Telemedicine System in Bangladesh: A Proposed Cost-effective Internet-based Implementation

Manzur Ashraf
Faculty, Dept of CSE,
East West University

Mohammad Lutful Kabir
Dept of CSE,
East West University

{manzur_bd,lutful_ewu}@hotmail.com

Abstract:

Telemedicine, the use of information technology to deliver health care from one location to another, has the potential to increase the quality and access to health care and to lower costs. This growth of telemedicine installations is a necessity particularly in under-developed countries where most of the people don't get health-care due to poverty. In this paper, we focus on the necessity of implementing telemedicine application in Bangladesh where a majority of rural people are deprived of adequate health-facilities. In addition, different technological aspects regarding telemedicine are highlighted. Among them, we propose Internet-based telemedicine (IBT) as the optimal and cost-effective solution in this regard. We also illustrate a case study of cancer disease in Bangladesh-scenario highlighting rule-based implementation and decision tree-based approach. DICOM based image analysis and flat-file oriented ECG data-mapping methodology are also focused with proposed IBT methodology.

Keywords*: Telemedicine, Expert system, Web-services, DICOM, Decision tree, Data-communication.*

1. Introduction:

Telemedicine is basically a multimedia application that combines a myriad of technologies (live video and audio, static DICOM-encoded, medical images and data, text, graphics and vital signs) into a time and space independent system for medical purposes. As each of these information types has a different set of requirements, it is not trivial matter, particularly for the underlying communication infrastructure [1].

Most of the telemedicine applications have a common technological aspect that is high-end technology. It requires moderate to fast networks (medium to very high bandwidth and fast routing), moderate to fast end-user workstations, so handling data types from live-video and audio to fast image-processing tasks can be done at reasonable time and cost, and a high-resolution data encoding and display (diagnostic quality) for medical images. Patient vital signs monitoring requires low bandwidth, but continuous transmission, data queries and textual information operate require in short burst of moderate bandwidth, but require a powerful server to perform these quires [1].

The telemedicine goals in Bangladesh are:

- Improving patient care.
- Improve access to health care for rural areas and underserved areas.
- Reduce or eliminate the time and expense of travel necessary to bring the patient to doctor or vice versa.
- Give physician better access to tertiary consultation.
- Give physician access to conduct remote examinations.
- Reduce health-care costs.
- Provide health care services of a physician or facility to larger audience (larger geographic regions and populations).

- Reduce patient transfers to secondary and tertiary care centers.

In Bangladesh, a least developed country, a very significant portion of the total population does not get medical services due to poverty. In this paper we propose a generalized telemedicine application based on Internet that is cost effective in terms of implementing in Bangladesh considering available telecommunication facilities.

The structure of this paper is as follows. In the next section we focus history of telemedicine. In section 3 we describe services offered by the telemedicine. In section 4 we give an overview of existing health facilities in Bangladesh. In section 5 we comprehensibly explore the technical requirements that are required to implement telemedicine facilities. In section 6 we present a case study on cancer disease to show necessity of telemedicine application. In section 7 we implement our proposed telemedicine application based on Internet.

2.History of Telemedicine:

Telemedicine has been used since 1959 when early experimenters demonstrated telepsychiatry and telefluroscopy and new surgical procedures were first broadcast live at national medical conferences [2]. Then the National Aeronautics and Space Administration (NASA) played an important part in the early development of telemedicine (Bashshur and Lovett, 1977). NASA's effort in telemedicine began in he early 1960s when human began flying in space. Physiological parameters were telemetered from both the spacecraft and the space suits during the missions. These early efforts and the enhancement in communications satellites fostered the development of telemedicine and many of medical services in the delivery of health care today [1]. However, there has been a clear rebirth of telemedicine since early 1990s. Now Telemedicine is increasingly global in its reach around the world, including Israel, Chile, India, Taiwan, Japan and the USA.

3. Services offered by Telemedicine:

Telemedicine offers a growing number of services in the field of health-care and its delivery. These services can be roughly cut into three major topics: Direct-patient examination, Patient-information sharing and Physician information gathering [1]. In this paper, we focus on Patient-information sharing perspective of Bangladesh.

