in various ways to cure man's disease and/or bring relief to the sick. In an almost complete absence of scientific medical knowledge, it would not be fair to say that the early practitioners of medicine contributed nothing to the alleviation of man's suffering from disease. Medical knowledge in fact has been derived, to a very great degree, from the intuitive and observational propositions and cumulative experiences gleaned from others. A history of medicine thus contributes a review of accomplishments and errors, false theories and misinformation ad mistaken interpretations. It is also a study of the evolution of man and human knowledge down the ages; of the biographies of eminent individuals who developed medicine; of the discoveries and inventions in different historical periods; and of the ever-changing concepts, goals and objectives of medicine. In the course of its evolution, which proceeded by stages, with advances and holts, medicine has drawn richly from the traditional cultures of which it is a past, and later from biological and natural sciences and more recently from social and behavioral sciences. Medicine is thus built on the best of the past. In the crucible of time, medicine has evolved itself into a social system heavily bureaucratized and politicized. The "explosion" of knowledge during the 20^{th} century has made medicine more complex, and treatment more costly, but the benefits of modern medicine have not yet penetrated the social periphery in many countries. The glaring contrasts in the state of health between the developed and developing countries, between rural and urban area and between the rich and poor have attracted world-wide criticism as "social

injustice". Currently, the commitment of all countries, under the banner of the world Health organization, is to wipe out the inequalities in the distribution of health resources and services, and attain the goal of healthcare for all by the year 2000. The goal of modern medicine is no longer merely treatment of sickness. The other and more important goals which have emerged are prevention of disease, promotion of health and improvement of the quality of life of individuals and groups or communities. In other words, the scope of medicine has considerably broadened during recent years. It is also regarded as an essential component of socio-economic development.

2.5.1 Modern Medicine:-

The dichotomy of medicine into two major branches namely curative medicine, and public health. Preventive medicine was evident at the close of the 19^{th} century. After 1900, medicine moved faster towards specialization, and a rational scientific approach to disease. The pattern of disease began to change with the control of acute infections diseases, the so-called modern diseases such as cancer, diabetes, cardiovascular disease, mental illness and accidents came into prominence and have become the leading causes of death in industrialized countries. These diseases could not be explained on the basis of the germ theory of disease, nor treated with "magic bullets". The realization began to down that there are other factors or causes in the aetiology of diseases, namely social, economic, genetic, environmental and psychological factors which are equally important. Most of these factors are linked to man's life style and behavior. The developments in modern medicine may be reviewed broadly under the following heads Curative medicine, Preventive medicine, Social medicine.

(a) Curative medicine:-

Although curative medicine is thousands of years old, modern medicine, as we know today, is hardly 100 years old. Its primary objective is the removal of disease from the patient (rather than from the mass). It employs various modalities to accomplish this objective, e.g. diagnostic techniques treatment. In the middle of the 20th century a profound revolution was brought in “allopathic medicine which has been defined as treatment of disease by the use of a drug which produces a reaction that itself neutralizes the disease”, by the introduction of antibacterial and antibiotic agents. Curative medicine, over the years, has accumulated a vast body of scientific knowledge, technical skills, medicaments and machinery – highly organized – not merely to treat disease but to preserve life itself as far as it could be possible.

Specialization has no doubt raised the standards of medical care, but it has escalated the cost of medical care and placed specialist medical care beyond the means of an average citizen, without outside aid or charity. It has infringed upon the basic tenants of socialism (i.e., the greatest good of the greatest number) and paired the way to varying degrees of social control over medicine. Specialization has also contributed to the decline of general practice and the isolation of medical practitioners at the periphery of the medical care system.

(b) Preventive medicine:-

Preventive medicine developed as a branch of medicine distinct form public health. By definition, preventive medicine is applied to “healthy” people, customarily by actions affecting large numbers or populations. Its primary objective is prevention of disease and promotion of health.

Prevention medicine did not confine itself to vaccination and quarantine. Discoveries in the field of nutrition have added a new

dimension to preventive medicine. New strategies have been developed for combating specific deficiencies as for example, nutritional blindness and iodine deficiency disorders. The recognition of the role of vitamins, minerals, proteins and other nutrients, and more recently dietary fibre emphasize the nutrition component of preventive medicine.

Preventive medicine has become a growing point in medicine. Advances in the field of treatment is no way has diminished the need for neither preventive care nor its usefulness. Preventive measures are already being applied not only to the chronic, degenerative and hereditary diseases but also to the special problems of old age. In fact, as medical science advances, it will become more and more preventive medical practice in nature.

Scientific advances, improved living standards and fuller education of the public have opened up a number of new avenues to prevention. Three levels of prevention are now recognized: primary, intended to prevent disease among healthy people; secondary, directed towards those in whom the disease has already developed; and tertiary, to reduce the prevalence of chronic disability consequent to disease. Preventive medicine ranges far beyond the medical field in the narrow sense of the word. Besides communicable diseases, it is concerned with the environmental, social, economic and more general aspects of prevention. Modern preventive medicine has been defined as “the art and science of health promotion, diseases prevention, disability limitation and rehabilitation”. It implies a more personal encounter between the individual and health professional than public health.

(c) Social medicine:-

Social medicine has varying meanings attached to its label. By derivation, social medicine is the study of man as a social being in his total environment. Its focus is on the health of the community as a whole

professor crew had ably stated that social medicine stands on two pillars – medicine and sociology. Others stated that the maiden sociology married public health and become social medicine. McKeown has this to say “In contemporary usage social medicine has two meanings, one broad and ill-defined, the other more restricted and precise. In the broad sense, social medicine is an expression of the humanitarian tradition in medicine and people read into it any interpretation consistent with their own aspirations and interests. Thus it may be identified with care of patients, prevention of disease, administration of medical services; indeed with almost any subject in the extensive field of health and welfare. But in the more restricted sense, social medicine is concerned with a body of knowledge embodied in epidemiology and the study of the medical needs or medical care of society. Social medicine is not a new branch of medicine but rather a new orientation of medicine to the changing needs of man and society. It emphasizes the strong relationship between medicine and social sciences. The pre-eminent concern of social medicine has unquestionably been the development of epidemiological methods and their application to the investigation of disease. It has entered into a productive relationship with social sciences and statistics to be able to elucidate the role of social factors in disease aetiology. These developments represent a forceful bid for the expanding concept of medicine. However, social medicine was criticized because it was virtually isolated from the service world and confined mostly to academic study of health services and chronic disease.

2.5.2 Health care:-

It was recognized that in both developed and developing countries, the standard of health services the pubic expected is not being provided. The services do not cover the whole population. There is lack of services in some areas and unnecessary duplication in others. A very high

proportion of the population in many developing countries, and especially in rural areas does not have ready access to health services. The health services favoured only the privileged few and urban dwellers. Although there was the recognition that health is a fundamental human right, there is a denial of this right to millions of people who are caught in the viscious circle of poverty and ill health. There are marked differences in health status between people in different countries as well as between different groups in the same country, the cost of health care is rising without much improvement in their quality. There has been growing dissatisfaction with the existing health services and a clear demand for better health care.

The health service covers a wide spectrum of personal and community services for treatment of disease, prevention of illness and promotion of health. The purpose of health services is to improve the health status of population. To be effective, the health services must reach the social periphery, equitably distributed, accessible at a cost the country and community can afford and socially acceptable.

2.5.3 Health system:-

The health system is intended to deliver health services; in other words, it constitutes the management sector and involves organizational matters e.g. planning, determining priorities, mobilizing and allocating resources, translating policies into services, evolution and health education.

The components of the health system include: concepts (e.g. health and disease); ideas (e.g. equity, coverage, effectiveness, efficiency, impact); objects (e.g. hospitals, health centers, health programmers) and persons (e.g. providers and consumers). Together, these form a whole in which all the components interact to support or control one another. The

aim of a health system is health development – a process of continuous and progressive improvement of the health status of a population.

2.5.4 Levels of health care:-

Health services are usually organized at three levels, each level supported by a higher level to which the patient is referred. These levels are Primary health care, Secondary health care, Tertiary health care

(a) Primary health care:-

This is the first level of contact between the individual and the health system where "essential health care (primary health care) is provided. A majority of prevailing health complaints and problems can be satisfactorily dealt with at this level. This level of care is closest to the people.

(b) Secondary health care:-

At this level, more complex problems are dealt with this care comprises essentially curative services. This level serves as the first referral level in the health system.

(c) Tertiary health care:-

This level offers super-specialist care. This care is provided by the regional central level institutions. These institutions provide not only highly specialized care, but also planning and managerial skills and teaching for specialized staff. In addition, the tertiary level supports and complements the actions carried out at the primary level. [18]

2.5.5 Information display:-

Images are the basic source of information in telemedicine. Their effective use demands sophisticated storage of images and associated information. In all areas of telemedicine, diagnosis, quality assurance and control, quantitative evaluation of images and panel discussions, improving methods of storage and retrieval of images is important.[5]

The method of information display will depend mainly on the format in which the information is originally captured. For example, audio information will usually be 'displayed' in the form of sound. Several options are available for displaying images. Videoconferencing units commonly use standard TV sets as their display, while still images are often displayed on PC monitors. However, PC monitors are sometimes used instead of TV screens for viewing video, and TV screens are sometimes for viewing the output form a PC. This is more than a matter of simply connecting them together, because PC display monitors and TV screens operate in a fundamentally different way.

PC screens also come with different resolutions (the number of dots per unit area). High-resolution screens are used for detailed work, but are more expensive.

2.6 Applications of Telemedicine:-

Telemedicine supplies high quality health care and may be useful in developing of providing health care in private clinics or organizations.

Telemedicine can also be used for educating health professionals in rural or remote communities and to give them access to specialized information that might be difficult to obtain in a long time. Telemedicine can be used in public health programs and assist local organizations in health-related campaigns such as accident and prenatal care.[(12)] Telemedicine can enhance efforts for disaster response. Disasters are catastrophic events that overwhelm a community's emergency response capacity, threatening health and safety of the public and environment. In the predisaster situation, telemedicine could be employed in education and training of health care personnel and general community. Telemedicine could support disaster plan implementation, modification, assist with management of critical resources, and provide consultation from within and outside the disaster area. In the postdisaster

rehabilitation, telemedicine can provide a variety of traditional medical consultations and continue to provide support to both resource management and continuing assessment activities. It can provide urgently needed health care in instances of natural disaster.

In many areas ambulances and emergency rescue teams are equipped with telemetry equipment to allow physiological data to be transmitted to a nearby hospital for interpretation. Through the use of telemetry equipment, physiological data can be interpreted and treatment begun before the patient arrives at the hospital. To be effective, the system must be capable of providing reliable reception and reproduction of the transmitted signals under any conditions. Emergency medical care has become an important part of the overall health delivery system.

Telemedicine is not a new concept to space flight. Since its very beginning, space medicine has used communications and information processing technologies. In many aspects, operational boundary conditions in space medicine such as remoteness, telediagnostics, and biotelemetry are characteristics of telemedicine applications.

Telemedicine is utilized by health providers in a growing number of medical specialties including cardiology, pathology, radiology, endoscopy, pediatry, orthopedics, dermatology, psychiatry, pharmacy, surgery, obstetrics, diabetic patients management, ophthalmology, and otolaryngology.[11]

Chapter - Three

IMAGE QUALITY OF TELEDERMATOLOGY AND TELEPATHOLOGY

3.1 Importance of photography and imaging:-

Photography has proven itself to be a valuable aid in many aspects of medicine. Dermatologic care, research and publishing have been enhanced through the use of images. For instance, photo-documentation of patients with a typical nevi, skin cancer, or chronic ulcers, assists the clinical assessment by providing objective measures of the clinical exam over time. Dermatology and Pathology pictures are also the basis for teledermatology and telepathology, are sometimes required by insurance reimbursement plans and are used throughout medical education. Traditionally images are used to communicate the fundamental morphologic and distribution patterns of the disease process itself. Images are central to traditional publishing, and are likewise critical to the new media of the Internet and computer based applications. The Internet provides a new channel for resident and continuing medical education but also allows for transmission of images for telemedical purposes. As the ability to make, save, retrieve, print or transmit images continues to get faster, so will the volume and use for the approaches.

Now digital photography becomes the next milestone in the evolution from the first medical daguerreotype into modern practice.[20]

3.2 Defining a good image:-

The aim to provide the knowledge necessary to use digital photography, this is written with the belief that the camera, regardless of technologic advances, will in the foreseeable future require, at least, a semi-skilled operator. There is also the absolute that overarching themes

are far more critical than specificity. The world of electronic imaging is complete dynamic.

Before discussing the specifics of some relatively inexpensive digital camera and effective methods for using them, it is important to re-iterate that basic and sound medical photography approaches are still needed independent of the capture media. These techniques are described in chapter five and include the need to properly compose the image, remove all distracting clothing and jewelry, provide a neutral backdrop.[20]

To be a good image, high image resolution, alignment of frames, color quality and constancy, good pose certainty are required.

3.3 Image acquisition limitations:-

The equipment and environmental constraints that adversely affect the reproducibility of the images quality of the target are

a) Low image resolution due to equipment limitations.
b) Misalignment of frames acquired with interlaced cameras.
c) Shading and noise due to sensor limitations.
d) Color quality and constancy.
e) Variable environment illumination.
f) Reflections due to skin nature and illumination constraints.
g) Pose uncertainty due to target movement.

The use of commercially available photographic cameras is quite common in skin lesions inspection systems, particularly for telemedicine purposes. However, the poor resolution in very small skin lesions(i.e. lesions with diameter of 0.5 cm or less) and the variable illumination conditions are not easily handled and thus these devices, have been proven insufficient for capturing skin lesions with high requirements in resolution and colour measurement.[21]

3.4 Analogue and Digital images:-

An analogue image is represented electronically by continuous wave form as opposed to a digital image which represented by digital values in figure 3.4.1, derived from the anologue image. Digital values are discrete electronic pulses that have been translated into strings of zeros for black spot and ones for white spot, the only digits in a binary numbering system. [22]

1	1	1	1	1	1	1	1	1	1
1	0	0	0	1	1	0	0	0	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	0	0	0	0	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	0	0	0	1	1	0	0	0	1
1	1	1	1	1	1	1	1	1	1

Fig. 3.4.1[22]

3.5 Image captured in CCD:-

The various component involved in imaging are

- Input device– the source of the images; camera, microscope, scanner, etc.
- Interface hardware – the connection between the input devices and the computer; takes the input signal and digitizes it for use on a personal computer.
- Imaging software – the user interface to all the imaging components.
- output devices – printers , image storage devices, monitors.

A basic image capture system contains a lens and a detector. In digital photography, the detector is a solid state image sensor called a charge coupled device, CCD for short. On an area array CCD, a matrix of hundreds of thousands of microscopic photocells creates pixels by sensing the light intensity of small portions. A CCD consists of a number of light sensitive diodes in figure 3.5.1, which convert photons (light) into electrons (electrical charge). These diodes are called photosites or photocells and are made up from polysilicon (p^+ in the figure) electrodes embedded on a silicon substrate.

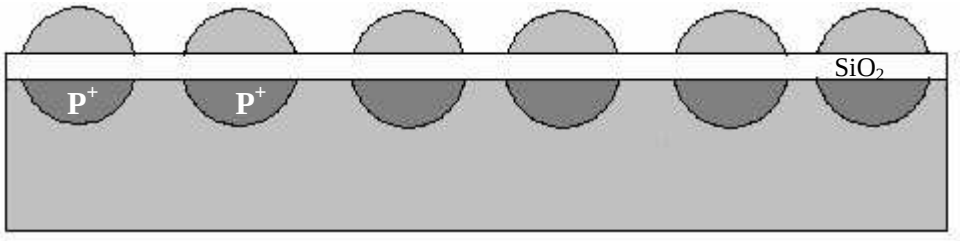


Fig. 3.5.1: Schematic diagram of CCD [22]

The mini electrodes are separated from the silicon substrate by an oxide-insulated layer. Incident photons cause excitation of electrons which are trapped in the depletion layer on the silicon substrate. This charge is transferred (coupled) to adjacent electrodes by altering their relative potentials. The charged pattern (current) is proportional to the corresponding intensity of incident photons. [22]

To capture images in colour, red, green and blue, filters are placed over the photocells. Red, Green, and Blue are the primary colours and our eye perceives different colours by adding these primary colours in different proportions. Thus the principle used in colour obtaining is to measure the intensity of Red, Green and Blue colours (called RGB) in the light reflected by a picture element in figure 3.5.2. The RGB components in reflected light are found by

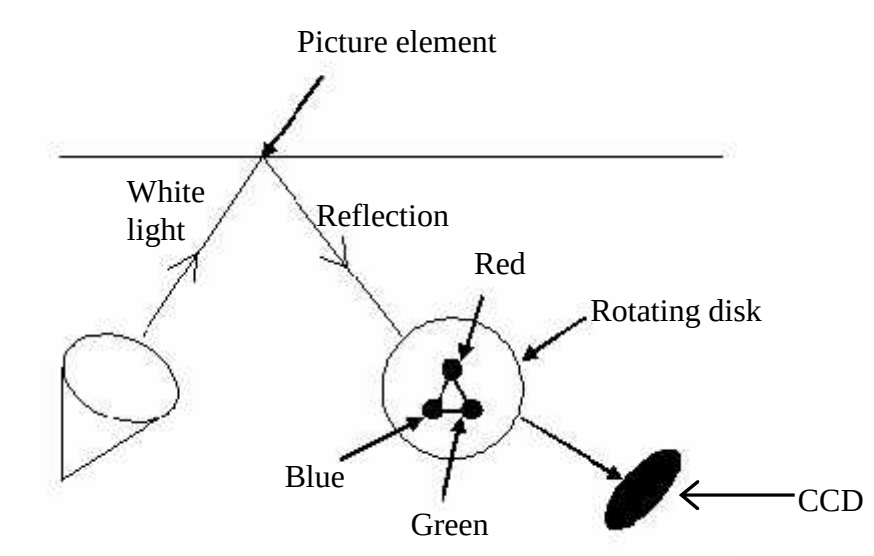


Fig. 3.5.2: Finding RGB components in reflected light[23]

R, G, B filters and picking up R, G, B components separately. The intensity of each of these is measured by a CCD to 8 significant bits if R, G, B are combined. We have 24 bits left to represent different colours. Thus 2^{24} = 16.7 million colours can be represented. All 1s represent white and all 0s black and each bit pattern one colour. If more colours are required then the number of bits used to represent R, G, B intensities must be increased. (23)

3.6 Performance of CCD in image quality:-

Differenting manufacturing techniques and specifications result in different performances of CCD microchips. These performance parameters are

3.6.1 Spatial Resolution:-

Basically resolution means the “quality” of the image. The higher the resolution, the finer detail in the image. Spatial Resolution is the ability to distinguish fine spatial detail. The spatial frequency at which a digital image is sampled (the sampling frequency) is often a good indicator of resolution. The spatial resolution ranges from 640×480 to 5140×5140 pixels.

