DEVELOPMENT OF USER FRIENDLY SOFTWARE IN BANGLA FOR A PC BASED RURAL HEALTH MONITOR WITH OPTION FOR TELEMEDICINE

A dissertation submitted as a partial fulfilment of the requirements of the degree of M.Phil. in Biomedical Physics & Technology under the University of Dhaka

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DECLARATION

This thesis entitled *"**Development of user friendly software in Bangla for a PC based rural health monitor with option for telemedicine**"* is an original work carried out by me under the supervision of Professor K.Siddique-e Rabbani of the Department of Biomedical Physics & Technology, University of Dhaka, Bangladesh. I further declare that this thesis has been completed by myself and no part of it has been submitted anywhere else in any form for any academic degree.

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DECLARATION

I hereby certify that the present work entitled *"**Development of user friendly software in Bangla for a PC based rural health monitor with option for telemedicine***" is an original research work being submitted by AhamadImtiaz Khan as a thesis for the award of the degree of Master of Philosophy. He conducted these studies under my close supervision at the Department of Biomedical Physics & Technology, University of Dhaka, Bangladesh.

To the best of my knowledge the work embodied in this thesis or any part thereof has not been submitted anywhere in any form for any academic degree.

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Abstract:

Providing quality health service in rural areas is one of the major challenges for developing countries like Bangladesh. Even if infrastructures are provided, retaining qualified medical doctors in a village is almost impossible. The solution to this problem can be Telemedicine. Bangladesh has a good internet and mobile phone infrastructure spread almost all over the country which can be used to advantage. However, a proper telemedicine system requires PC connected digital diagnostic equipment at all rural centres. Importing such devices from the industrialized countries will be cost prohibitive. Besides, maintenance and repair will suffer contributing to frequent interruption of service. Looking towards a sustainable long term solution, our department at Dhaka University has already developed some basic diagnostic equipment the outputs of which are all digitized and interfaced to a PC. This includes, Stethoscope, X-ray viewer, Microscope, Colposcope and ECG (12 lead). Other information like temperature, blood pressure, weight, etc. of patients can be taken by a rural technician using low cost standard equipment and the operator can then type in the resulting values for integration with our telemedicine system.

Necessary software was developed to integrate the diagnostic devices to the PC, to acquire and store the data into a PC at the rural centre and for transmission of relevant data over internet. For real time sound transmission we used Google Talk software which reproduced low frequency heart sounds well.

Web based application was developed for our telemedicine solution. The purpose of this application is to maintain the whole system properly as its hub. Patient registration, request forwarding, patient acceptance, prescription preparation with mouse clicks using an updatable library of necessary phrases and drugs, report submission etc. can be done using this web based application. PHP and MySQL languages was used to develop this application. The goal of our task was to make it user friendly and appropriate for using in our rural areas.

Graphical User Interface of both data acquisition software and web based application was developed in both English and Bangla languages. Bangla will make it easier for the rural operators to use it comfortably. The rural or semi-rural centres for telemedicine will be run by trained operators who will have basic knowledge and experience of using a PC. Operators will

transmit data through internet to expert centres. Doctors from expert centre will talk to the patient and see the diagnostic test results, in real time if wanted. The doctor will finally provide a prescription, again through web based application.

Contents

Chapter 1: Introduction

Providing quality health service in rural areas is one of the major challenges for developing countries like Bangladesh. Put aside the word "Quality" from "Quality health service", we will get "health service (of any kind)", even which is scarce in rural areas of our country. With the sentence "of any kind" it is meant that any kind of recognized health service is absent in most of the rural areas of Bangladesh. Due to the absence of any recognized health service the people of rural areas mostly depend on village quacks.

Basic needs of human beings are food, shelter and clothing but in modern society basic needs are not only these three, sanitation, education and healthcare, are also added to them. We are not living in ancient society. So we must provide every basic need, we must provide quality health service to every citizen of our country. The barrier is huge. None but us can overcome the problem. We ourselves must solve our own problems. We should find a way to pass the barrier easily.