Telemedicine holds great promise to enhance health care delivery in rural areas by allowing a physician or other health professional to examine a patient while linked by video or other means to expert consultant at a distant medical center. Radiologists and other specialists can review biopsies done in rural hospital while the patient is still under anesthesia. Without telemedicine, these services would require travel on the part of either the patient or the consultant, or would simply not be available at all.

4. Health facilities in Bangladesh:

From [3] we find in Bangladesh, the lowest static health facilities are at the union level. There are at present 4048 health facilities at the union level, of which 1362 belong to the Directorate general of Health Services and the remaining (2706) to family welfare centers belongs to the Directorate general of family planning. These facilities have provisions for outpatient care, both

clinical and non-clinical contraceptive services, and preventive, promotive and rehabilitative health care.

There are 460 upazilas (sub-district) in Bangladesh of which 397 rural or outlying upazilas and 63 are sadar upazilas. These 397 rural upazila health complex have 31 inpatient beds. In additions, there are 14 Rural Health Centers having 10 beds each beyond upazila level. An upazila health complex has provisions in-patient care, outpatient care, clinical and non-clinical contraceptive services [3].

There are 60 district hospitals functioning throughout the country. Of them 3 have 150 beds each, 29 have 100 beds each and the remaining have 50 beds in each. These hospitals provide inpatient and outpatient care and limited number of specialized services such as medicine, Surgery, Gynae & Ob., pediatrics. Three Medical college hospitals and one specialized Mental hospital are located at the district level (Mymensingh, Sylhet, Rangpur and Pabna) [3].

Eight medical college hospitals, five post graduate hospital and other specialized hospitals are located at the other levels (division and nation level)[3]. A number of specialized medical services are provided from the medical college hospitals. Other specialized services provided from mono-discipline institutional hospitals include cardiac, orthopedic, ophthalmology, and cancer and tuberculosis facilities. The hospitals attached with institute of post-graduate medicine & Research provides highly specialized services in surgery, medicine, gynae, & ob., neprology, urology, gasteroenterogy and specialized diagnostic services. The level of care and type of facilities in Bangladesh is shown in table 1.

Level of Care	**Administrative Unit**	**Health Facility**	**Population**
Tertiary Referral Level	Division (6) or District	Teaching Hospital/Institute (16) 250-1050 beds each	10-15 millions
Second Referral Level	District (64)	District Hospital (59) 50-150 beds each	1-2 million
Frist Referral Level	Upazila(460) Rural: 397 Sadar upazilas do not have UHC	Upazila Health Complex (UHC) with 31 beds each	200,000-450,000

Table1: Level of Care and Type of Health Facility [3]

Our observation from [3][4] is that the ratio of one hospital bed to citizen in Bangladesh is 1:2985. This ratio in other SARRC countries is 1:1333, 1:1490, and 1:2703 in India, Pakistan , and Nepal respectively[5][6]. In United States this ratio is 1:212 [6]. To get to a more reasonable 1:1000 ratio would require the annual construction of 300 new 250-bed hospitals for years to come. Bangladesh has one doctor for every 4188 citizens. But most doctors live in the cities, town whereas 76 percent of the country population of just nearly hundred million lives in rural areas. So a pathetic sight fervently reveals the necessity of establishing immediate cost-effective health-medicine.

In the above we have shown health facility in Bangladesh thoroughly, poor people rarely get any specialist doctor's advice when they go to health centers in Upazila / small Town area. We propose the concept of telemedicine in upazilas, districts and divisional cities using existing

health and telecommunication facility so that patients are able to get specialist doctor's advice through local doctor, paramedics at remote area.

5. Technical Requirements:

From a technology standpoint, telemedicine is the application of telecommunication and computer technologies that already in use in other industries. The technology infrastructure is a telecommunications network with input and output devices at each connected location. Table 2 summaries the range of technology used in telemedicine.