This is why dots per inch (dpi) or pixels per inch (ppi) are common and synonymous terms used to express resolution for digital images. Generally, but within limits, increasing the sampling frequency also helps to increase resolution. The very much higher resolution makes the file sizes much larger. (22)

3.6.2 Brightness Resolution:-

The brightness or colour value of each pixel is defined by one bit or by a group of bits. The more bits used, the higher the brightness resolution. The number of bits used to define each pixel determines bit depth. The greater the bit depth, the greater the number of tones (grey scale or colour) that can be represented. Digital images may be produced

in black and white (bitonal), grayscale, or colour. A bitonal image is represented by pixels consisting of 1 bit each, which can represent two tones, using the values 0 for black and 1 for white. A greyscale image is composed of pixels represented by multiple bits of information. For example in a 2-bit image, there are four possible combinations 00, 01, 10 and 11. if “00” represents black, and “11” represents white, then “01” equals dark grey and “10” equals light grey. The bit depth is two, but the number of tones that can be represented is 2^2 or 4. At 8 bits, 256 (2^8) different tones can be assigned to each pixel.

A colour image is typically represented by higher bits which are mostly above 8 bits. Now, the bits value and corresponding tones are given below:

1 bit (2^1) = 2 tones

2 bits (2^2) = 4 tones

3 bits (2^3) = 8 tones

4 bits (2^4) = 16 tones

8 bits (2^8) = 256 tones

16 bits (2^{16}) = 65,536 tones

24 bits (2^{24}) = 16.7 million tones

3.6.3 Noise:-

Noise is data or unidentifiable marks picked up in the course of image capture or data transfer that do not correspond to the original. It appears as small, random variations in brightness or colour. Sensor sites with low signal-to-noise ratio, introduce noise. Sensor sites with high signal-to-noise ratio represent the image accurately. [(22)]

3.6.4 Quantum Efficiency:-

Quantum efficiency (QE) is defined as the ability of a CCD in generating electrons form the incident light reaching the CCD; it is a

function of the wavelength of the incident light. QE measures detection efficiency. [22]

3.6.5 Dynamic Range or density range:-

The ability of discerning minute differences in low light levels is known as the dynamic range or intensity resolution. Dynamic range indicates how well the camera can differentiate between light levels. It is the range of tonal difference between the lightest light and darkest dark of an image. The higher the dynamic range, the more potential shades can be represented. Dynamic range also describes a digital system's ability to reproduce tonal information. With low dynamic range, shadows lose detail and saturated areas are washed out. [22]

3.6.6 Accuracy and Linearity:-

Ideally, each pixel acts a high fidelity photometric device producing an electronic signal that is exactly proportional to the intensity of the incident light level. A typical linearity reading on a high performance camera deviates less than 0.1% over the entire dynamic range. Also these cameras have excellent pixel-to-pixel response uniformly with deviations less than 0.1% in the best cases. Both of these factors are important in quantitative digital imaging analysis CCD cameras should be linear over their entire dynamic range. [22]

3.6.7 Image Processing flexibility:-

The exposure time can be varied continuously between an open shutter and the fastest scan rate possible. When a low light image situation is encountered, it is often necessary to average many captured frames (over sampling), in order to improve the rather poor signal-to-noise ratio inherent in this type of system. However, with high performance CCD cameras, the image can be "integrated" on the CCD sensor thus providing a superior signal-to-noise ratio in each captured frame and eliminating the need to compute frame averaging. [22]

3.7 Image compression and image formats

Generating digital images results in big digital image files. Image archival requirement have resulted in bigger and faster hard or optical drives (storage devices) and data Compression techniques. There are many image-compression formats capable of storing 24 bit images. Some of them operate with “lossless” compression algorithms; others operate with “lossy” compression algorithms. Lossless compression achieves only about a 2:1 compression ratio, but the reconstructed image is mathematically and visually identical to the original. Lossy compression provides much higher compression rates, but the reconstructed image shows some loss of data compared to the original image. This loss can be visible to the eye or visually lossless. Visually lossless compression is based on knowledge about colour images and human perception. Visually lossless compression algorithms sort image data into “important data” and “unimportant data”, then discard the unimportant. The selection of popular image formats currently available for personal computers are[22]

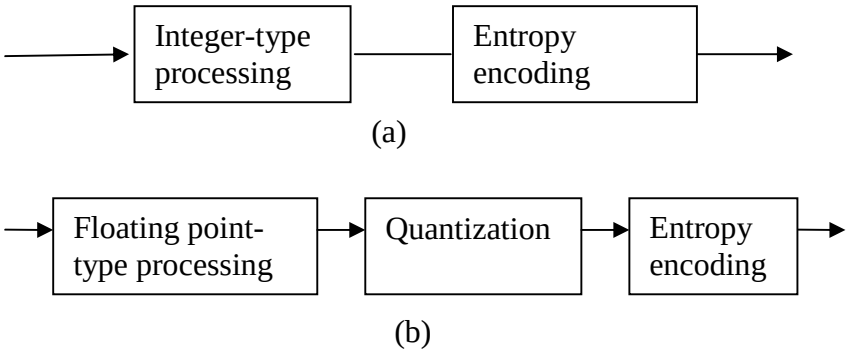
- BMP (Bit Mapped Picture)
- GIF (Graphic Interchange Format)
- JPEG (Joint Photographic Expert’s Group)
- PCX
- PNG (Portable Network Graphics)
- PS/EPS (Postscript an Encapsulated postscript)
- TIFF (Tagged image File Format)
- WMF (Windows Metafile)
- DICOM (Digital imaging and Communication in Medicine)

3.8 Requirements for medical image compression:-

There is no arguing that high quality is desirable when performing medical diagnoses, and high quality images require vast amounts of storage space. Also high-speed communications lines are required for

sending receiving image data in a short time. This means that we must determine the level of image quality suitable for particular fields and type of diagnosis. In addition, data compression must be applied to efficiently store and transfer vast amounts of data.

This figure 3.8.1 shows the basic forms of reversible and irreversible compression methods. Almost all reversible compression methods are a combination of integer type processing and entropy encoding. Integer type processing here refers to differential calculation between pixels and pyramid decomposition calculation of the image. These calculations are carried out additively and subtractively on pixels that have integer values, making it possible to use reverse processing in a decoder to fully restore the original pixel values. Entropy encoding reduces the code length according to the occurrence probability of the input symbol. Entropy coding cannot compress images below the entropy rate of the input signal. Consequently, the overall characteristics of the coding system using the ideal form of entropy coding depends on just how much the integer type calculation reduced the entropy of the input signal.



Encoder configuration of
(a) lossless and (b) lossy compression

Figure 3.8.1 [24]

Irreversible compression consists of real type processing (including integer type processing), quantization, and finally, entropy encoding, real type processing consists of DCT (Discrete cosine transform) and sub-band decomposition and other such processes for lowering the

distribution value of the distortion produced by the quantization at the next stage. When coding color images, it also includes transform processing for the luminance and color difference components. In the next stage, quantization reduces the number of levels in the input signal and gets rid of the low level signals, there by reducing the dynamic verge and number of signals for the signals being encoded. Irreversible compression is a lossy coding method, which means that it loses some of the information possessed by the original image through quantization processing. The entropy coding in the final stage is exactly the same as that used in reversible compression.[24]

3.9 Digitization of medical images

3.9.1. Need for digitization:-

The kinds of medical information used these days are different. They include text information such as patient charts, one-dimensional data such as waveforms and audio and two- and three-dimensional data such as images. The ultimate goal of digitizing such medical information is to create a filmless and paperless system. The radiological images have been traditionally been kept on film, requiring large areas to physically store all of them for long periods of time. As the number of sheets of film being stored increases, so does the difficulty of locating the one for which you are searching. A filmless paperless system, in other words, a digital system will solve such problems and make it possible to quickly access and display the required images anytime and anywhere. Implementing this system requires a union of basic technologies for image input, storage, display, management/databases, and transmission. A medical image management system integrating all of these technologies is known as a picture archiving and communication system (PACS) or an image management and communications system (IMACS).

The main benefits to be gained through the digitization of medical information are as follows:

- Centralized management of image information obtained from a variety of input devices.
- Speedy image searches.
- Highly accurate diagnoses by making comparisons with past image data.
- Prevention of loss and degradation in image data.
- Improvement of diagnostic performance including the extraction and emphasizing of diagnostic information made possible by the easy application of digital processing.
- Ease of exchanging information between hospitals using digital charts, thereby preventing redundant exams.
- Leads smoothly to informe consent since doctors will be able to display a variety of images and information on screen while they are explaining the details to patients.
- Makes hospitals operate more efficiently by reducing storage space and decreasing waiting time.

Realizing the above mentioned benefits requires the building of high-speed medical information networks within and between hospitals. The building of high-speed, high-bandwidth networks in recent years has spurred on the digitization of medical information.[24]

3.9.2 Quality of medical images:-

The definition of medical images can be said to be the direct or indirect detection of visible and invisible information from carriers such as light and x-rays, and subsequent representation of that information as medical image. At present, a variety of medical images are being used for diagnosis. The pixel depth (number of bits used to display each pixel)

represents the digital data format, which is the most generally used form in each type of image, and therefore, the number of bits per pixels is not necessarily the same as the substantial spatial resolution of the pixels. Discovering the proper number of bits per pixel in each image requires evaluations both from a physical standpoint and a diagnostic standpoint. Furthermore, the results of such evaluations must be thoroughly studied to see whether or not the required quality has been fulfilled. [24]

Chapter – Four

DIGITAL CAMERA

4.1 Physics of digital camera:-

A photographic digital camera consists essentially of a convex lens, a light sensitive material called CCD (charge couple device) at the back and a focusing device for adjusting the distance of the lens. There is an adjustable aperture known as diaphragm that permits different amounts of light to enter the camera in figure 4.1.1. The image is focused on the light sensitive material by altering the distance of the lens from it. There is a shutter placed in the path of light and the time for which it is opened depends upon the brightness of the object, the sensitivity of the photographic emulsion, the focal length of the lens and the size of the stop (aperture). The lens system may contain an achromatic doublet and separated lenses which together reduce considerably chromatic and spherical aberration. An aperture or stop of diameter d is provided so that the light is incident centrally on the lens.

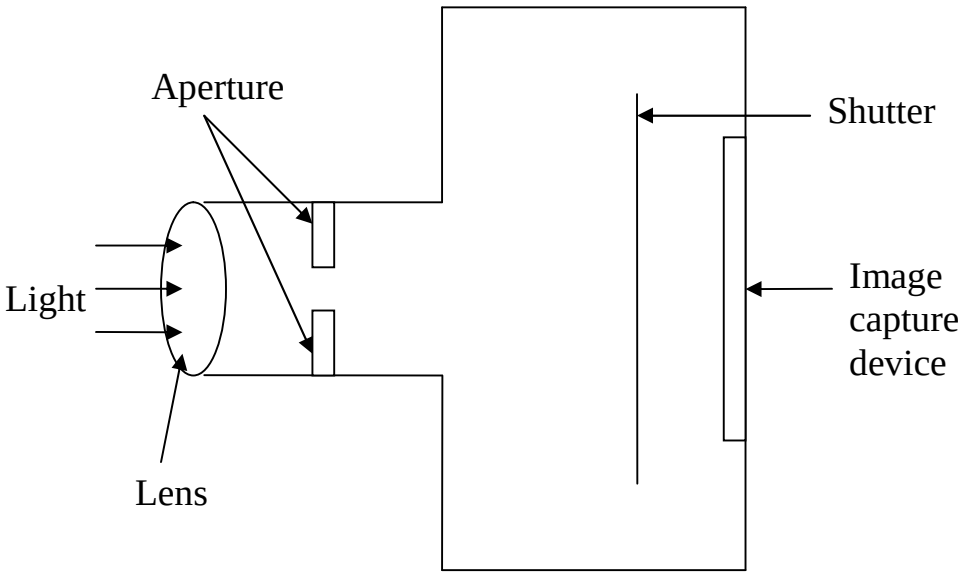


Fig. 4.1.1: Camera[26]

The amount of luminous flux falling on the image in a camera is proportional the area of the lens aperture or to d^2, where d is the diameter

of the aperture. The area of the image formed is proportional to f^2, where f is the focal length of the lens. Since the length of the image formed is proportional to the focal length, as illustrated by figure 4.1.2. It therefore follows that the luminous flux per unit area of the image or brightness B

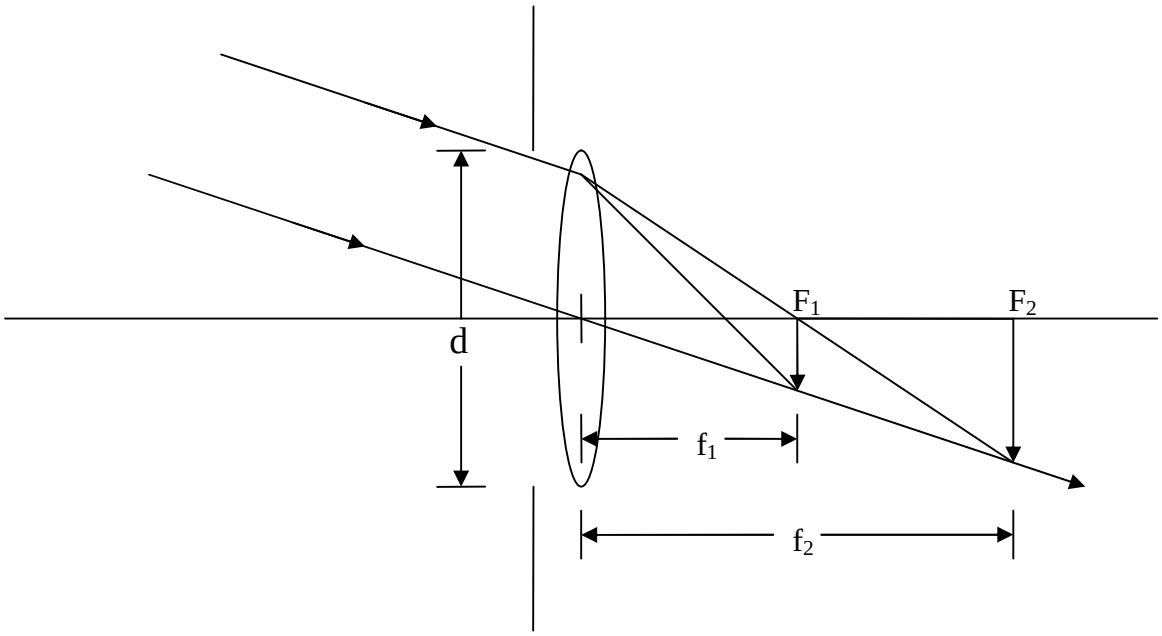


Fig. 4.1.2: Brightness of image[26]

of the image is proportional to d^2/f^2. The time of exposure, t for activating the CCD (Charge Couple device) is inversely proportional to B.

Hence,

$$t \propto \frac{f^2}{d^2}$$

The relative aperture of a lens is defined as the ratio d/f. The aperture is usually expressed by its f-number. If the aperture is f4, this means that the diameter d of the aperture is f/4, where f is the focal length of the lens.[25]

4.2 Exposure:-

The meaning of exposure is simply allowing the image capture device to be exposed to the image of the scene. We need to form an image capturing device and this requires the use of a lens.

Image capturing devices are sensitive to light. If more light than necessary can reach the device, the image will be over-exposed, and, as a result, a white-out image is recorded. On the other hand, if insufficient light can reach the image capturing device, the image will not be able to form properly, and will be dark (i.e. under-exposed). An over- or under-exposed image contains less detail. Therefore, a camera lens must control the right amount of light that can reach the image capturing device.

To control the amount of light that can reach the image capturing device, a lens has an aperture, which is just a variable opening. Modern aperture construction usually consists of a number of blades. A better lens may have 9 blades so that out-of-focus spots become more circular rather than polygonal. These blades can close down to form a smaller aperture; or completely open to produce the maximum aperture. The aperture is set to its maximum when focusing. It closes down to the selected size when the shutter release button is pressed halfway down.

In addition to aperture, a camera also has shutter. In theory, a shutter is a device that opens for a specific period of time so that the image capturing device can be exposed to the incoming light. Normally, before taking a photograph, the shutter covers the image capturing device. When the shutter release button is pressed, the shutter opens, exposing the image capturing device to the incoming light through the lens. After a specific period of time elapses, the shutter closes. This specific period of time is referred to as a shutter speed.[26]

4.3 Lens and Focal length:-

A camera lens collects the available light and focuses it on the sensor. Most digital cameras use auto-focus techniques. The important difference between the lens of a digital camera and the lens of a 35mm camera is the focal length. The focal length is the distance between the lens and the surface of the sensor. The surface of a film sensor is much larger than the surface of a CCD sensor. In order to project the image onto a smaller sensor, it is necessary to shorten the focal length.