The solution to the problem of healthcare in rural areas can be Telemedicine. Now the question is what is telemedicine? The term "Telemedicine" was first used in 1970s which means "healing at a distance [1]". It implies the use of information and communication technologies (ICTs) for improving the health services at remote areas. ICTs already made revolution in personal communication in our country. We use computer, internet and cell phones every day for communicating with each other. So why don't we use the power of ICTs to boost up health sector? Telemedicine is not a new concept. Many countries are using telemedicine in many dimensions.

Almost 70% of total population live in rural areas of Bangladesh [2]. There are only 3.6 doctors for 10,000 people [3]. This means for about every 10,000 people will get 4 doctors if we can uniformly distribute all doctors to all possible regions of our country. But reality is doctors are not very much interested to go and stay in rural areas. So though statistics says every 10,000 of population have 3.6 doctors but reality is millions of them don't have any. For this reason 70% people consult village doctors or quacks with little or no formal training for curative purpose [4]. According to the current scenario of health sector of our country there is no doubt that

telemedicine can be a very good solution for improving health sector of Bangladesh. As we don't have qualified physicians in most areas of our country so telemedicine can establish a bridge between patients and doctors. Though our country is divided into several districts, zillas, upazillas etc. but by establishing a robust telemedicine system it will be possible to create system through which health service can be served to the people without any border or region.

Telemedicine can be established through any medium that links doctors in towns or cities to patients in villages. With internet and mobile phone networks expanding to almost the whole of Bangladesh telemedicine can use both these media. Our department of Biomedical Physics & Technology at Dhaka University started with a PC based system that uses internet. A PC gives a greater capability of data capture, and most rural centres will be built upon a PC. Therefore, in this thesis by telemedicine it will be assumed a "PC based rural health monitor system". One reason behind choosing PC based rural health monitoring system is PC is very much available. Necessary interfacing between PC and medical devices has already been developed in Biomedical Physics and Technology Department of Dhaka University. Besides, the ministry of Health and Family Welfare of the Bangladesh Government has established almost all Upazilla Health Complexes, running into several hundred, with PC and internet facility. Recently thousands of rural community clinics have also been provided with laptop computers and internet connections. Our aim is to develop a telemedicine system which will be suited in the current infrastructure.

In Bangladesh also several groups are working in Telemedicine. However, most of these depend on video conferencing only having no diagnostic equipment at the rural end. Although some of them are using some diagnostic equipment from abroad, but the costs are prohibitively high. Besides, most of the foreign equipment are not designed to work in the hot and humid climate and under an abnormal electricity supply that are experienced in Bangladesh. Therefore, the services will be interrupted frequently.

Recently the Biomedical Physics and Technology Department of Dhaka University has developed a number of PC based diagnostic equipment with the objective of using these for telemedicine. These are; Stethoscope, Microscope, X-Ray Viewbox, Colposcope and ECG. The

present work was taken up to develop Telemedicine software incorporating these equipment. Besides most of the software used by others are in English which may not be understood well by the people in the villages. Therefore our aim was also to develop the software in Bangla to make it user friendly and useful.

We will equip rural centres with the devices duly developed by Biomedical Physics and Technology Department of Dhaka University. Operator of these centres will get trained so that they can operate the devices as well as the software properly. Patients will come to rural centres. The operators will send request about patient to doctor. After accepting request patient and doctor will get connected. Operator will provide necessary information about patient to doctor. Based on those information doctor will diagnose patient or want more information about patient and after getting those finally diagnose the patient or refer patient to appropriate hospital or physician.