We propose two types of telemedicine backbone in Bangladesh: i) Expensive / Dedicated Telemedicine Link (DTL) ii) Cost-Effective/ Internet Based Telemedicine Link (IBTL)

In case of DTL integrated services digital network (ISDN) and asynchronous transfer mode (ATM) is considered as potential backbone technologies for telemedicine networks. Both ISDN and ATM require high-speed link. At present moment required telecommunication infrastructure for ISDN and ATM in Bangladesh is absent. Hence it is not possible to implement telemedicine in ISDN or ATM due to low bandwidth. To implement it requires huge investment to make required telecommunication infrastructure.

In second case considering available telecommunication infrastructure in Bangladesh we propose cost effective Internet based telemedicine (IBT) system to promote the idea of E-medicine.

Communication Link	Copper Telephone Lines Fiber Optic Lines Satellite Microwave Radio Co-Axial Cables
Telecommunication Services	Switched *Switched 56k* *ISDN* *ATM* Dedicated *Fractional T1* *Full T1 (or multiple T1)*
Peripherals	Endoscope Electronic Stcthoscope Otoscope Ophthalmoscope Dermascope Microscope X-ray Scanner Document Camera Remote Monitoring Equipment
Methodology of Videoconferencing	Studio Videoconferencing Desktop Videoconferencing Full-Motion Uncompressed Video Full-Motion Compressed Video Analog Transmission Digital Transmission
Data/Image Transfer	Real Time *Full-Motion Interactive Video* *Still Images with 2-way Audio* *Video "clips " with 2-way Audio*

	Store and Forward *Still Images for later Review* *Video "clips" for later Review* Text E-Mail

Table 2: Telemedicine Equipment Available

5.1 The major aspect of the telemedicine system:

The major features of the system are described as following:

♦Provides the efficient and convenient methods for paramedics, local doctors and specialist doctors to communicate with each other and allows patient's medical data/image through the Internet.
♦Provides a circumstance for "Case Diagnosis" and "Case Consultation" on the remote situation.
♦Build computer-based patient records and other electronic information systems that provide relatively easy and fast access to large databases.
♦Formulates strategies for providing information to patients, clinicians, and others in ways that promote informed decision and stimulate desired changes in behaviors and outcomes.
♦Potentially allows easier access to more information about a patient than the user either requests or needs.
♦Automatically produces a payment including types of telemedicine services and would be divided into professional and facility components.
♦Provides a secure web payment system and authentication procedure to ensure that messages are received from the stated source exactly as they we sent

5.2 System Architecture:

Our proposed cost effective Internet based telemedicine (IBT) system has two important sub systems: Service System, Security System. In the following we briefly describe theses two-sub system.

5.2.1 Service System:

The service system is the most important subsystem of IBT including the modules for "Case Submission", "Medical image upload", " Case diagnosis", "Case presentation", "Case consultation" for doctors, paramedics, and specialist doctor to communicate with each other through the Internet. The module for "Case submission" satisfies the medical needs inside a hospital, in the medical enterprise. In general, a local doctor or paramedics request a consultation by submitting a case. In "Case submission", any electronic medical record, such as text-based report and digital medical images should be able to submit. Subsequently, the "Specialist selection" is an automatic process to select the appropriate specialists for the patients based upon various criteria. The "Case presentation" as an interface to the specialists, should support the characteristics of human thought and communication, so that specialist doctor can have an associative, explicative and complete picture of a case interactively. After obtaining all of the patient information, the specialists can then start their consultation. The "Case consultation" module should not only be where consultants write consultation reports sent to local physician, but also allow discussions of the case among consultants. The "Case consultation" could either asynchronous or AI-based decision making embedded in the system. The result of the

consultation will be archived into patient database and will also be assessed in the module of "Outcome Assessment".

5.2.2 Security System:

Security and privacy are among the most critical problems of telemedicine over the Internet and they have to be well-studied before telemedicine practice on the WWW [7]. Security here refers to network security and end-point security in a distributed environment. Network security concern is due to a third party between a client and a server. Network security may be solved by using the public key algorithms. By adding on the top of TCP/IP layers , SSL is to be implemented for encryption technology. PHP and MySQL program may give the chance to solve end-point security problems. It includes an E-commerce web site that stores sensitive information such as information of patient history and profiles encrypted with a one way hash function.