Focal length is also the critical information in determining how much magnification you get when you look through your camera. As the focal length is increased, magnification becomes greater and objects appear to get closer. As the focal length is decreased, things appear to get further away, but a wider field of view in the camera can be captured. In other words, when the focal length is changed, the two important effects are noticed: angle of view and magnification. When the focal length becomes smaller (respectively, larger), the coverage of the scene is wider (respectively, narrower). [26]

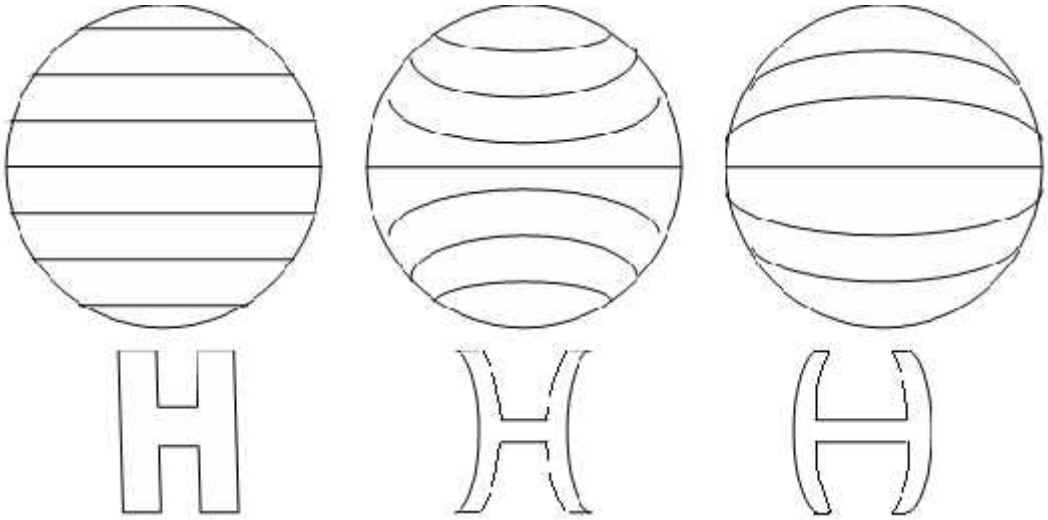
4.3.1 Lens Flare and Ghost:-

When the lens is pointed to the sun or a very strong light source, lens flare and/or ghost may occur in the image. Flare (washed out effect) occurs due to light bouncing off the glass surfaces of the lens (i.e. internal reflection) rather than transmitting through. Because of this internal reflection, image constrast and tonality are reduced. Ghost (a string of color dots appearing in the image) is dots usually in green, purple or violet color appearing in the image which has the shape of the aperture of the lens and are not part of the actual scene. With a multicoated lens in the on-camera one, flare and ghost cannot be eliminated completely. To overcome this problem, the lenses are not pointed directly toward or near a strong light source. [26]

4.3.2 Distortion:-

The failure of a lens to form a point image due to a point object is due to the presence of spherical aberration, coma and astigmatism. The variation in the magnification produced by a lens for different axial distances results in an aberration called distortion. This aberration is not due to the lack of sharpness in the image. Distortion is of two types viz (a) pin-cushion distortion and (b) barrel shaped distortion. In pin-cushion distortion, the magnification increases with increasing axial distance and the image of an object in fig 4.3.2 (a) appears as shown in 4.3.2 (b). On the other hand, if the magnification decreases with increasing axial

distance, it results in barrel shaped distortion and the image appears as shown in fig 4.3.2(c).



Object

Fig. 4.3.2 (a) [27]

Pin cushion Distortion

Fig. 4.3.2 (b) [27]

Barrel shaped

Fig. 4.3.2 (c) [27]

In the case of optical instruments intended mainly for visual observation, a little amount of distortion may be present but it must be completely eliminated in a photographic camera lens, where the magnification of the various regions of the object must be the same.

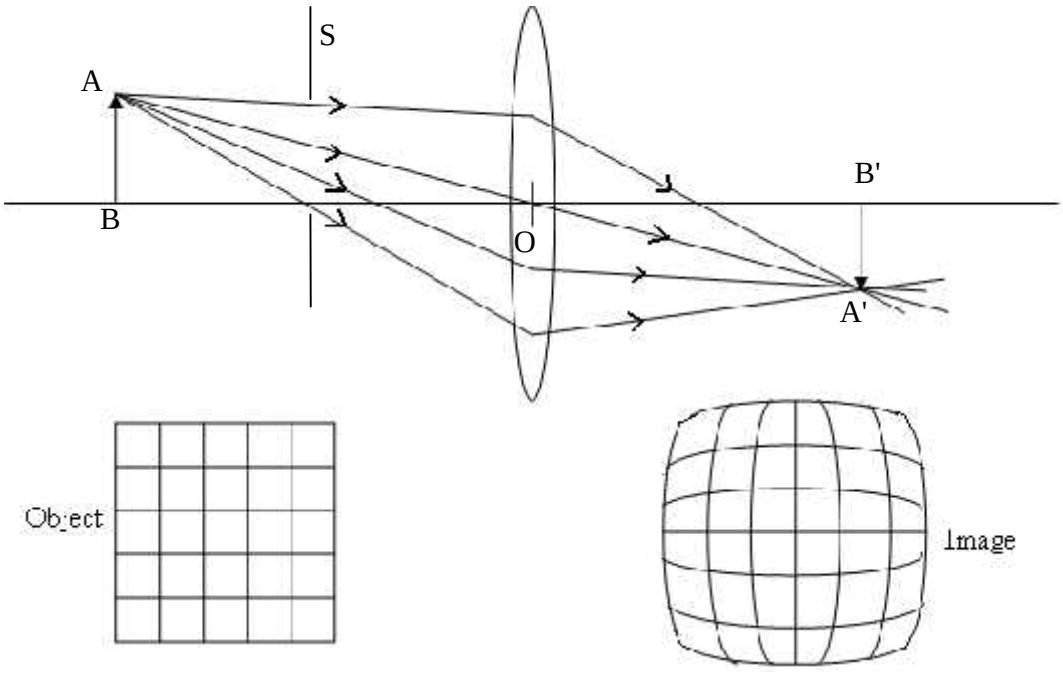


Fig 4.3.2 (d)[27]

In the absence of stops, which limit the cone of rays or light striking the lens, a single lens is free from distortion.

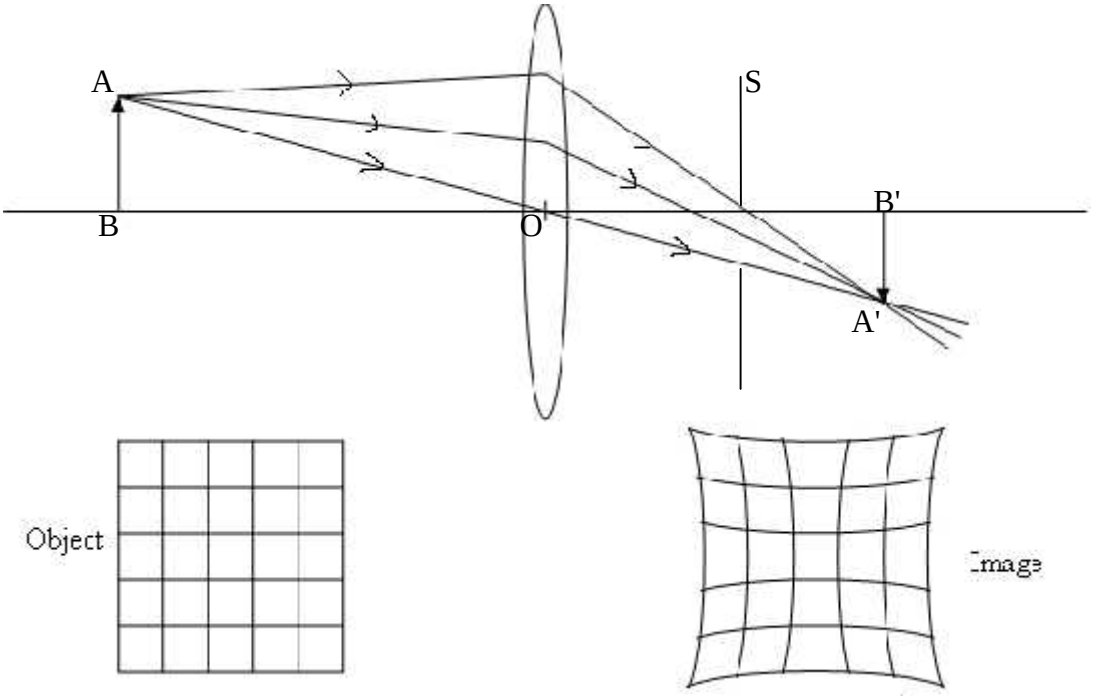


Fig. 4.3.2 (e) [27]

But, if stops are used, the resulting image is distorted. If a stop is placed before the lens the distortion is barrel-shaped in fig 4.3.2(d) and if a stop

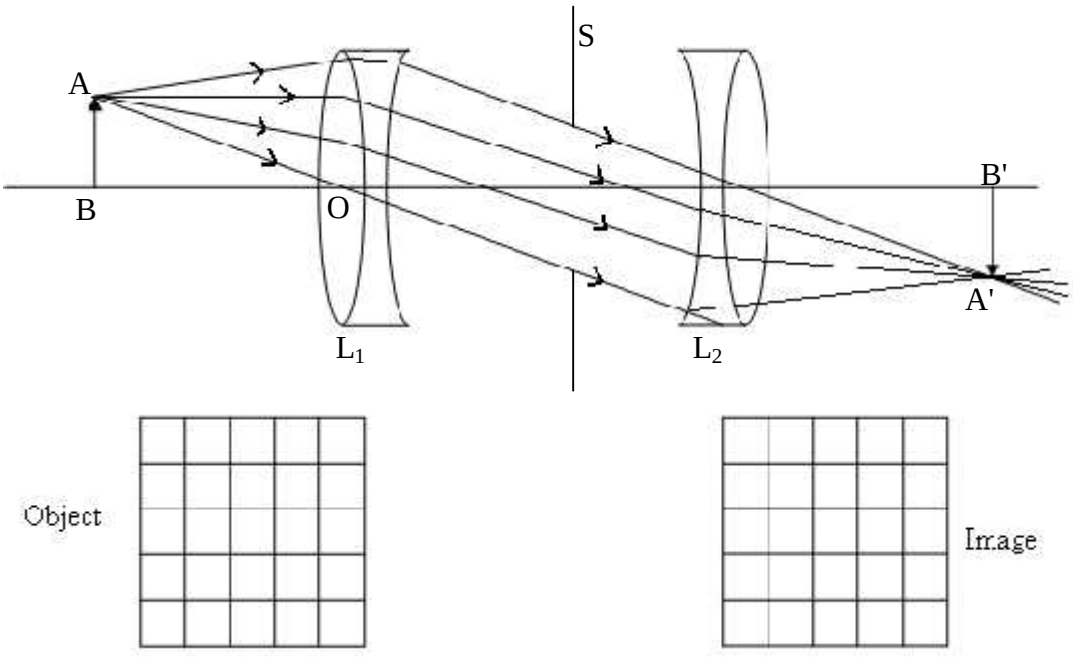


Fig. 4.3.2 (f) [27]

is placed after the lens, the distortion is pin-cushion type in fig. 4.3.2(e) to eliminate distortion a stop is placed in between two symmetrical lenses, so that the pin-cushion distortion produced by the first lens is compensated by the barrel-shaped distortion produced by the second lens in fig 4.3.2(f) projection and camera-lenses are constructed in this way.[27] Barrel distortion usually occurs in the wide angle side and pin-cushion usually occurs in the tele side. [26]

4.3.3 Chromatic Aberration:-

The refractive index of the material of a lens is different for different wavelengths of light. Hence the focal length of a lens is different for different wavelengths. Further, as the magnification of the image is dependent on the focal length of a lens, the size of the image is different for different wavelengths (colours). The variation of the image distance from the lens with refractive index measures axial or longitudinal chromatic aberration and the variation in the size of the image measures lateral chromatic aberration. Fig 4.3.3(a) illustrates chromatic aberration present in an image formed by a single lens L. AB is an object placed in front of the lens. A'B' and A"B" are the violet and the red images. The violet image is formed nearer the lens than the red image. The monochromatic aberrations are assumed to be absent in this case. The

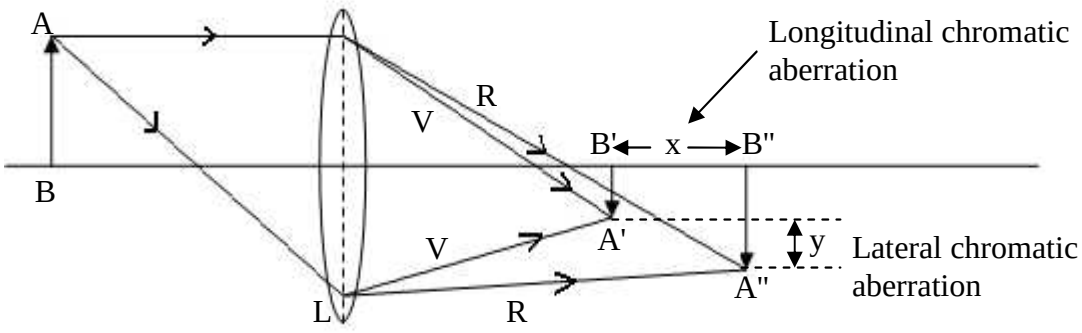


Fig. 4.3.3 (a) [27]

distance x measures the axial or longitudinal chromatic aberration and the distance y measures the lateral chromatic aberration. The images of intermediate colours between violet and red lie in between the images A'B' and A"B" and their size increases from violet to red. At no one position the images are in sharp focus. Thus, a single lens produces a coloured image of an object illuminated by white light and this defect is called chromatic aberration.[27] Therefore, the image produced by such a lens frequently contains color fringes that are not part of the actual scene. In digital cameras, the image capturing devices (e.g. CCDs) also contribute some degree of aberration. Because the photo sites of an image capturing device are densely packed, it is possible that the color captured by one photo site may "propagate" to its neighbours. In the worst case, an over-charged photo site (i.e. over-exposed) may have its charge "leaking" to its neighbouring photo sites. This is an effect, which is similar to chromatic aberration is usually referred to as blooming.[26]

4.3.4 Angle of view:-

The angle of view of a lens is determined by its focal length and the image size. Because image is in general not a square, angle of view is measured diagonally.

4.4 Sensitivity of CCD:-

The image capturing device is sensitive to light. Therefore, sensitivity means the sensitivity of the image capturing device (CCD – Charge Couple device). The more sensitive this device is, the less light is required to form an image setting the image capturing device to a higher (or faster) rating decreases image quality.

The sensitivity can be changed only if the camera is in the program (p) mode, Aperture-priority (A) mode, shutter-priority (s) mode and Manual-exposure (M) mode. By the default, the camera uses the ISO 100 rating and raise the ISO when it is necessary. This is the fully automatic Automode. Or, we can set the sensitivity to 100, 200, 400, or 800

manually. Setting the sensitivity to 200 means that the CCD is twice more sensitive to the light than of 100. Thus, only 50% of the light originally for 100% is needed. For example, suppose under sensitivity 100 aperture F5.6 and shutter speed 1/125 second are required to have a good exposure. Setting sensitivity to 200, we can either keep the aperture at F5.6 and half the shutter speed (i.e. changing 1/125 second to 1/250 second), or keep the shutter speed at 1/125 second and reduce the aperture to F8.0. There are certainly other equivalent (aperture, shutter speed) combinations, and the above only suggests a set of possibilities.[26]

4.5 Aperture:-

The aperture is the size of the opening in the camera. It is located behind the lens. On a bright sunny day, the light reflected off in the image may be very intense, and it doesn't take very much of it to create a good picture. In this situation, the aperture is very small. But on a cloudy day, or in twilight, the light is not so intense and the camera will need more light to create an image. In order to allow more light, the aperture must be enlarged.

An aperture (i.e. X.Y in FX.Y) is defined as

$$\text{Aperture} = x, y \text{ in } Fx,y = \frac{\text{Focal length}}{\text{diameter of opening}}$$

The size of the opening of an aperture is denoted as Fx.y such as of examples: F1.4, F2.0, F2.8, F5.6, F8.0, F11.0 and so on. These numbers are usually referred as f-number or f-values. The larger the f-number, the smaller/narrower the aperture lens opening. For example, an aperture F5.6 has an opening smaller than that of F4.0 and F2.8. Hence, by varying the aperture, we can control the amount of light that can reach the image capturing device.

From the above definition, given a fixed focal length, the larger the opening, the smaller the value of x.y and smaller the opening, the larger

the value of x.y. Therefore, the value x,y in Fx.y is inversely proportional to the size fo the aperture opening (i.e. diameter of opening).

Suppose an aperture (i.e. f-number) is defined by focal length f and aperture diameter d (i.e. a=f/d). If the amount of light is reduced by half, the diameter must be smaller. In fact we can achieve this by reducing the area of the aperture opening by half. Let the diameter of the new opening be D. Then, we have

$$D = \frac{\sqrt{2}}{2} d$$

The new aperture A with this new diameter is calculated as follows.

$$A = \frac{f}{D} = \frac{f}{\frac{\sqrt{2}}{2} d} = \sqrt{2} \frac{f}{d} = \sqrt{2}\, a$$

Therefore, if the amount of light is reduced by half, the aperture value is approximately 1.4 (i.e. the square root of 2) times larger than the original.[26]

4.6 Shutter speed:-

The time elapsed between the opening and closing of the shutter is referred to as shutter speed. Traditionally, the shutter speed is the amount of time that light is allowed to pass through the aperture. Think of a mechanical shutter as a window shade. It is placed across the back of the aperture to block out the light. Then, for a fixed amount of time, it opens and closes. Therefore it can also be defined as the amount of time it is open is the shutter speed. One way of getting more light into the camera is to decrease the shutter speed. In other words, leave the shutter open for a longer period of time.

Film-based cameras must have a mechanical shutter. Once the film is exposed to light, it can’t be wiped clean to start again. Therefore, it must be protected from unwanted light. But the sensor in a digital camera can be reset electronically and used over and over again. This is called a

digital shutter. Some digital cameras employ a combination of electrical and mechanical shutters.

It is usually denoted by an integer whose reciprocal gives the shutter speed in second. For example, shutter speeds 3, 100, 250 and 1000 really mean 1/3 sec, 1/100 sec, 1/250 sec, and 1/1000 sec. It is also possible that the shutter may open for more than a second. A shutter speed of greater than or equal to a second is frequently denoted by an integer followed by a double quote. For example, 1", 2" and 4" are 1 sec, 2 sec and 4 sec.[26]

4.7 Optical zoom and Digital zoom:-

Digital cameras may have an optical zoom, a digital zoom, or both. Optical zoom works just like a zoom lens on a film camera. The lens changes focal length and magnification as it is zoomed. Image quality stays high throughout the zoom range. Digital zoom simply crops the image to a smaller size, then enlarges the cropped portion to fill the frame again. Digital zoom results in a significant loss of quality.