So the tasks to be done here are as follows:

1. Developing software for data acquisition of the above mentioned PC based diagnostic equipment.
2. Developing software for telemedicine. The features of the software will be as follows:
    a. Transmission of data for different instruments
    b. Establishment of easy and appropriate doctor to centre interaction
    c. Consultation of patient with doctor
    d. Prescription generation at the end of diagnosis.
3. Ensuring user friendly aspects of the software including Bangla user interface.

For fulfilling the tasks stated above we will need to develop software. The software can be desktop application and/or web based application. For developing desktop application(s) Java programming language has been chosen. Necessary interfacing between Java application and hardware will be needed to develop. For web based application development PHP and MySQL has been chosen. PHP will be the front end of the web based application. It will contain application logic and present Graphical User interface to user. PHP alone cannot present Graphical User Interface. HyperTextMarkup Language (HTML) and Cascading Style Sheet

(CSS) will do that. MySQL will be used as back end of web based application. MySQL will be used for database management.

The people of most areas of Bangladesh cannot get in touch with qualified doctors. In rural areas it is often heard that someone felt dizzy and died, someone felt chest pain and died. They in fact didn't know that they were suffering from serious diseases. If doctors can detect their problems early, they can give the requisite treatment, or at least they can advise on what to do. If there is no hospital in that area, doctors can refer them to go to the nearest one, but to let the doctor know and identify the problems there should be a way, a bridge for communication. If enough information about patient can be transmitted using the devices developed by Biomedical Physics and Technology Department of Dhaka University through the telemedicine software developed in this work it will be rather easy for doctors to diagnose the patients or at least find their disease and refer them to appropriate hospital or physician before it is too late.

People are dying every day without medication which is utterly unacceptable but we accepted it as normal incident. We hope after implementing our solution it will be possible to present our nation a better scenario of our health sector.

Chapter 2: Background

When we think about telemedicine normally the picture comes to our mind is a doctor video conferencing with a patient. Video conferencing is a part of telemedicine solution but it is absolutely not the only part. Without any diagnostic tests only video conferencing may lead to wrong diagnosis and mistreatment. Ideally a telemedicine system needs to resemble a doctor treating a patient face to face so that the doctor gets sufficient information about the patient. For this one needs diagnostic probes (medical devices) a doctor uses, in addition to tests done in a clinic or pathological laboratory. The latter, although absent in most rural areas, may be performed at small townships in the neighbourhood, but getting a qualified doctor in the rural neighbourhood is almost out of question. At rural telemedicine centres it will be trained technicians or paramedics who will be using the remote facility to probe the patient while a qualified doctor sitting at a console in a distant town or a city will see or listen to the outputs on his/her computer to make a decision on the diagnosis and treatment. The diagnostic equipment can be operated by paramedic or trained operators in the rural centres. These medical devices will be helpful for doctors to diagnose a patient properly.

Now the question is, from where we will get these diagnostic devices? Using foreign machines is not a very good idea. The first reason is they are very much expensive in context to our country and if they have any kind of trouble they cannot be repaired in most cases and become useless. Another reason is it is difficult to find machines that will be well suited in our system. We have a solution now. Our Department i.e. Department of Biomedical Physics and Technology, University of Dhaka has a rich experience in research and development of electronic devices. It has developed some PC based medical devices from scratch and also improvised some devices from other easily available equipment so that these can be well suited to PC based telemedicine system. Initially the department has developed the following equipment after discussing with relevant experts regarding the importance of these equipment in diagnosis [5].

A. Stethoscope
B. X-ray viewer
C. Microscope
D. Colposcope
E. ECG (12 lead, diagnostic quality)

These equipment will be connected to a PC through its USB ports and sound input jack. Conventional equipment will be used to measure patient's temperature, blood pressure, height, weight etc., which will be recorded and sent to the doctor by manually typing the values on a keyboard. A brief description of the devices is given below.