5.2.3 Image file format used by IBT system:

To aid the distribution and viewing of medical images, such as CT scans, MRI and Ultrasound we suggest the Digital Imaging and communication in Medicine (DICOM) standard created by the National Electrical Manufacturer Association (NEMA) in this regard. The DICOM file format is a high resolution, extended gray scale images format popular in the medical and health care information industry for accessing patient records[10]. It contains both a header (which stores information about the patient's name, the type of scan image dimensions, etc), as well as all of the image data (which can contain information in three dimensions). The DICOM image data can be compressed (encapsulated) to reduce the image size. File can be compressed using lossy or lossless variants of the JPEG format, as well as a lossless Run-Length Encoding format (which is identical to the packed-bits compression found in some TIFF format images).In figure 1 we present MRI data of a patient in DICOM format [10] .

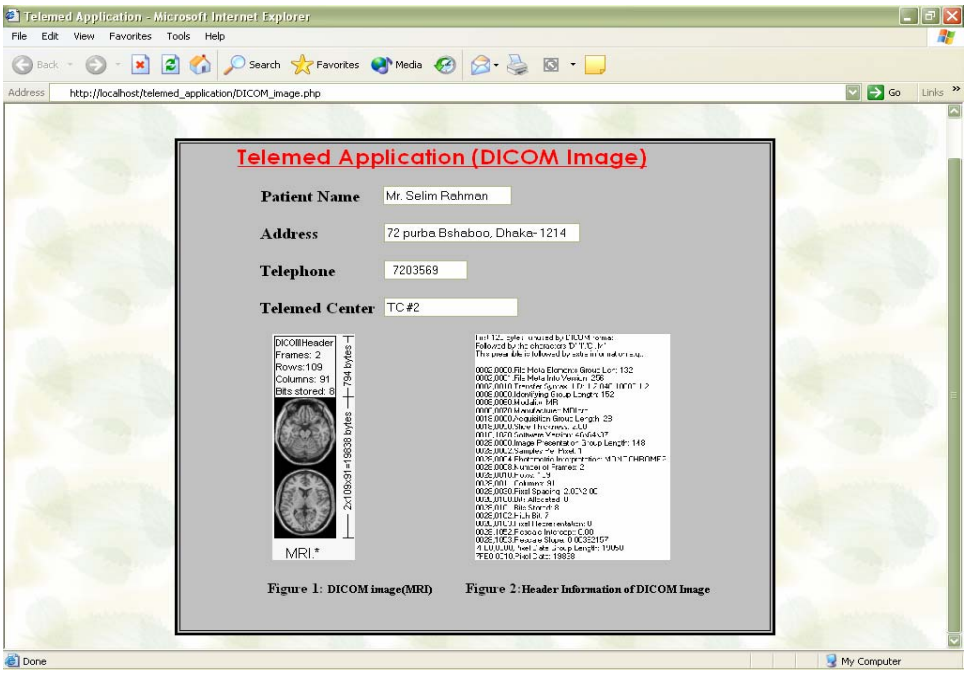


Figure 1: MRI image of a patient is shown using DICOM standard

5.2.4 Audio Coding Technique used by IBT system:

We propose applying an improved MIDI (Musical Instrument Digital Interface) technology to code bio-medical auscultation sound signals such as heart sounds, lung sounds for retrieving medical records and performing telemedicine. This improved MIDI encoding algorithm is based on constructing harmonic complex functions from the sinusoidal waveforms analyzed by Generalized Harmonic Analysis [9]. We have been interested in multimedia medical databases, especially audio databases .Using the technique of [9] we could encode 4-minute 40[Mbytes] audio-data into 195[Kbytes] SMF format MIDI data including vocal sounds..

5.2.5 ECG Analysis:

For initial testing of ECG analysis, 250 samples/s from a data acquisition unit is taken using parallel port programming and is stored in server as flat file format. We also preserve sampling rate, record time and duration in patient-wise fashion.. We implement PHP script to perform preview task in client side (in figure 2). Using 'gd' library of PHP [13] we draw ECG curve (PNG format) and provide factors of time scale preview.