An optical zoom actually changes the focal length of lens. As a result, the image is magnified by the lens (sometimes called the optics, hence optical zoom). With greater magnification, the light is spread across the entire CCD sensor and all of the pixels can be used. An optical zoom is a true zoom, that will improve the quality of the pictures.

A digital zoom is a computer trick that magnifies a portion of the information that hits the sensor. When the picture is taken with a 2x digital zoom, the camera will use half of the pixels at the centre of the CCD sensor and ignore all the other pixels. Then it will use interpolation techniques to add detail to the photo.[26]

4.8 Depth of field:-

When a lens focuses on a subject at a distance, all subjects at that distance are sharply focused. Subjects that are not at the same distance are out-of-focus and theoretically are not sharp. However, since human

eyes cannot distinguish very small degree of unsharpness, some subjects that are infront of and behind the in-focus subjects can still appear sharp. The zone of acceptable sharpness is referred to as the depth of field. Thus, increasing the depth of field increases the sharpness of an image using the smaller aperture, the depth of the field can be incerased.

Suppose the lens focuses on the yellow dot as shown in the figure 4.8 (a) below. This subject generates a yellow dot on the image plane. Once focused all subjects that have the same subject-lens distance as that of the yellow dot will appear sharp. Now, consider a white dot that is behind the yellow dot (i.e. with larger subject-lens distance). Since it is out-of-focus, it will not produce a sharp white dot image. Instead, its image is formed some where in front of the image plane. On the image plane, it image of this white dot is a circle as shown below. This circle is usually referred to as a circle of confusion. As the subject-lens distance increases, the size of this circle increases. The same holds true for a subject in front of the yellow dot (i.e. the green dot in the figure below). Since these circles of confusion are actually out-of-focus images of dots, if we can reduce the size of circle of confusion, we can increase the sharpness of the resulting image. [26]

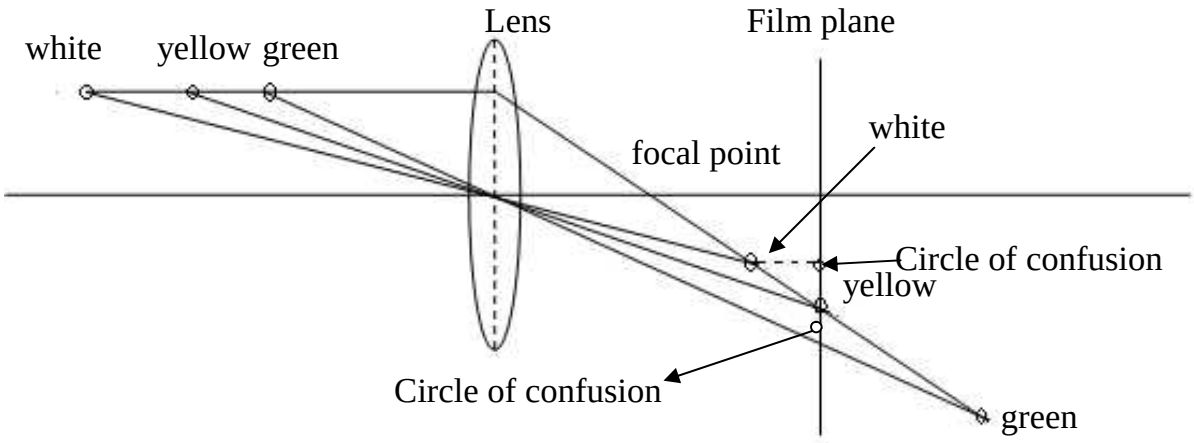


Fig. 4.8 (a)

Since circles of confusion are formed by light rays passing through the lens tube, the size of a circle of confusion is proportional to the amount of light that can pass through the lens tube. This means smaller (resp., larger) circles of confusion will be formed if less (resp. more) light can pass through. Restricting how much light can pass through the lens is the function of aperture in the lens tube. Therefore, a smaller aperture means allowing less light to reach the image capturing device, which means there is a smaller circles of confusion, and, as a result the image is sharper.[26]

4.9 Exposure value:-

Exposure value (EV) is defined mathematically as follows

$$EV = \log_2 \frac{(\text{Aperture})^2}{\text{shutter speed}}$$

An EV of 0 produces the correct exposure, while +EV will increase exposure making the values brighter. Using –EV will reduce exposure and create an image that is darker. This feature is quite useful when photographing dark or bright subjects.

To maintain a constant amount of light, there is several combinations of wider aperture and faster shutter speed, or a narrower aperture and slower shutter speed. This constant amount of light is measured in an unit of EV (i.e. exposure value).

Suppose the sensitivity of the image capturing device is fixed. To allow constant amount of light to reach the image capturing device, we have two variables, namely an aperture and a shutter speed. There are infinite numbers of combinations of aperture and shutter speed.

Consider an aperture F1.0 at 1 second (where F1.0 is aperture and 1 second is shutter speed). The above formula yields an EV of 0. If we reduce the aperture by half (i.e. F1.4) and double the shutter speed (i.e. 2 second), the EV is still 0. Similarly, the combination of (F2.0, 4 second),

(F2.8, 8 second) and so on all yield an EV 0. Now consider the case of reducing the amount of light that can reach the image capturing device by 50%. This means keeping the shutter speed same and use a smaller aperture or half the shutter speed and use the same aperture.

Let us keep F1.0 fixed and cut the shutter speed by half. Thus F1.0 and shutter speed ½ second yields an EV +1. Certainly (F1.4, 1 second), (F2.0, 2 second), (F2.8, 4 second) are on the EV line of +1. Now reducing the speed to a quarter of 1 second and keeping the aperture at F1.0 gives EV +2. Similarly, (F1.4, ½ second), (F2.0, 1 second), (F2.8, 2 second) and so on are all on the EV line of +2. An for aperture F1.0 and shutter speed 2 second, the EV is -1. similarly F1.4 and 4 second. Figure 4.9.1 shows the EV of different aperature and shutter speed. [26]

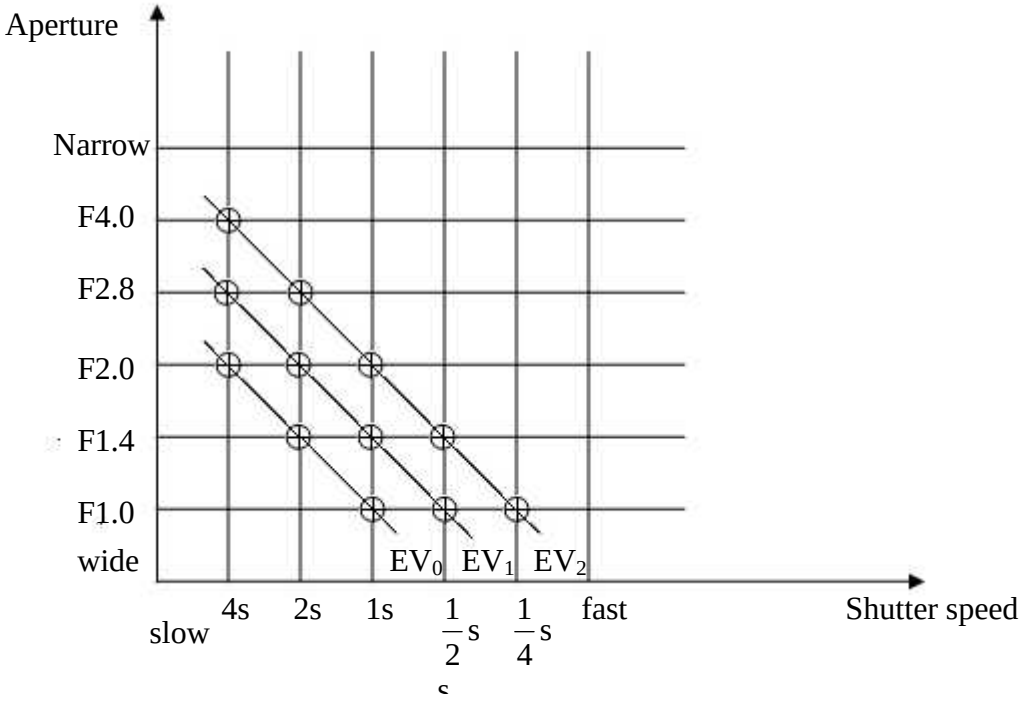


Fig. 4.9.1 [26]

Chapter – Five

MATERIALS AND METHODOLOGY

5.1 General Consideration:-

Methodology is the important aspect of research work. Reliable and relevant study can be made possible by applying scientific method.

This chapter deals with the discussion of the methods used in the present work to maintain the image quality in teledermatology and telepathology of Telemedicine using a digital camera which was done at Teaching Hospital, T.U. Kathmandu; Kanti Hospital, Kathmandu; Kathmandu Medical College, Kathmandu University, remaining works were done at Health Net, Kathmandu, Nepal.

A significant number of digital images in any new store and forward consult system will have some fundamental problems with the quality. In identifying some of these problems, we found that there is a real lack of an understanding of the fundamental concepts in dermatology and pathology. Dermatologists and pathologists use certain clues to diagnose skin and pathologic slides (Histopathology and cytology) conditions respectively; the goal of photography is to reproduce these clues or findings.

In fact, most dermatologic and pathologic photography are currently taken by dermatologists and pathologists respectively who already have an idea of what the particular diagnosis is. The dermatologist and pathologists have been trained and use all the visual clues to render a diagnosis. Thus, taking photographs is merely an attempt to capture the unique characteristics of the particular skin, histopathology and cytology condition that the dermatologists and pathologists see and recognize with their won eyes.

For the non-dermatologist and non-pathologist who are not trained in the art of dermatology and pathology, it is difficult to capture the particular characteristics of the skin rash or lesion and in pathology

without understanding what they are looking for first. However, this exactly what is required in teledermatology and telepatholgy: a non-dermatologists and non-pathologists must be trained first to be able to identify the extent of the skin, histopathology and cytology condition. He or she must then attempt to reproduce the characteristics findings for the remote physician via still digital images so that a correct diagnosis can be rendered.

Good photographic techniques will yield good quality images, and by optimizing the quality of information on the images, we are attempting to maximize the diagnostic accuracy.

5.2 Steps in the image making process:-

Subject → light/energy → reflection → lens → exposure → CCD → record → store → move → save → process → save → read → archive.[20]

5.3 Configuration of experimental system of teledermatology and telepathology: -

A typical teledermatological system is constituted of a local station, a distant station, and the network in figure 5.3.1. In local station A are installed the tools for storing and managing the medical data. The doctor is able to manipulate the images and to store them along with the patient's demographic and textual clinical data into a database. In case that the doctor is unable to make a reliable diagnosis and a specialist is needed, then the data are sent to distant station B. in station B a TCP/IP application server is deployed, which stores the images. The only data needed by station A are the IP address of station B and a port number from which the application server waits for data.

When the data transmission is completed, the doctor at station B can examine the images and make a diagnosis. For the support of diagnosis, the image viewing application provides digital processing tools. These include enlargement, rotation, increase of dynamic range,

contrast enhancement etc. when they complete the diagnosis, he sends it to station A with directives to the local doctor. Then he stores the clinical and demographic data along with the images to a database. These

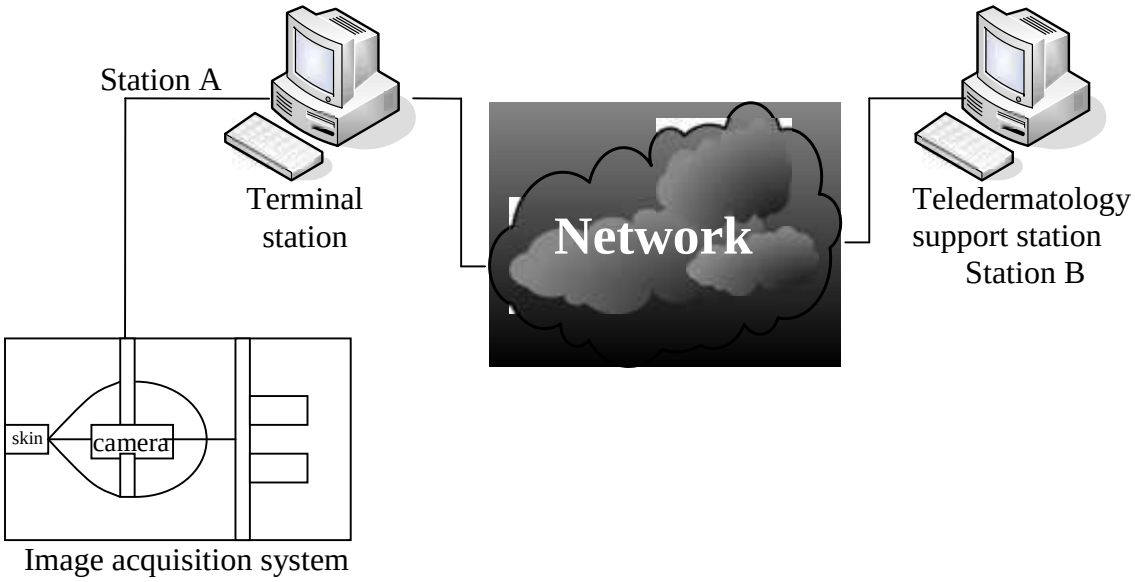


Fig. 5.3.1: The architecture of a teledermatology system

Data, accompanying to the image, were determined by the requirements of he expert medical personnel.

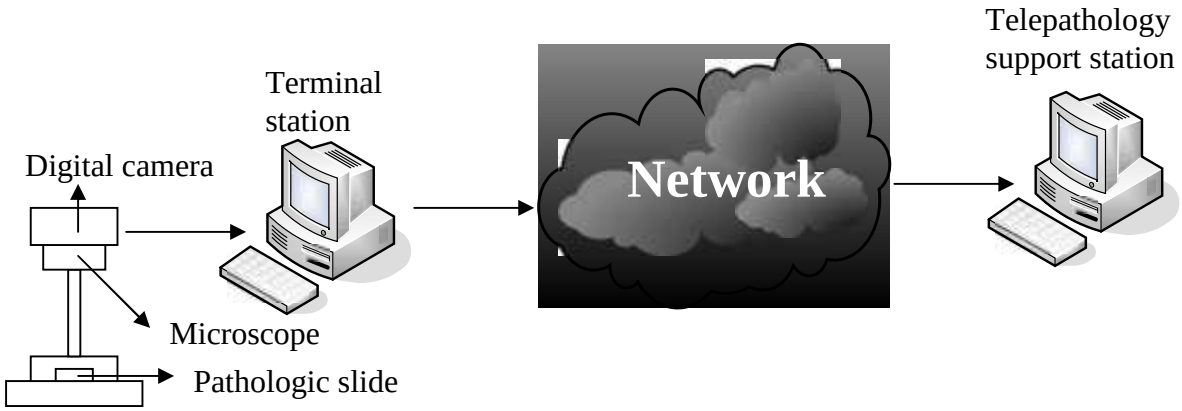


Fig. 5.3.2: The architecture of a telepathology system. [28]

In case of telepathology, a microscope is used to magnify the microscopic organs and experimental system is performed in the same way as above after digitizing the sample images. [28]

5.4 Selecting a digital camera:-

There is a wide range of cameras in the market with features for different applications from outdoor photography to fashion photography. The Internet is a useful resources for evaluating the capabilities of different cameras. Most camera manufacturers have their updated home pages on the Internet.[29] Some features that have been selected in camera for dermatological and pathological images are macro mode, quality settings, program mode, image size, optical zoom.

For the image capture device, COOLPIX 4500 digital camera was used which is shown in appendix A.

5.5 Principles of dermatologic photography:-

Dermatologists use visual clues to make diagnosis. Before this, while taking photographs using digital camera, a non-reflectant surface light blue cloth is backdropped. The clues can be broken down into several categories: [30]

Visual clues/characteristics;

Distribution (Location of the involved areas)

- Single, Acral, Sun-exposed area, Diffuse, unilateral, segmental, etc.

Configuration (Arrangement of lesions with respect to one another)

- Linear, zosteriform, annular, nummular, grouped, etc.

Primary Lesion (represent the fundamental lesion of the skin)

- papule, macule, plaque, vesicles.

Secondary changes: (represent overlying skin changes)

- scale, crust, and keratoses.

By having a good understanding of these four visual clues/characteristics, we can now talk about what is required to reproduce these characteristics for each lesion or rash.

5.5.1 Distribution:-

Distribution information is usually best portrayed using a far-view image whether this is the whole body or just a body part such as a hand. Remember that this distant-view usually requires that the entire area involved including some uninvolved areas. In addition, unless it is a single lesion, including the contralateral views of the body gives information on symmetry in this far-view. For example, if there is a lesion or rash on one knee, the frame should include both knees and the surrounding uninvolved areas of the leg. [30]

5.5.2 Configuration:-

Configuration information is usually best portrayed using a medium-distance view as you are attempting to show any spatial relationship between the individual lesions if they exist. One should look for common configurations such as any linearity or annularity or other common configurations such as grouped lesions. [30]

5.5.3 Primary lesions and secondary lesions:-

Primary lesions and secondary lesions are best portrayed using a close up view in order to capture the most detail of the individual lesions along with any surface changes. This macro or close up requires that a zoom lens is available or that the digital camera has to be physically close to the skin.

Most standard images should be taken at 90 degrees form the lesion of interest. However, in some cases, overlying skin changes may be subtle in which case an oblique view may be particularly helpful.

The area of interest should always be centered and marked (using an arrow or etc) of the skin if possible. [30]

Overview of visual clues / characteristics

Distribution	Explanation
Single	Only one
Acral	Usually seen in hands and feet (extremeties) including lips, tip of the nose, ears.
Sun exposed	Face, tip of ears, dorsal (upper) part of hands and feet
Diffuse	Wide spread or extensively distributed without clear margin
Unilateral	Affected only one side
Segmented	Band like distribution (line form) in the lines of the veins usually

Configuration	Explanation
Linear	Arranged in line (in any direction)
Zosteriform	Similar to segmental
Annular	Circular with clear center
Nummular	Coin shaped

Primary Lesion	Explanation
Papule	Small elevated lesion usually ranging from 0.5 to 1mm.
Macule	Flat, skin lesion with different colour
Plaque	Raised flat lesion. Larger than papule
Vescicle	Any fluid lesion, (smaller ones upto 2mm

Secondary changes	Explanation
Scale	Dry peeling of the skin
Crust	Yellowish in colour (papra)
Keratosis	Thickening of the skin, rough appearance

5.6 Framing image by type and involvement of skin lesion/rash

(i) Single lesion (2 – 3 images)

a. Medium view: (1 image) The lesion should be in the center of the frame. Include some anatomical landmark (e.g. belly button or joint) to ensure that the location is obvious.

b. Max optical zoom: if available (1 -2 images) at the closest distance (usually 12” away from the lesion). Do not get much closer than 12”. Consider getting an oblique view.