A. Stethoscope

It was made using a standard stethoscope and an electret microphone. The flexible rubber tubing of the stethoscope was cut at a suitable place with the chest piece connected at one end. The electret microphone (diameter about 5mm) was inserted at the other end of the tube (Fig.1). Output of the electret microphone was given as input of PC'S microphone port. For listening output a good quality earphone was used. We can either "store and forward" the sound using standard sound software. For real time transmission, available voice communication service of instant messaging service software can be used. This system works well for listening heart and chest sounds. Since heart sounds have a low frequency, the software is adjusted to give high boost at low frequencies.

Figure 1: Digital Stethoscope

B. X-ray viewer

This was needed to send images of X-ray films. A good quality webcam mounted on a 3D movable stand and a uniformly illuminated screen was used for making this (Fig.2). The X-ray view box was made up using wooden particle board with a milk-white acrylic sheet on top on which the X-ray film is to be placed. Two fluorescent tube lights were used as backlight for the acrylic sheet. In a later version LED Strip lights were used. Instead of making X-ray view box ourselves we can also use the X-ray viewer available in market. The webcam with stand can be used for multipurpose use. Beside this X-ray viewer it can be used as a dermatology camera for taking images of an affected skin. It can also be used as a photocopier to capture written pathological reports, prescriptions, etc., to send these through the web application.

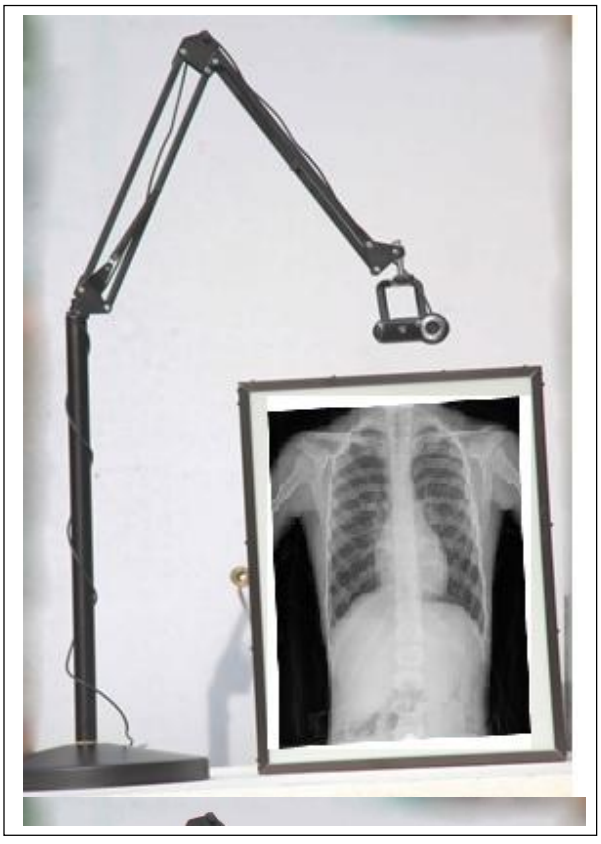


Figure 2: Digital X-ray Viewer

C. Microscope

Digital Microscopes available in market are expensive. Here a standard pathological microscope was improvised to make a digital microscope. A good quality web cam of resolution 2 Megapixel with 4x software zoom was mounted over the eye piece of the microscope (Fig: 3). Careful adjustment of the webcam was needed for achieving proper optical alignment. The webcam can be connected to PC through USB. Still picture can be captured as well as video using software provided with webcam.

Figure 3: Digital Microscope

D. Colposcope

Colposcopy is a medical diagnostic procedure which gives illuminated and, magnified view of the cervix and tissues of vagina and vulva [6]. A colposcope is basically a microscope that gives magnified image of cervix. Distance of colposcope from cervix is important. It is made in such way that we can get magnified image of cervix from a short distance i.e. about 30 cm so that the doctor can also perform some operations by hand. Analysing the optical requirements it was decided that rather than doing the whole optics from basics, it could be made by improvising a

telescope through increasing the distance between eye piece and the objective lens using a piece of extra tubing (a standard telescope cannot be focused at such a short distance). Prism telescope in typical binoculars was found appropriate for this device. It is possible to make 2 colposcopes using 2 telescopes of a binocular. A webcam was then mounted on the eye piece of the improvised device. These were mounted inside a black plastic box which was mounted on a 3D movable arm [5] (Fig-4).