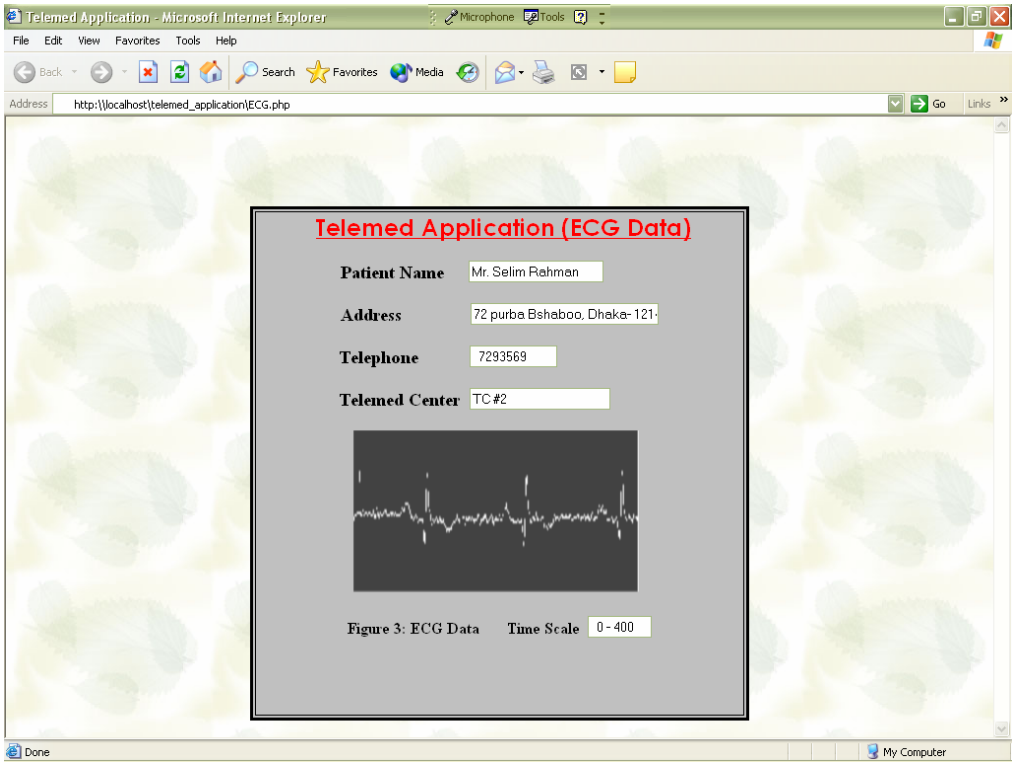


Figure 2: ECG-image is drawn from flat file data using 'gd' library of PHP

6. Necessity and Application of Telemedicine: A case study of Cancer disease in Bangladesh:

We have chosen cancer disease as a case study as it is one of prominent diseases that take many people's lives. Another reason is scarcity of specialist doctor's advice for a cancer

patient. We can provide better treatment for a distant cancer-patient using our proposed telemedicine application.

Cancer is a universal menace. As a cause of death it stands second in the world. In Bangladesh the incidence of cancer is not less than other countries. Prevalence of cancer that develops in the specific organs is due to some racial characteristics religious, customs, peculiar habits, dietary deficiencies, hazardous occupation and environmental influences etc. It has been estimated that about 1,50,000 persons die of cancer per year in Bangladesh. [12].

In our survey to National Institute of Cancer Research and Hospital (NICR), Dhaka, Bangladesh, there were 1221, cancer patient recorded in Radiotherapy Department, 275 (22.52%) were Lungs cancer, 184 (15.07%) Cervix cancer (5.57%) Breast cancer 59(4.85%) Larynx cancer 41(3.36%) esophagus cancer 36(2.95%) Piriform fossa, 34(2.78%) pharynx cancer, 31(2.54%) Tongue cancer, 29(2.38%) Urinary Bladder cancer and 26 (2.13%) tonsil cancer cases [11]**.** From table 3 we see that most of patient of cancer diseases are rural areas people.