(ii) Localized rash or Lesion (3 -4 images)

a. Distant view (1 image): Frame the rash or lesions so that the entire rash or lesions +25% of normal area are included within the image. Ensure that the location is obvious by ensuring that an anatomical location is obvious.
b. Medium (1 image): Look for configuration (linear, annular, circular lesions) if none, take a picture of a skin surface area of 2’×2’.
c. Close up (1 – 2 images): Look for a representative lesion and take a close up image at the maximum optical zoom at the closest allowed distance (user 12”). Consider getting an oblique view.

(iii) Generalized Rash (3 – 4 images)

a. Distant view (2 images): Frame the rash or lesions so that the entire rash or lesions +20% of normal area are included within the image. This will be either a total body (head to toe) image or Truncal depending on the extend of involvement. If face/head and the distal arms and legs are not involved, take an image of the trunk and prox extremities in one frame –Front and back if face and trunk is involved.
b. Medium (1 image): (Linear, annular, circular lesions) if none, take a picture of an area of area of 1 square foot.
c. Close up (1 image): Looking for a representative lesion and take a close up image at the maximum optical zoom at the closest allowed distance (usually 12")

5.7 Microscopy imaging:-

The image standardization in telepathology derives from the large number of factors that can influence image quality. The following system components are required for a general pathology imaging station.

(a) Microscope: - Each microscope can have different setting, such as magnification, objective lenses, type of objective lenses, condenser, aperture, filters and light voltage. Each user can change or choose each item every time he/she uses it. For microscopy imaging, the Olympus microscope (CX31) has been used which is shown in appendix B.

(b) Optical coupler: - This connects the microscope and camera which has been shown in appendix C.

(c) Camera: - There are analogue and digital types where digital camera with a variety of technical features such as CCD size, sampling interval, dynamic range and colour characteristics.

(d) Computer/Software: - Sizes of RAM and VRAM and CPU power change the speed of controlling large pathology images and the number of colours to display. Image acquisition and manipulation software directly influence image quality.

(e) Display: - Each display has different characteristics (e.g. spatial resolution, maximum luminance) and the user can change the brightness and contrast, affecting the perceived image quality. It is also important to calibrate displays properly.

(f) Compression/image format: - Since the images are so large, it is often necessary to compress them.

Pathology imaging systems can be constructed in many different ways because there are so many choices for each component. Furthermore, the same system constructed from the same components can

produce different levels of image quality because of the user's skill and knowledge.

Pathological microscopic images are used during pathological exams and are classified either as tissue images or cellular images. Generally, the latter requires high resolution to display the internal structure of cells. It is said that due to human vision properties and the properties of optical microscopes that are currently available, between 4 to 6 millions pixels are observable using a microscope in fig. 5.7.1. [24]

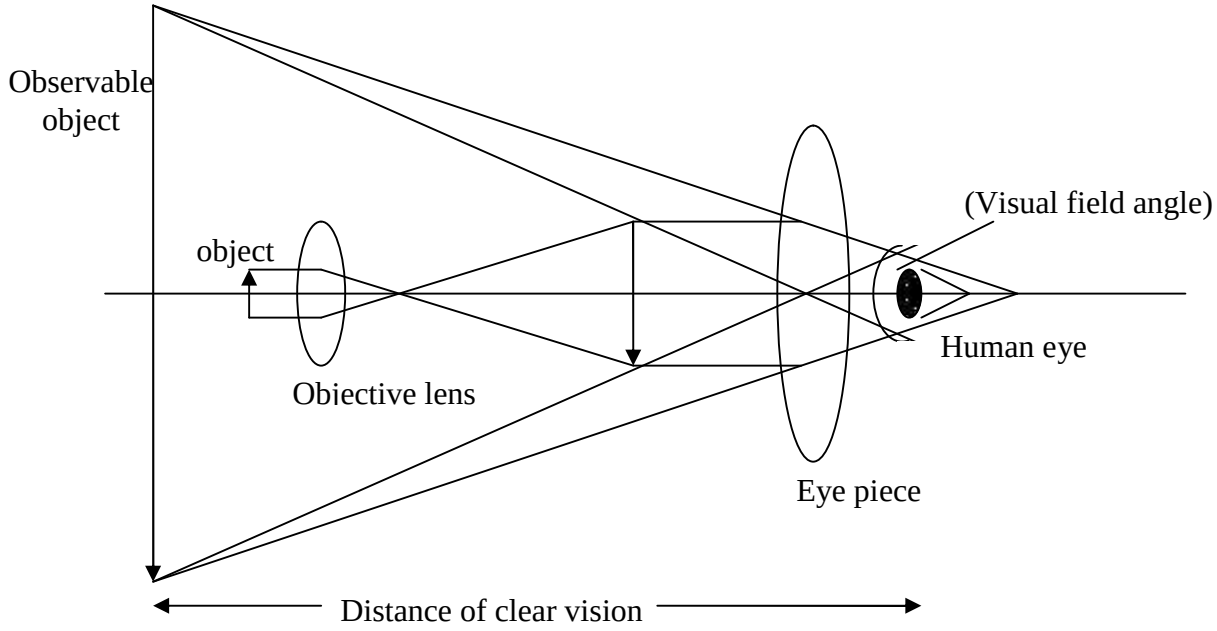
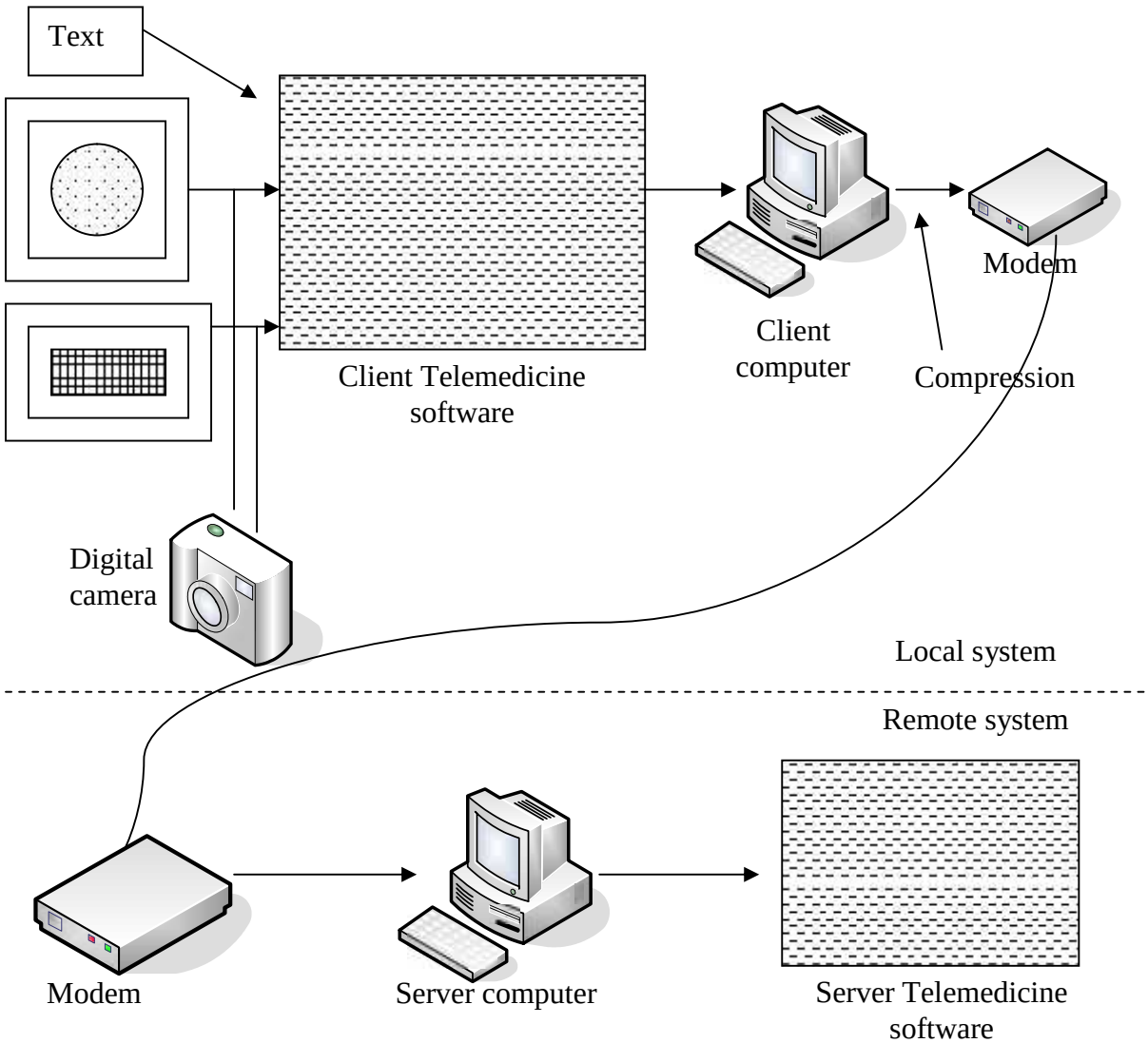


Fig 5.7.1: Viewing of objects by microscope [24]

Here to increase the magnifying power; two separate lenses are used. The lens near the object is called the objective and the other which is nearer the eye is known as the eyepiece. The objective and the eyepiece are both convex lenses. The objective is of small diameter and small focal length (high power) whereas the eyepiece is of large focal length than the objective. An object placed at a distance slightly greater than the focal length of the objective lens makes the image in front of the eyepiece which is again object for that eyepiece and forms the larger image. [27]

It must be noted that this applies to observations at low magnifications. At medium to high magnifications, the lens resolution drops as does the required structural resolution, removing the need for very high resolution. This means that even images from low-resolution camera can be used for diagnosis, but since minute structures of images at low magnification are not visible, the chance increases that a lesion will be overlooked. To increase resolution, one could observe at medium to high magnifications only the part of the required image. [24]

5.8 A typical store and forward teledermatology and telepathology system



The local system works with dial up connection. The local system is used by rural health worker. The remote system works with real time. The remote system is used by subject specialist.[31] A typical page of Client Hnet and Server Hnet System is given in Figure 5.8.1 and 5.8.2 respectively.

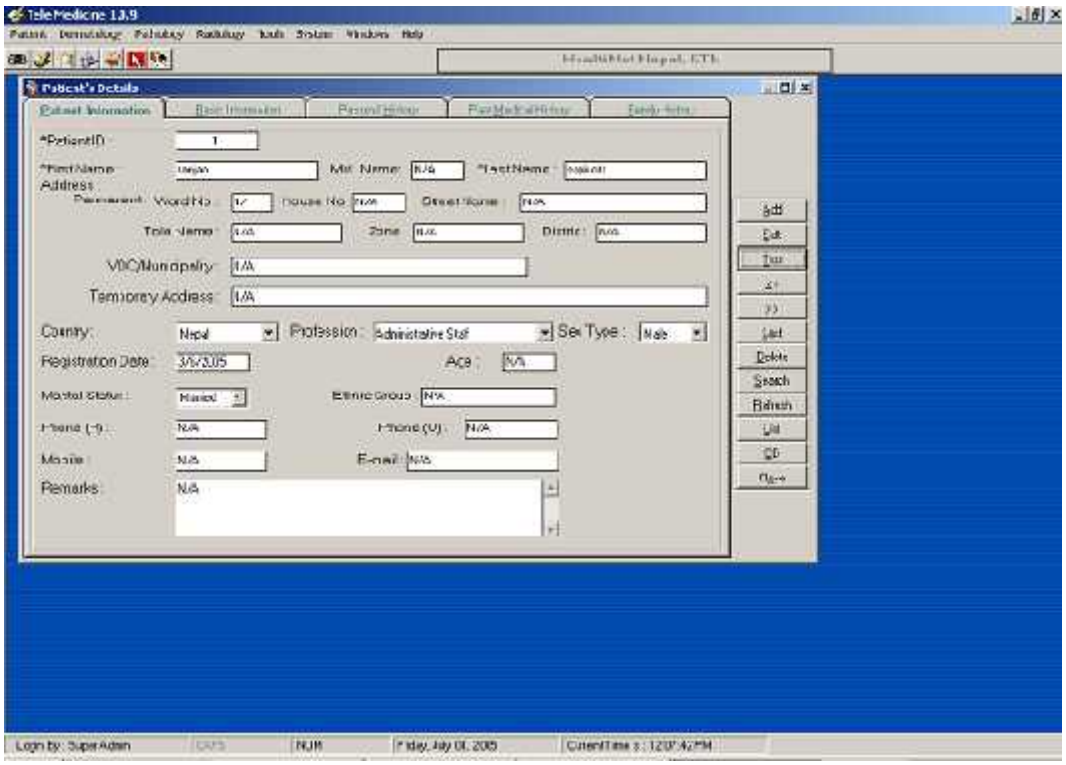


Fig. 5.8.1: Local System[31]

The local system collects clinical history and image which is sent to medical specialist for diagnosis.

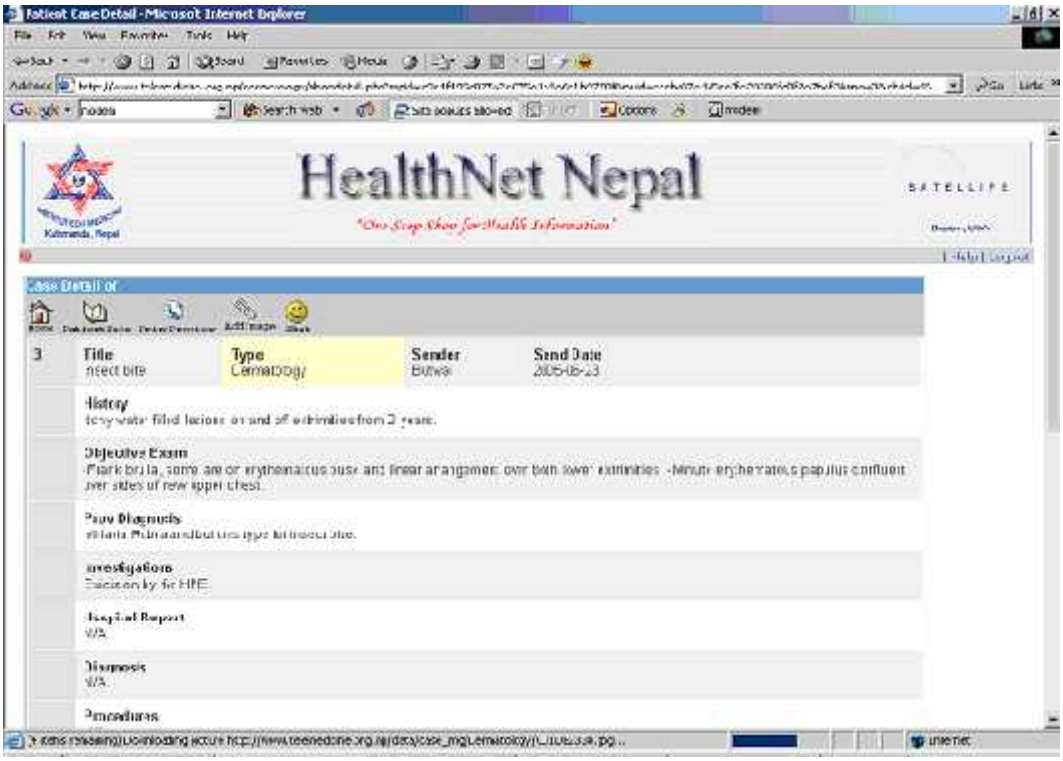


Fig. 5.8.2: Remote System [31]

5.9 Clinical History Forms:-

For collecting clinical history, two types of information are collected. They are General information and Discipline specific information.

5.9.1 Under this general information, common information under the following headings are collected:-

- Patient information
- Basic information
- Personal history
- Past medical history and
- Family history.

Blank forms of general information are given in the fig. 5.9.1(a) to fig. 5.9.1(e).