An illuminating system is also needed for colposcope so that it can give white and green/blue light. This was done using rings of white and green LEDs mounted on a PCB which was fixed around the telescope. The green/blue lights can be eliminated by simply applying software filter over the picture captured by the device.

Figure 4: Digital Colposcope

E. Diagnostic ECG, 12 Lead

This device was entirely designed from scratch by the Biomedical Physics and Technology Department of University of Dhaka. Standard integrated circuits (IC) and other electronic components were used for developing this ECG circuit. The idea of developing ECG from scratch was that it is possible to make it at a low cost and as the whole technology is known by the designers it will be possible to provide a sustainable service through local maintenance and repair.

At first our experts tried to capture analogue signal from commercial ECG equipment available in the market and digitize it. Most of the commercially available ECG machines do not provide analogue signal as an output. They found one that provide analogue signal as output. But the problem was the analogue outputs were good for the leads that are in frontal plane. Some outputs of transverse plane are comparatively large and the analogue outputs were heavily distorted. So they decided to develop this equipment from scratch.

The front end amplifier was based on a low cost but high performance instrumentation amplifier IC, available commercially. Switching for the 12 lead configuration at the input was performed through appropriately designed resistor network and program control of hardware through the connected PC. Electrical isolation, both from the requirements of patient safety and noise reduction, was achieved through analogue techniques using an optocoupler [7].

For digitizing the analogue signal a microcontroller was used for establishing an interface with PC through USB. Necessary firmware was also developed.

Figure of our ECG machine is given bellow (Fig-5).

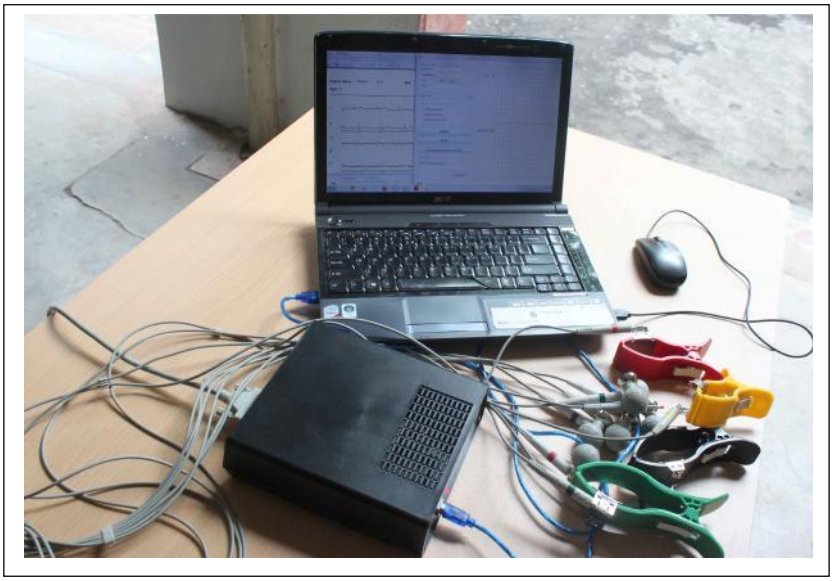


Figure 5: Diagnostic ECG, 12 Lead

So let's catch a glimpse of the overall system. Rural and semi-rural centres will be provided with above mentioned equipment. The 5 equipment mentioned will be connected to PC through the USB port. Some other common but necessary devices will also be used and the measured data will be entered manually through keyboard input. The rural or semi-rural centres will be operated by trained operators who should have basic knowledge about the operation of computers and the above mentioned equipment. Necessary web based application will be developed in the present work for transferring captured data, either by device directly, or through manual entry using standard internet facilities. Operators will transmit data through internet to expert centres. Doctors from expert centre will finally provide prescription through web based application.