Residence	**Number**	**Percentage(%)**
Rural area	957	78.38
Urban area	264	21.672
Total	1221	100.00

Table 3: Residence- wise distribution of cancer patients

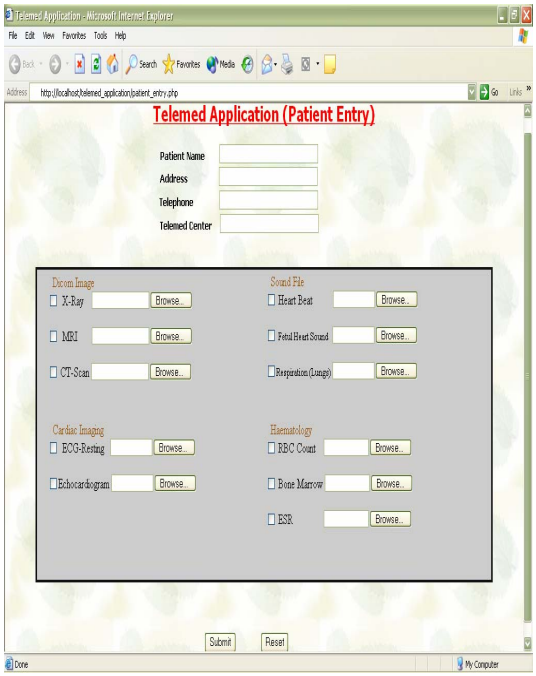
7. Implementation:

We suggest two approaches of IBT to implement telemedicine in Bangladesh: a) Online Telemedicine(ONT) b) Offline Telemedicine (OFT).

In first case(ONT) Internet based asynchronous communication is required. We consider following database schema to store required information**:**

Patient Info = (Patient_ID, Name, Address, Age, Sex, Occupation, Date, Time)
History Info = (History_ID, Disease, Patient_ID, Doctor_ID, Symptoms, DICOM_Image_Format, MIDI_Sound_Format, Notes, Symptom,Date)
Doctor Info = (Doctor_ID, Name, Address, Specialist, Department, Office Address, Status, Phone, Telemedicine_ID)
Telemed_Center_Info = (Telemed_center_ID, Name, Address)

In figure 3 we give a patient entry interface in our proposed internet based telemedicine application and a patient view interface in figure 4.



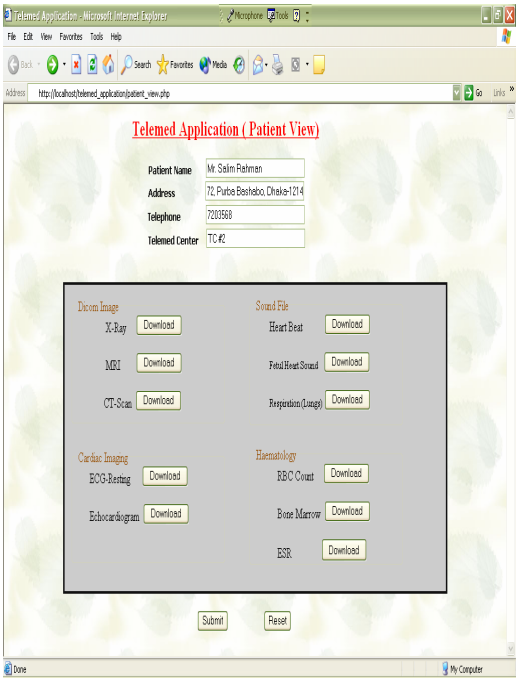


Figure 3: Telemed Application (patient entry)

Figure 4: Telemed application (Patient view)

In second case (OFT) we propose rule-based decision making embedded in the system. To classify symptoms of different cancers we use rule-based data mining algorithm as in figure 5. It is particularly useful in remote rural places or flood or cyclone affected areas where paramedics or health-worker can use this DSS tool (Decision support system) in laptop or PC.