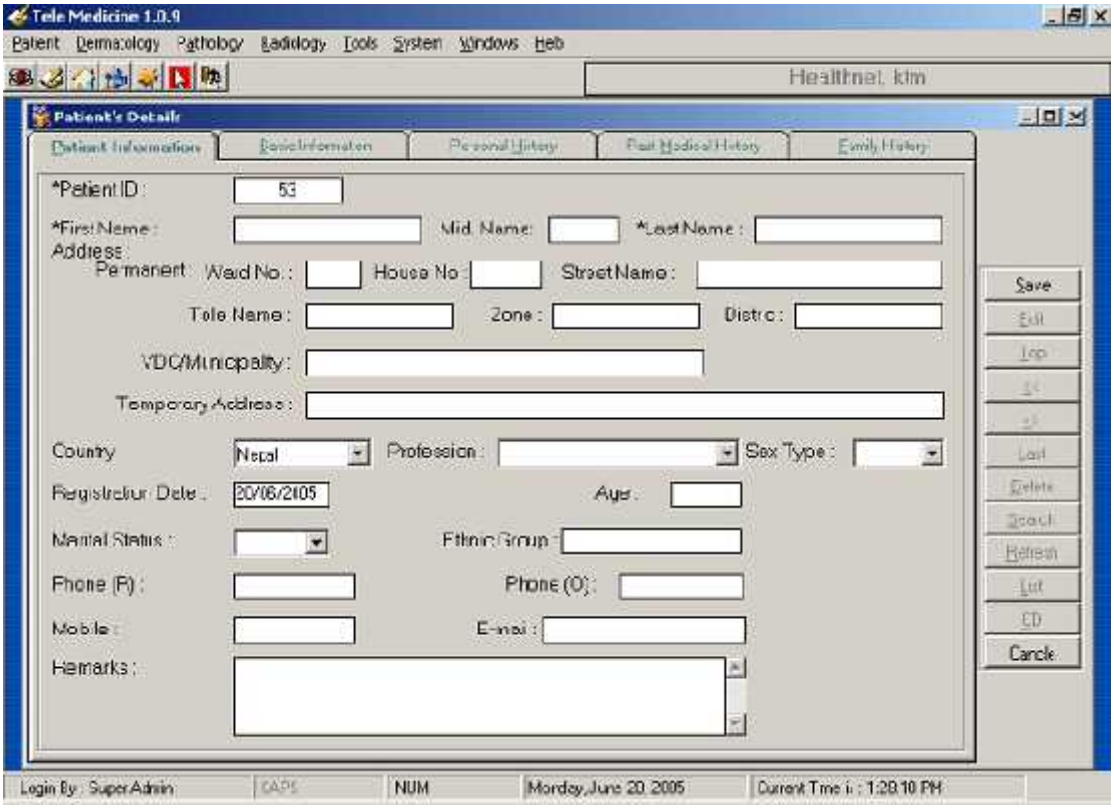


Fig. 5.9.1 (a): Form for collecting Patient Information

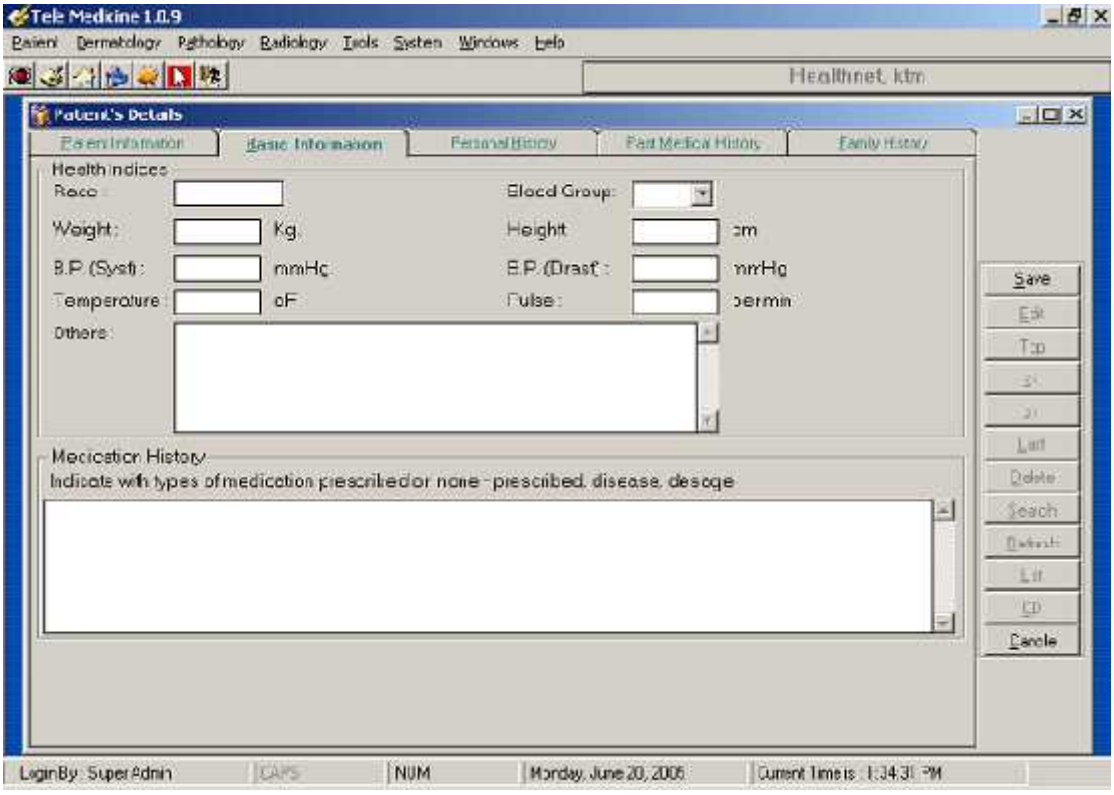


Fig. 5.9.1 (b): Form for collecting Basic Information

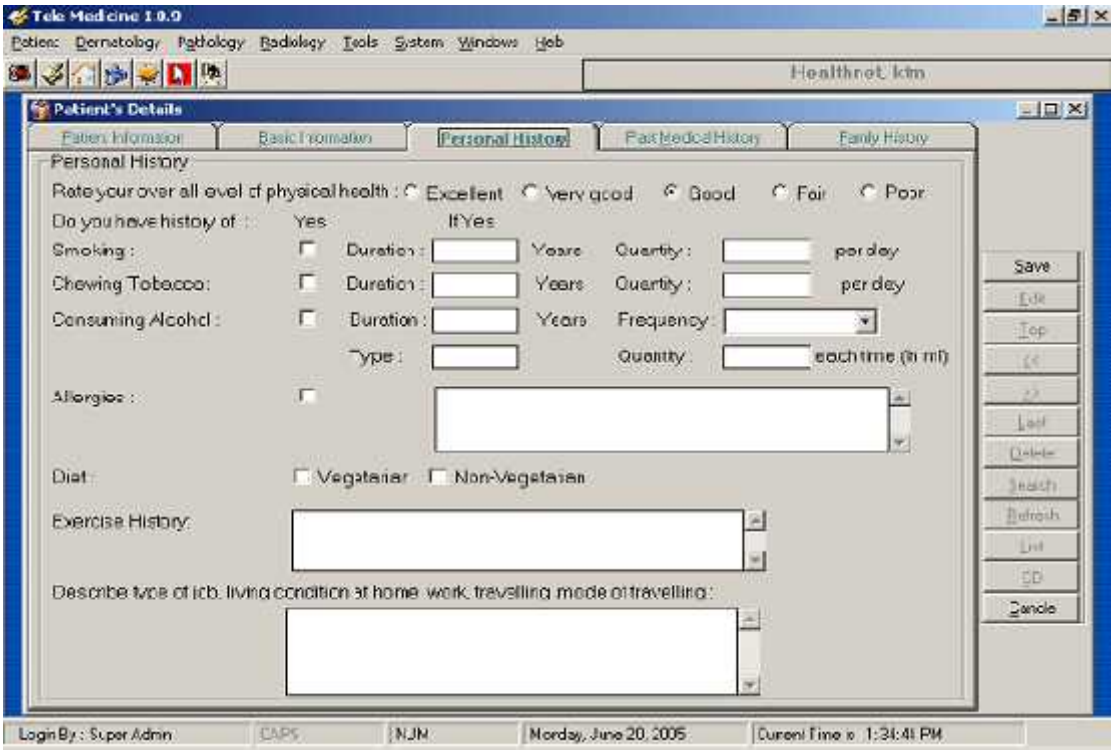


Fig. 5.9.1 (c): Form for collecting Personal History

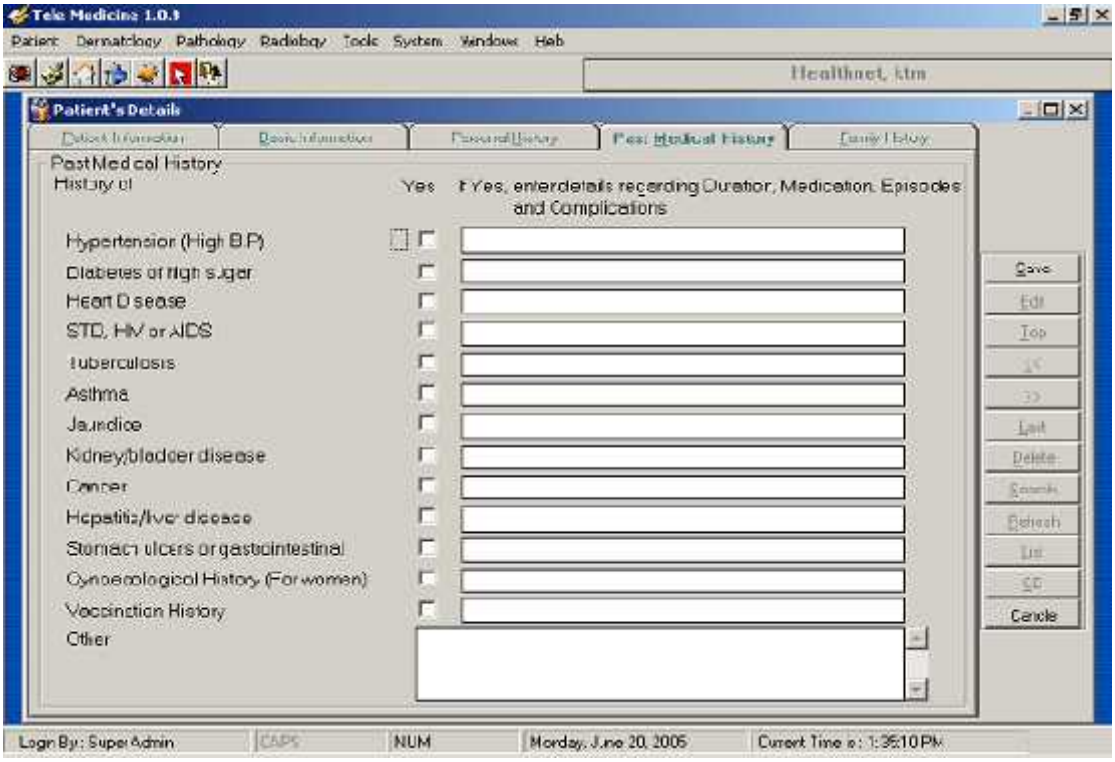


Fig. 5.9.1 (d): Form for collecting Past Medical History

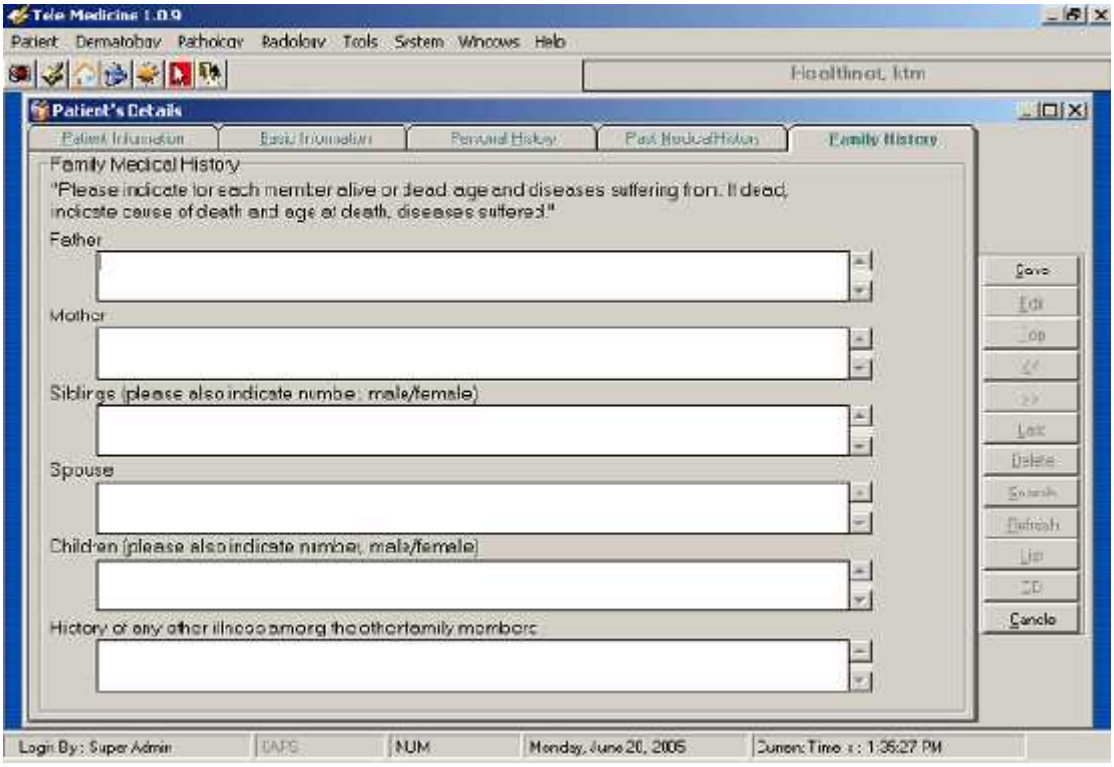


Fig. 5.9.1 (e): Form for Collecting Family History

5.9.2 Specific informations are collected under the following disciplines:-

- Dermatology and
- Pathology

These specific information are used by the medical specialist for the diagnosis of diseases based on clinical history collected through general information along with images. Some form of each one is given in the fig 5.9.2(a) to 5.9.2(d).