Chapter 3: Methods

The basic scheme of our telemedicine system is described with the help of Fig.6. It gives an overall purview of the telemedicine system. First part (top) of the figure shows the basic scheme of the telemedicine system and the second part (bottom) shows basic scheme of a system at a rural/semi-rural healthcare centre. It consists of several diagnostic devices developed by Biomedical Physics and Technology Department of University of Dhaka. Amongst the 5 devices Digital Stethoscope will be connected to the sound input jack of the PC the other 4 devices will be connected through USB port of the PC. Some other devices like thermometer, blood pressure meter will not be connected to PC. Their data will be entered manually by keyboard. As mentioned before, a few diagnostic devices, if linked to a telemedicine system, will enhance the capability and quality of the service manifolds.

Diagnostic devices developed by Biomedical Physics and Technology Department of University of Dhaka are ready. Now it's time to develop user friendly software in Bangla for establishing a full-fledged telemedicine solution. In this system there are several devices which give different kinds of outputs. So methods of transmission of these outputs are different. The outputs of the devices are shown in Fig. 7. Beside these devices, we will have some manual typed data entry from PC's keyboard which will be transferred as well. Now the process of developing a system/collection of systems for transmitting these outputs will be described for establishing a telemedicine solution.

Transmission of sound:

Existing voice communication service of instant messaging service software has been used for transmitting sound. In our case we tested Skype and Google Talk software for transmitting heart and chest sounds as acquired using a stethoscope. The problem with Skype is it filters low frequency sounds. As heartbeat produces low frequency sounds so those are filtered and cannot be heard on the other side, the doctor's end. On the other hand Google Talk does not filter low frequency sounds. So for transmitting heart and chest sounds Google Talk has been used.Sometimes for very slow internet speed Google Talk also does not work well. In that case