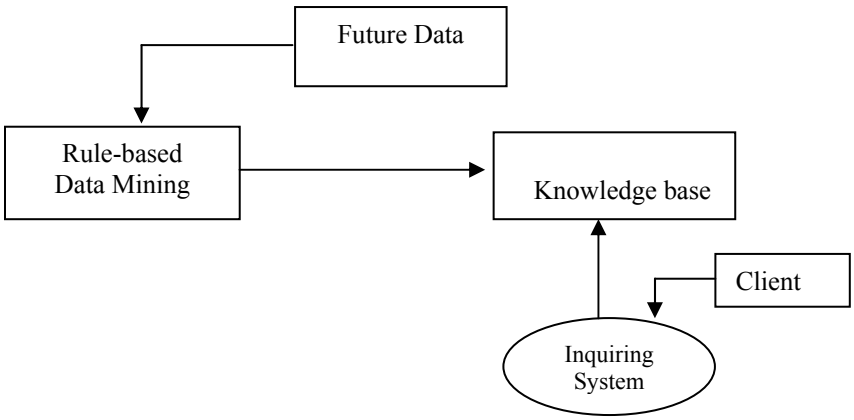


Figure 5: Rule-based Data mining to get symptoms of cancer

7.1 Construction of Decision Tree:

To find the probability of each class or the probability of occurrence of a specific cancer we suggest the use of decision tree. In the tree construction we need to find the probability of occurrence of a specific cancer disease. At first we count the number of cancer disease case and

then classify them on the basis of symptoms. So we use following formula [14] to get the probability of occurring a specific cancer disease.

$$p(Di) = \frac{|frequency(Di, S)|}{|S|} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Here S = total number of cancer cases
D*i* = a specific cancer
(D*i*, S) = in 'S' how many occurrences are of type D*i*

To make decision tree we use information gain formula. To use it , first we calculate the information a particular class D*i* conveys, which is $-\log_2(p(Di))$ bits

$$Eq-(1) \Rightarrow -\log_2\left(\frac{frequency(Di, S)}{|S|}\right) bits \cdots\cdots\cdots\cdots (2)$$

To find the expected information from such a message pertaining to class membership, we sum over the class membership in proportion to frequency in 'S' using

$$Info(S) = -\sum_{i=1}^{k} p(D_i) \times \log_2 p(D_i) bits \cdots\cdots\cdots\cdots\cdots (3)$$

When applied to the set of cases, info (T) measures the average amount of information needed to identify the classes of a case in T (this quantity is known as the entropy of S). The expected information requirement can be found from the weighted sum over the subset.

$$\inf o_x(T) = \sum_{i=1}^{n} \frac{|T_i|}{T} \times \inf o(T) \cdots\cdots\cdots\cdots\cdots\cdots\cdots (4)$$

$\therefore$ We get, gain (X) = info(T) – inf o_x(T) …….(5)

From our survey we consider cancer patients of five prominent types to clarify the symptoms in Bangladeshi environment. The construction of decision tree is shown in figure 6 with gain and in figure 7 without gain.