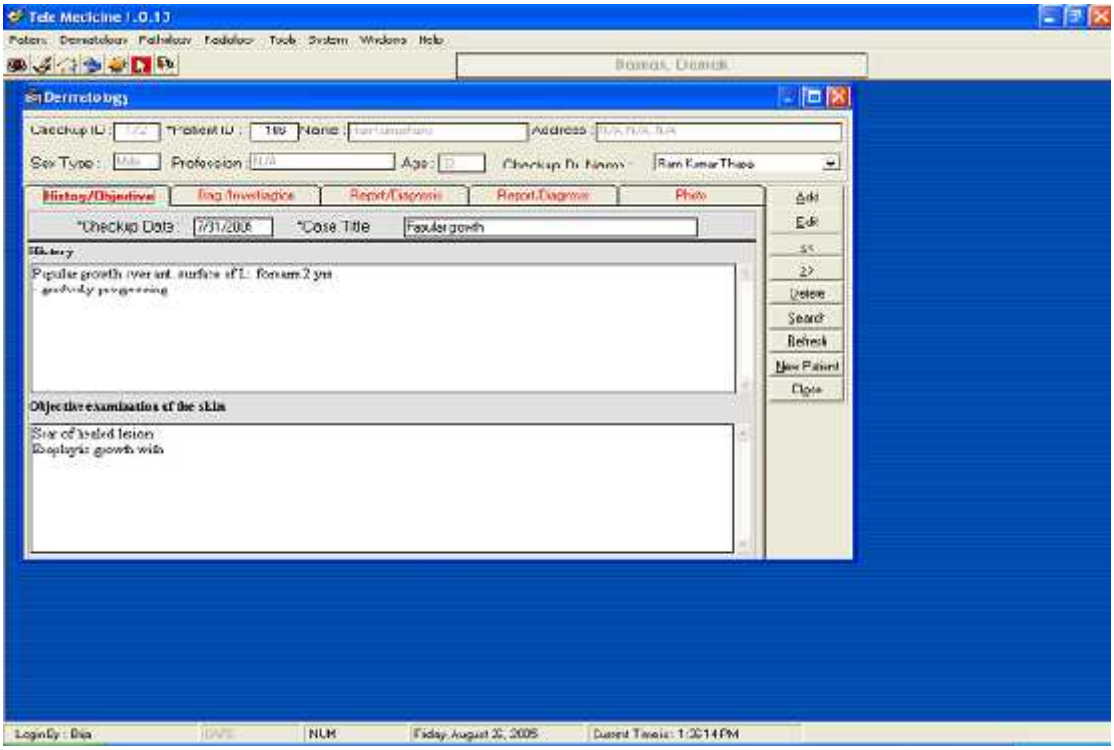


Fig. 5.9.2 (a): Form of Dermatology

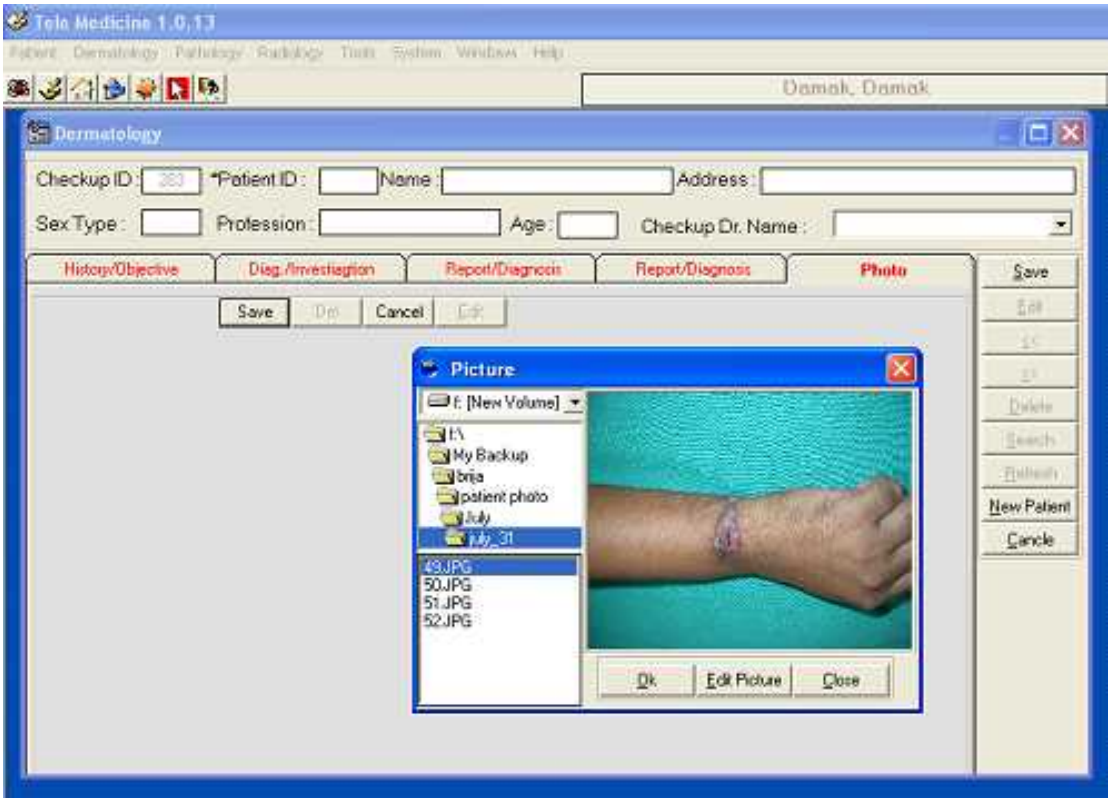


Fig. 5.9.2 (b): Image of dermatology

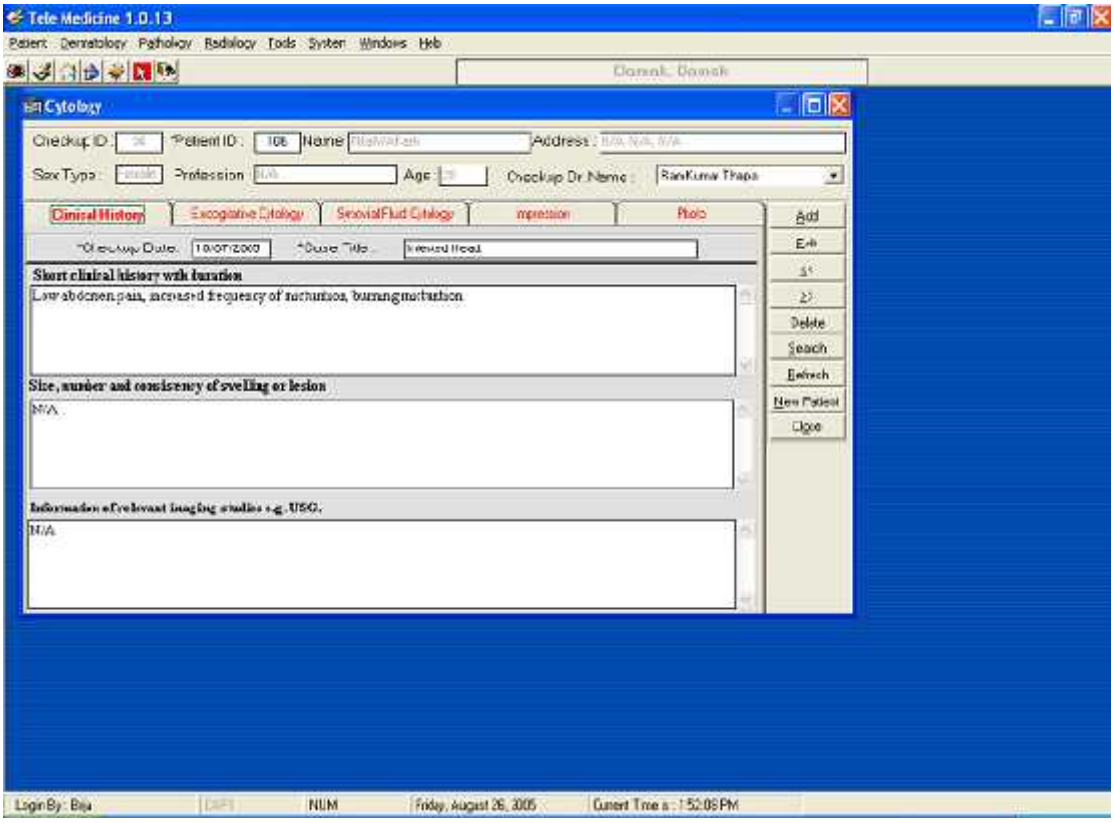


Fig. 5.9.2 (c): Form of Pathology

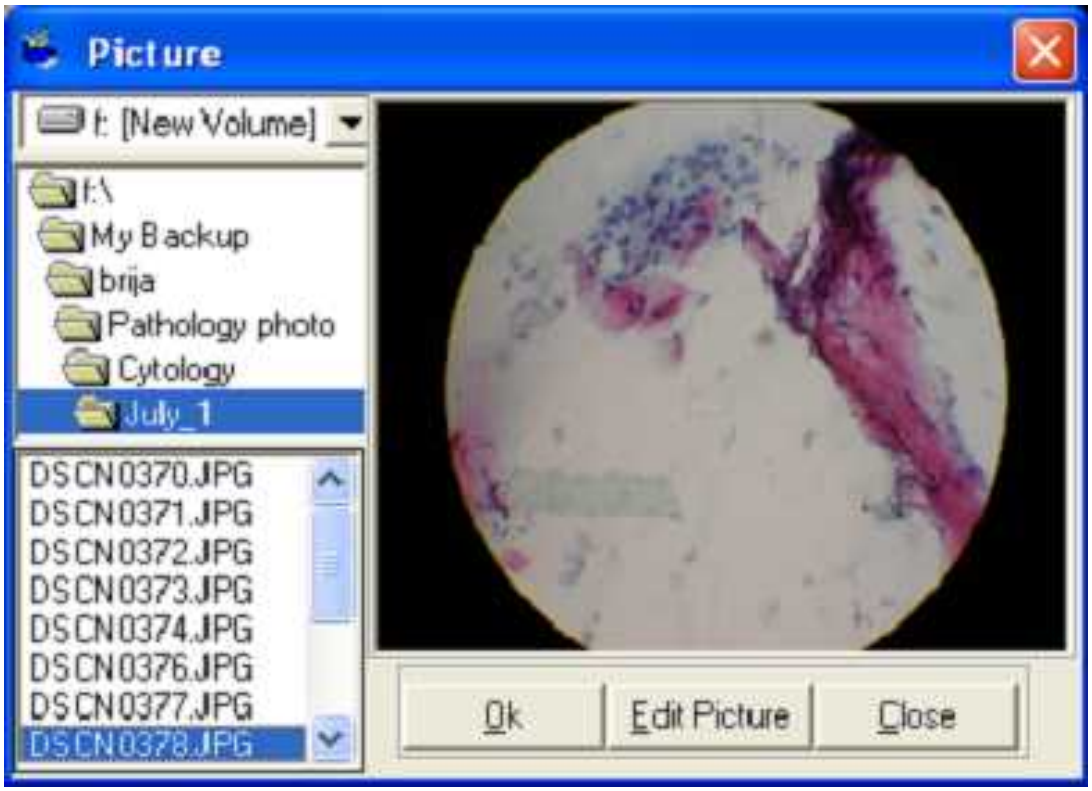


Fig. 5.9.2 (d): Image of Pathology

5.10 Receiving and Reviewing cases:-

The application after logon is point to point email between two physicians using it, typically a remote physician or health worker and a medical specialist in a hospital. Here, the sender simply sends an e-mail by choosing the send button. After uploading a case, server selects a doctor in round robin base listed in the roaster server regularly watches the reply from the doctor. If a doctor does not reply a case within 12 hours interval then the case will be automatically assigned to another doctor. For security reason, doctors are categorized in the groups of dermatology and pathology. These specialists can view only their cases in fig. 5.10.1 and fig. 5.10.2.

Fig. 5.10.1: Case Lists Received in Server Side

Once the medical expert enters into the appropriate discipline with login and password system, the concerned medical expert can see the list of cases to be diagnosed (Fig. 5.10.1). When the medical expert clicks into the hyperlink of case title, he/she can view details of cases to be diagnosed (Fig. 5.10.2).

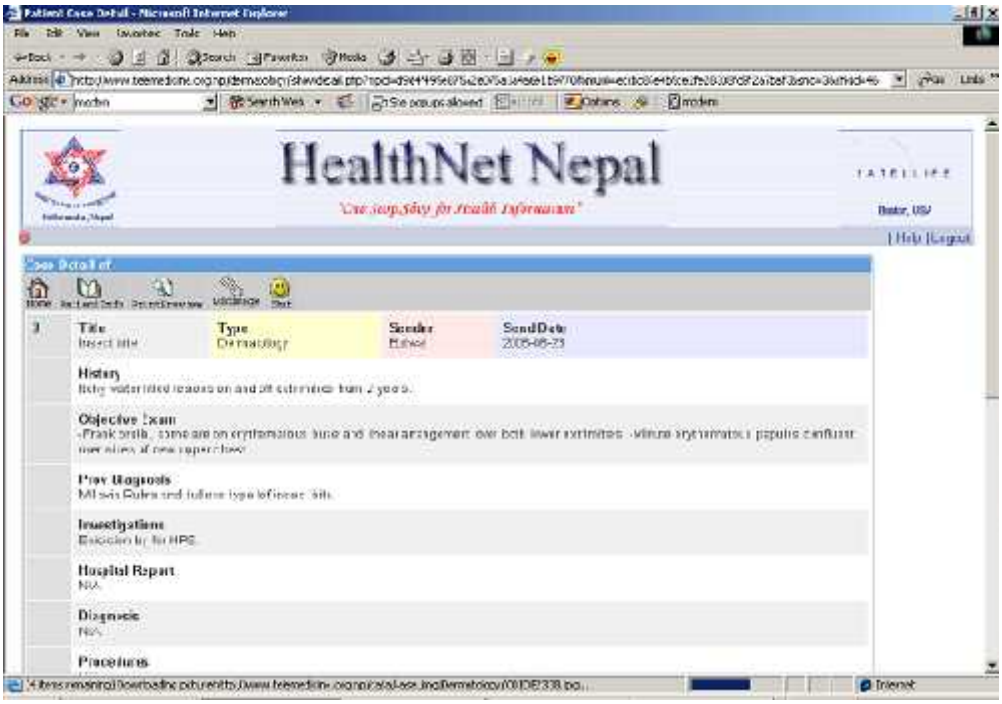


Fig. 5.10.2: Case Details Received in Server Side

Chapter – Six

RESULT AND DISCUSSION

6.1 Data Collection

For inclusion of cases, data were collected from the field sites. These cases were entered into the computer of client site and uploaded to the server side.

Similarly, provisional diagnosis used by primary care physicians and diagnosis done by clinical experts is used for comparing baseline medical knowledge of primary care physicians with clinical experts.

The total cases observed in different areas for telemedicine are 129, which is classified as below:

- Dermatology: 75 Cases
- Histology: 34 Cases
- Cytology: 20 Cases

The list of cases diagnosed through clinical history along with images are given in the table 4, table 5 and table 6.

Table 4: Case List For Dermatology

Case title		No. of patients
1.	Popular growth	1
2.	Itching	10
3.	Chicken pox	3
4.	Non Itching	1
5.	Purpura HSP	1
6.	Hair loss	1
7.	Injury	1
8.	Itching lesion	1
9.	Chewiling of fingers	1
10.	Depigmentation	1
11.	Insect allergy	1

12.	Baby with nodular lesions	1
13.	Lichen planus	1
14.	Coloring effects	1
15.	Impetigo contagious	1
16.	Cement allergy	1
17.	Insect irritation	1
18.	Lips problem	1
19.	Sorasis	1
20.	P sorasis	1
21.	Herpus Zoaster	4
22.	Infected Head	1
23.	Theula	1
24.	Chronic eczema	1
25.	Janai khatira	3
26.	Ulcertine growth	1
27.	Tuberous selerosis	1
28.	Rapidly growing mass of check	1
29.	Alopella areata	1
30.	Pyoderma gryscoresum	1
31.	Xeroderma pigmentosis	1
32.	Allergic contact dermatitis	3
33.	Varicella	1
34.	Pityriasis peanspllerіs	1
35.	Hypotrophic lichen planus	1
36.	Scabies	1
37.	Lupus Valgaris	1
38.	Tropic ulcer	1
39.	Sporotuchorn	1
40.	Ventura flora	1
41.	Compron wast	1
42.	Lichen simplex chromices	1
43.	Pitynayses	1
44.	Facial want	1

45.	Chronic Pyrronychia	1
46.	BL – LL	1
47.	Leprosy	1
48.	Leprosy (Fropriculcer)	2
49.	Leprosy (Pitrysiasis vesiculi)	1
50.	Leprosy (Erythenianodoison)	1
51.	Contact enzyme	1
52.	Foot	1
53.	Vitiligo	1
54.	Planter	1
55.	Atrophic dermatitis	1
56.	Facial pimples	1

Table 5: Case List for Histology

Case Title		No. of patients
1.	Larynx	1
2.	Neck swells	2
3.	Polypectomy	1
4.	Appendix	1
5.	Abdomen pain	1
6.	Duodenal pain	1
7.	Fistula	1
8.	TAH and BSO	1
9.	Endoscopic	1
10.	Oesophagal growth	1
11.	Cervical	1
12.	Thysoid module	1
13.	Left vocal cord	1
14.	Nasal cavity	1
15.	Prostatectomy	2
16.	Cervix	1
17.	Cervical growth	1
18.	Eye lid	1

19.	Cyst	1
20.	Cervical Polyp	1
21.	Swelling	1
22.	Vaginal biosopy	1
23.	Tumor	1
24.	Check cheek	1
25.	Vaginal hysterectomy	1
26.	Bleeding	1
27.	Follicular adenoma	1
28.	Appendix	2
29.	Rectal polyp	1
30.	Missed absortion	1
31.	Cholecystectomy	1

Table 6: Case List For Cytology

Case Title		No. of patients
1.	Lipoma	1
2.	Neck swell	1
3.	PID	1
4.	FNAC	9
5.	Fileroadenoma	1
6.	Celvities	1
7.	PAP Smear	2
8.	Haematoma over rt upper arm	1
9.	Atrophied uterus	1
10.	Smear	1
11.	Intra auricular cyst	1

6.2 Receiver Operating Characteristic (ROC) Analysis: Basic Principles and Applications in Telemedicine

Measures of image quality have been assumed to deal with the clarity and accuracy of the information contained in an image but not

with the consequences of its use nor with the associated observer involvement.

ROC analysis starts with the proposition that an observer exists and the observer uses some decision criterion or confidence threshold to reach a decision.[32] The ability of an image to diagnose a disease is evaluated using Receiver Operating Characteristic (ROC) curve analysis. ROC analysis has increasingly been used for this purpose, notably in telemedicine dependent on image. Here, we will describe the principles underlying ROC analysis, how to enter data for ROC analysis, how to use and interpret ROC curves. The major applications of ROC analysis will be discussed and their limitations will also be addressed.

6.2.1 Sensitivity, specificity and predictive value: Need for ROC analysis

Sensitivity, specificity and predictive value are aspects of data accuracy. They assist in evaluating the validity of a measure, especially the indirect performance indicators that are often used in health care. The sensitivity or True Positive Fraction (TPF) describes the fraction of diseased patients that actually has a positive test result. A measure is sensitive to the extent that it identifies every case in which the property of interest is truly present (cell a, Table 7). If the measure is not sensitive, it will not detect the property of interest when it is present (cell c) i.e. False Negative. Specificity is the aspect of measurement that results in exclusion of cases when property of interest is truly absent (cell d). The specificity or True Negative Fraction (TNF) describes the probability of negative test result in non diseased individuals. If the measurement is not specific, it will falsely detect the property of interest when it is not present (cell b) i.e. False Positive. The accuracy of a test or measure is dependent upon the number of false positives and false negatives that occurs as a result of

using the measure. If the test is accurate, the number of false positives and false negatives will be low. The predictive value is the proportion of positive tests that are truly positive (a/a+b). The predictive value of a positive test increases as sensitivity and specificity increase.

To determine the specificity and sensitivity of a proposed measure, test of the measure may be conducted and the results can be displayed. In this table 7, the rows represent the true situation-the presence or absence of the performance indicator. The columns represent the possible results of the measure for the performance indicator of interest. The test is

Test/Measure	Performance Indicator Present	Performance Indicator Absent	Total
Positive	a	b	a+b
Negative	c	d	c+d
Total	a+c	b+d	a+b+c+d
Sensitivity	a(a+c)		
Specificity	d/(b+d)		
Predictive value	a/(a+b), the predictive value of a positive c/(c+d): the predictive value of a negative		

Table 7: Assessing Sensitivity and Specificity of a Measure

positive when it tells us that the performance is present and negative when it tells us that the performance indicator of interest is not present.

6.2.2 ROC curve: basic principles

A conventional ROC curve describes the compromises that can be made between TPF (True positive factor) or sensitivity and FPF (False positive factor) and hence among the relative frequencies of true positive, false positive, true negative, and false negative decisions- as a decision threshold is varied. By appropriate choice of the decision threshold, a decision maker or observer can operate at (or near) any desired

compromise that lies on the curve. Since the ROC curve is a graph of TPF versus FPF, both of which are independent of disease prevalence, it does not depend on the prevalence of disease in the actual population to which the test may be applied. Thus, ROC analysis provides a description of disease detectability that is independent from both disease prevalence and decision threshold effects.

In general, it is concluded that better decision or detection performance is indicated by an ROC curve that is higher and to the left in the ROC space.

6.2.3 Measure of Accuracy based on ROC curve

One of the most popular measures of the accuracy of a diagnostic test is the area under the ROC curve. The ROC curve area can take on values between 0.0 and 1.0. A test with an area under the ROC curve of 1.0 is perfectly accurate because the sensitivity is 1.0 when the FPR is 0.0. In contrast, a test with an area of 0.0 is perfectly inaccurate. That is, all patients with disease are incorrectly given negative test results and all patients without disease are incorrectly given positive test results. With such a test it would be better to convert it into a test with perfect accuracy by reversing the interpretation of the test results. The practical lower bound for the ROC curve area is then 0.5. The line segment from 0,0 to 1,1 has an area of 0.5; it is called the chance diagonal. At (0,0) the observer is never convinced and at (1,1), the observer is always convinced.[32] If we relied purely on guessing to distinguish patients with from patients without disease, then the ROC curve would be expected to fall along this diagonal line. Diagnostic test with ROC curve areas greater than 0.5 have at least some ability to discriminate between patients with and those without disease. The closer the ROC curve area is to 1.0, the better the diagnostic test.

6.3 Practical Considerations

A two step rating method is used to plot ROC data. Firstly, a dichotomous variable indicating quality of image (0= negative, 1=positive) is used. Secondly, the dichotomous variable based upon positive quality of image is further rated based on five point scale such as (1) definitely or almost definitely negative; (2) probably negative; (3) possibly positive; (4) probably positive; and (5) definitely or almost definitely positive. The use of five categories seems to represent a reasonable compromise between the needs of ROC analysis and the precision with which an observer can be expected to reproduce his ratings. This five point rating scale is used to calculate 'Predicted Probability'. This predicted probability along with dichotomous variable can be used to plot ROC curve in order to provide a visual impression of the reliability of the points. Statistical Package SPSS 11.5 was used for calculating 'Predicted Probability' using logistic regression model. Based on dichotomous variable and 'Predicted Probability' ROC curve in graphic form was plotted.

6.4 Steps in performing the Statistical Analysis

The rating scale of image quality are converted into qualitative format and saved into CSV format. The CSV format can be read by MS Excel program. The rating of image quality is performed quantitatively in the following two stages. At the first stage, the medical specialist records their perception of the image exposure and diagnostic quality using a two point ordinal scale: 0=poor; 1= adequate. At the second stage, this perception is further recorded using a five point ordinal scale in the form of 5 = definitely present; 4 = probably present; 3 = can't decide; 2 = probably absent; 1 = definitely absent. The first stage data is given the heading: image and the second stage data is given the heading: variable.

Based upon these two sets of data, logistic regression is done to calculate predicted value to plot ROC analysis as follows:

- Click Analyze | Regression | Binary Logistic
- Select the image type as a dependent variable and the variable type as covariates
- Select a method for regression. In this exercise 'Forward: Conditional' method is chosen
- Click the save button and check the probabilities option to save the predicted probabilities

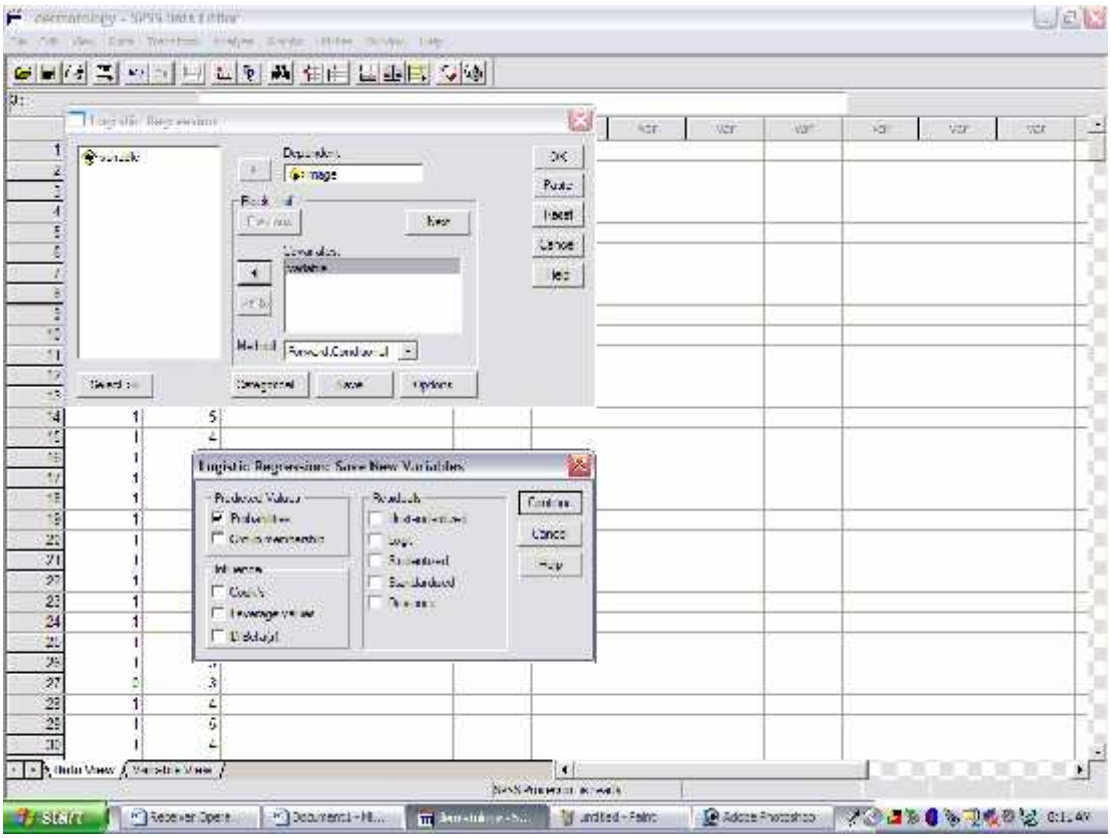


Fig. 6.4.1: Regression analysis variable form

- Click the 'Options' button to set the conditions for stepwise regression.
- Run the regression by clicking 'OK'
- Output will be generated in a special window.

6.5 Plotting ROC graph

- Click: Graphs | ROC curve. Select the image variable as ‘Test Varable’ with value 1 for Adequate for diagnosis occurrence and the ‘Predicted probability’ as ‘State Variable’. Click ‘OK’

The results will show a ROC Curve and the ‘area under the curve’ that is the test result.

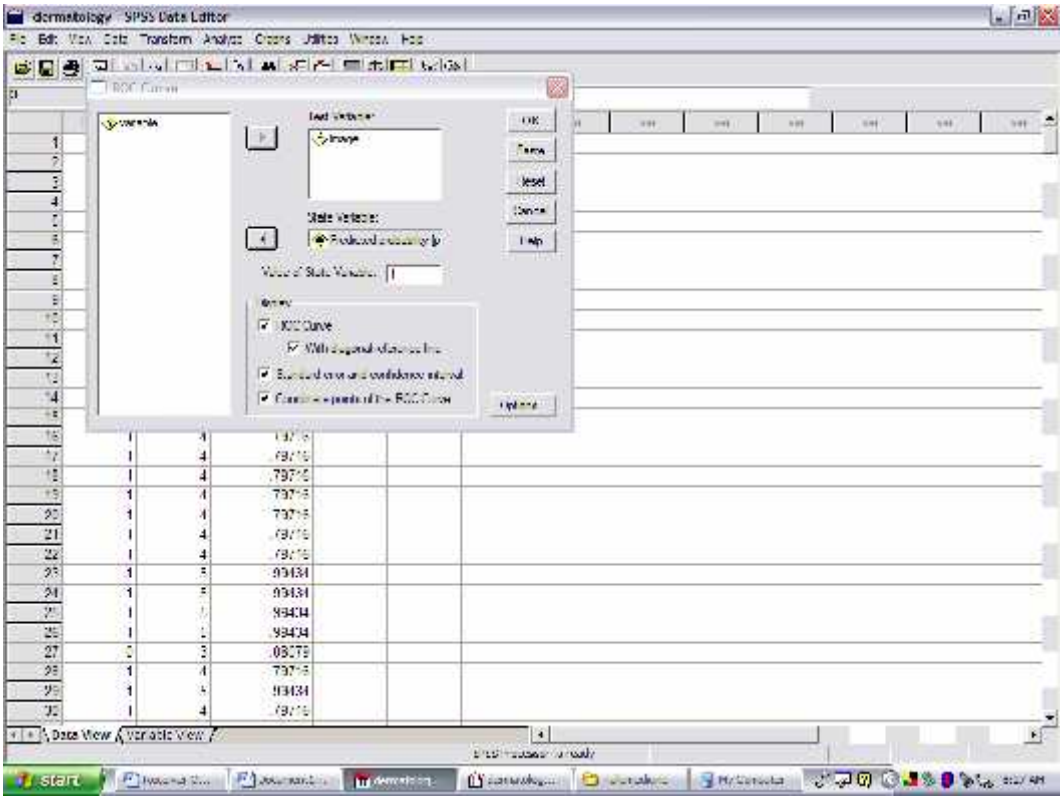


Fig. 6.5.1: Variable entry form for plotting ROC curve

ROC curves of dermatology, histology and cytology are given below respectively in fig. 6.5.2, 6.5.3 and 6.5.4:

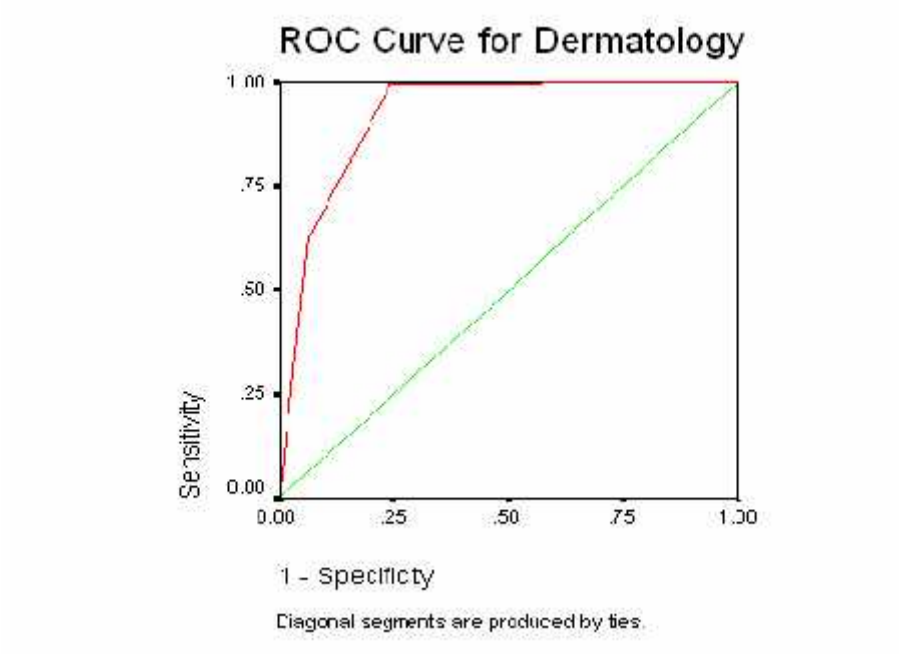


Fig. 6.5.2: Dermatology

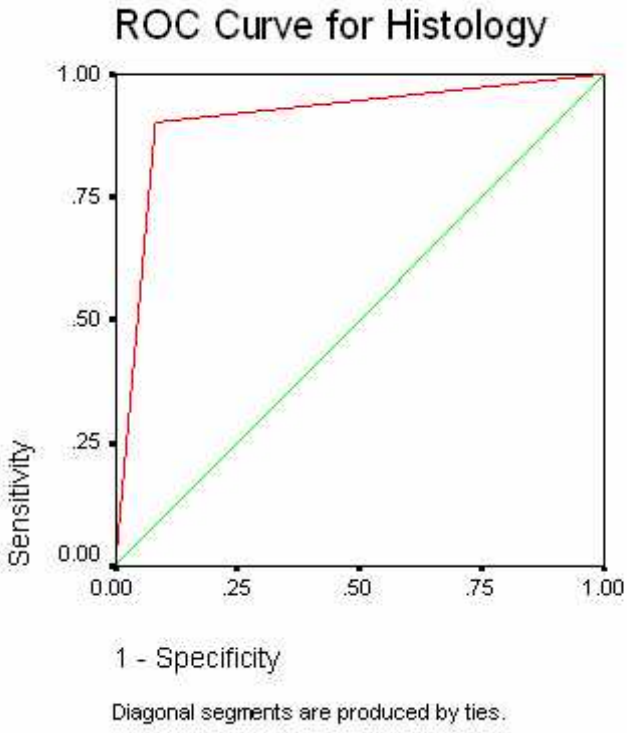


Fig. 6.5.3: Histology

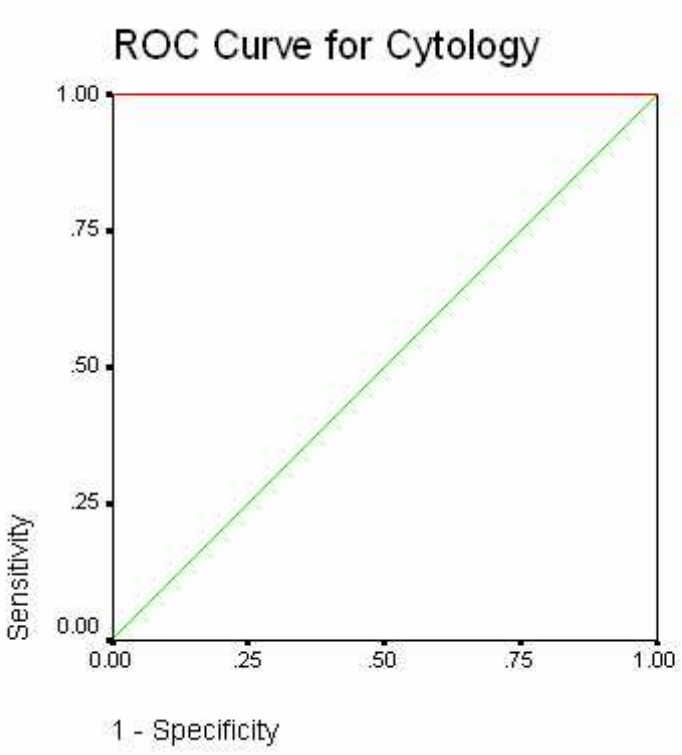


Fig. 6.5.4: Cytology

6.6 Test the capacity of expert doctor in the diagnosis of cases through image

For testing the capacity of expert doctor in the diagnosis of cases through image, the SPSS calculation for Chi-square (χ^2) goodness-of-fit test was done. Here, we are comparing observed frequency (i.e. actual frequency) with expected or theoretical frequency in a distribution. However, the expected counts are based on the collected data and observed counts are based on knowledge of the expert doctor given in table 8.

Table 8 displays the observed and expected frequency. If the calculated χ^2 is small, there is closed agreement between the observed and expected frequencies. As the discrepancy between the observed and expected frequencies increase, the calculated χ^2 increases and the more likely we are to reject the null hypothesis and conclude that the test

capacity of expert doctor in the diagnosis of cases through image fails due to low quality of image.

Here comparing observed frequencies with the expected frequencies across two categories rows on the expert doctor, the degree of freedom is based on the number of categories (k) and is equal to the number of categories minus 1 (i.e. k – 1). Therefore the degree of freedom 2 – 1 = 1 and for 1 degree of freedom (i.e. df), the critical value of Chi-square at 5% level = 3.841.

Expert Doctor

	Observed No.	Expected No.	Residual	Category
	3	17.0	-14.0	no
	31	17.0	14.0	yes
Total	34	34		

Test Statistics

	Expert Doctor
Chi-Square	23.059
df	1
P-value	0.000

Table 8: SPSS output for Chi-square Goodness-of-fit

SPSS reports that Chi-square value is 23.059 and P-value is 0.000 where P-value is less than 0.05 (i.e. P<0.05) which is statistically significant so it can be said that there is correct test capacity of expert doctor to diagnose the cases through the image. And to be diagnosed the disease cases, the image quality must be good. If P Ψ0.05, we fail to reject the null hypothesis (i.e. 5%) and conclude that the expert doctor for diagnosis cases and image to be diagnosed are independent because the image quality is poor.

6.7 Result and Discussion:-

A representation and interpretation of the area under a Receiver Operating Characteristics (ROC) curve obtained by the rating method based on the image of patient characteristics is presented. The data were collected to generate Receiver Operating Characteristics (ROC) curves.

In developing our system, consideration was given in establishing guiding principles for telemedicine services in Dermatology, Pathology. However, the gold standard for any specialist referred remains the traditional way of consultation i.e. in case of Pathology viewing through microscope and in case of dermatology face to face consultation.

For determining the quality of image sufficient for diagnosis, ROC analysis was performed. Concerning sample size, it has been suggested that meaningful qualitative conclusions can be drawn from ROC experiments.

The value for the area under the ROC curve can be interpreted as follows: in fig. 6.5.2, an area given by the table 9 is 0.922 in asymptotic 95% confidence interval having lower bound 0.892 and upper bound 0.952 for dermatology means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 92% of the time. In fig. 6.5.3, an area given by table 9 is 0.909 in asymptotic 95% confidence interval having lower bound 0.884 and upper bound 0.934 for histology means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 90% of the time. And in fig. 6.5.4, an area given by the table 9 for cytology can be interpreted similarly as above. Sometimes, the variable under study cannot distinguish between the two groups, i.e. where there is no difference between the two distributions, the area will be equal to 0.5 (the ROC curve will coincide with the diagonal).

Test Result Variable(s): Predicted probability

Area	Std Error	P-value	Asymptotic 95% Confidence Interval		
			Lower Bound	Upper Bound	
0.922	0.015	0.000	0.892	0.952	dermatology
0.909	0.013	0.000	0.884	0.934	histology
1.000	0.000	0.001	1.000	1.000	cytology

Table 9: Area under the Curve

The true area under the ROC curve is 0.5 (null hypothesis: Area = 0.5). The P-value under the ROC curve is 0.000 in the case of dermatology, 0.000 in the case of histology and 0.001 in the case of cytology which is low (i.e. $P<0.05$) then it can be concluded that the area under the ROC is significantly different from 0.5 and therefore there is evidence that image has an ability to detect disease. In our experiment, all the three tests i.e. dermatology, histology and cytology all the P is low (i.e. $P<0.05$) which is statistically significant.

So, it can be concluded that images have an ability to detect disease. For detection of disease through images, these images must have good and high quality.

We also found that the correct test capacity of expert doctor in the diagnosis of cases through image being high quality. This also supports the view that textual information followed by high quality image is sufficient for diagnosis of medical cases in the teledermatology and telepathology.

In this work, we have used the keep it simple principle by adopting affordable system appropriate to our needs and while compared to real-time system, store and forward system offers a more practical and less expensive solution. Store and forward methods allow the use of low-cost equipment, low bandwidth connectivity, and asynchronous consultation. This approach is successfully used in industrialized countries where high quality images are sent over telemedicine networks for consultation.

So, digital cameras have emerged as an efficient method for obtaining digital images. Due to which we have evaluated the effectiveness of digital photography for dermatology, histology and cytology diagnosis. And found digital camera generated images to be of sufficient quality so that high diagnostic concordance in the histology and cytology diagnosis. And for teledermatology, it is also found that high concordance with face-to-face diagnosis.

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ABBREVIATIONS

TCP/IP	– Transmission Control Protocol / Internetworking Protocol
ASCII	– American Standard Code for Information Interchange
ECGs	– Electrocardiograms
EEGs	– Electroencephalograms
ROC	– Receiver Operating Characteristics
LAN	– Local Area Network
MAN	– Metropolitan Area Network
WAN	– Wide Area Network
EMRs	– Electronic Medical Records
ISPs	– Internet Service Providers
PSTN	– Public Switched Telephone Network
ISDN	– Integrated Service Digital Network
ITV	– Interactive Televideo Conferencing
POTS	– Plain Old Telephone Service
ATM	– Asynchronous Transfer Mode
DSL	– Digital Subscriber Line
ADSL	– Asymmetric Digital Subscriber Line
LEO	– Low Earth Orbit
CCD	– Charge Coupled Device
dpi	– dots per inch
ppi	– pixel per inch
PACS	– Picture Archiving and Communication System

APPENDIX - A

APPENDIX – B

APPENDIX – C