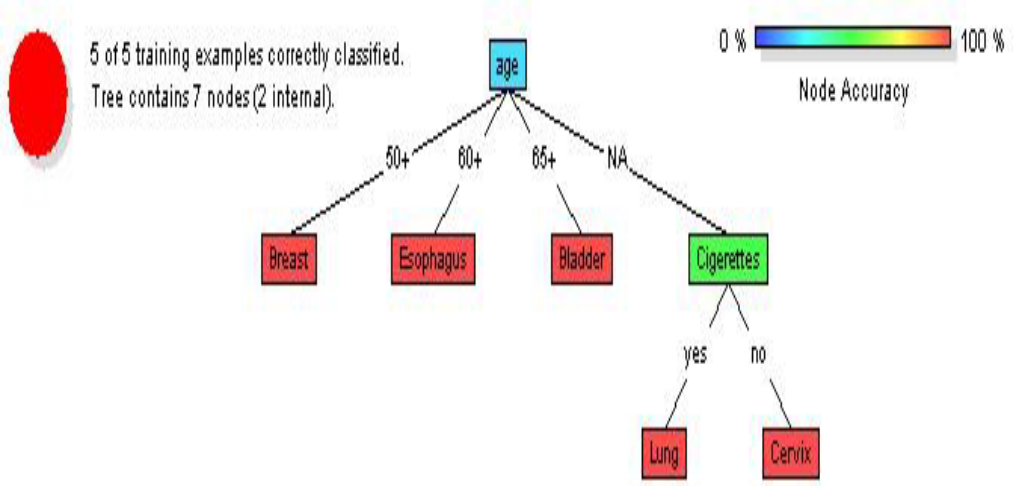


Figure 6: A decision tree for cancer symptoms with gain

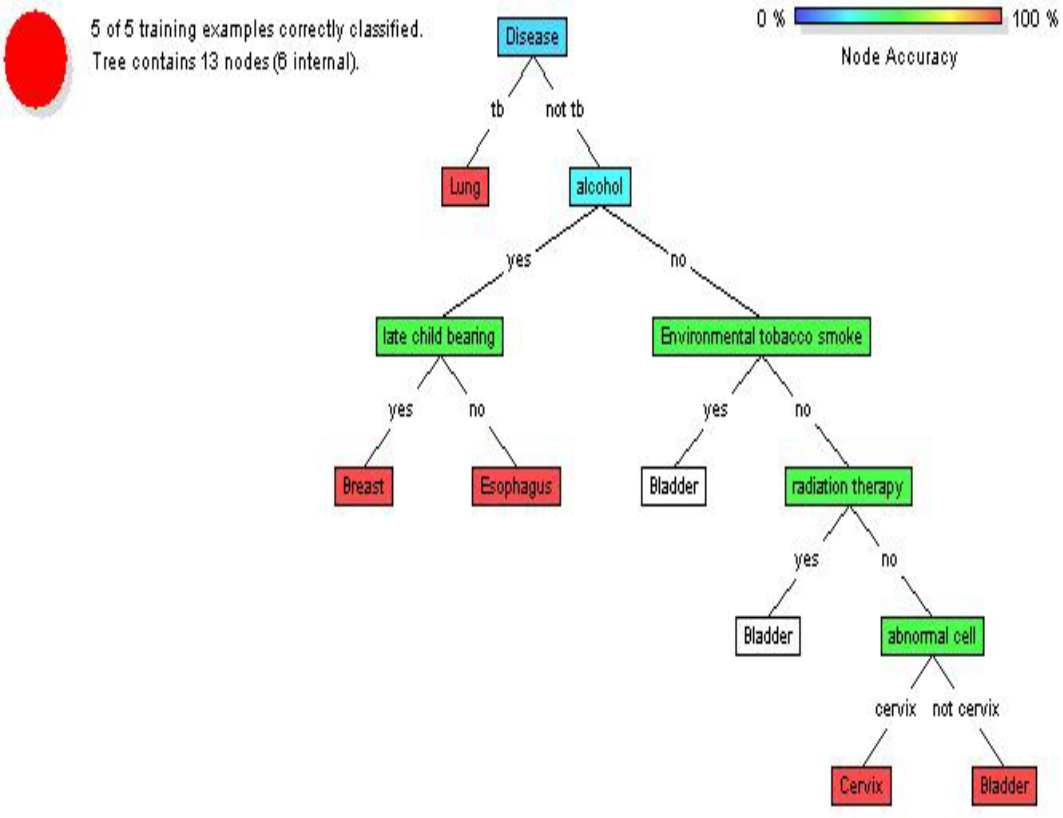


Figure 7: A decision tree for cancer symptoms without gain

8.Conclusion:

In this paper, we focus on the necessity of implementing telemedicine application in Bangladesh. In addition, different technological aspects regarding telemedicine are highlighted. We propose Internet-based telemedicine as the optimal and cost-effective solution in this perspective. We illustrate a case study of cancer disease in Bangladesh-scenario highlighting decision tree-based approach. We highlight DICOM based image implementation and flat-file oriented ECG data-mapping methodology which requires sound programming skill. Moreover, establishment of VSAT in major thana-complex of different districts is expensive and requires many experts and operators.

Future work will be on more cost-effective image-construction retaining standards, faster transmission facilities, synchronous video-conferencing between patient and doctor. Besides telemedicine issues regarding other prevalent diseases of Bangladesh (e.g., heart-disease, Diabetes) must be taken into account.

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