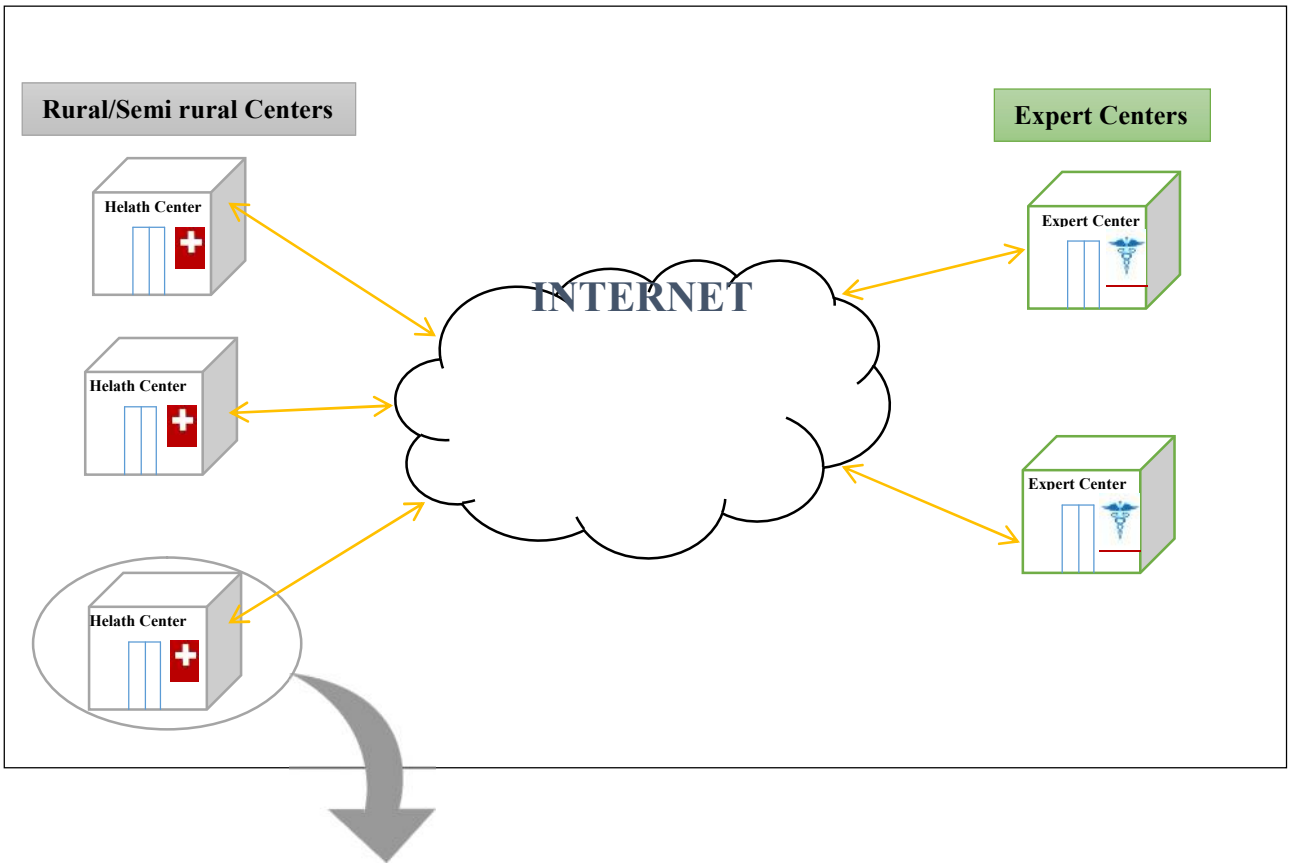
we have plan to develop another system basically a web based application that will store the batch of sounds in database and will forward it to the doctor's end.

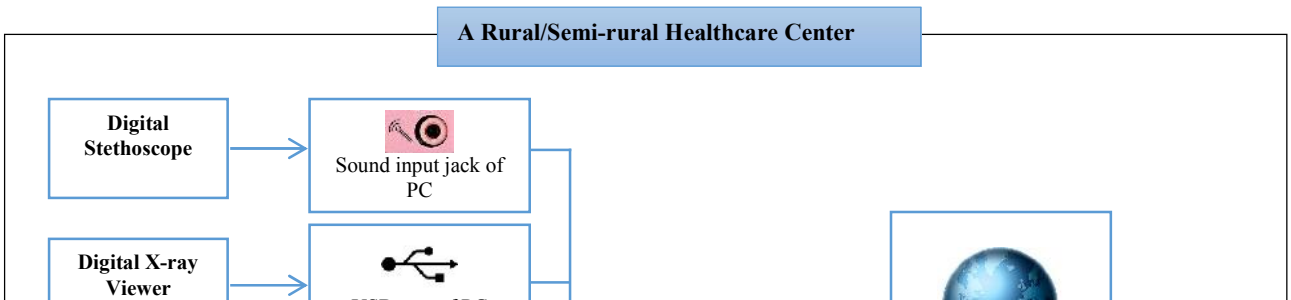
Transmission of image:

Proper Web based telemedicine software has been developed for transmitting images generated from Digital X-ray viewer, Digital Microscope and Digital Colposcope. A web based application has been developed that will not only transmit images but also do more functions as well. It will be a hub of our telemedicine solution. It will be described in details later. Before describing it let us discuss about transmission of the Digital ECG data.

Transmission of numerical data

Appropriate software using Java programming language for data acquisition, display, signal processing, storage and telemedicine has been developed in Bangla. The ECG machine developed by Biomedical Physics and Technology Department of University of Dhaka provides digital data of ECG signal. USB interface between our device and PC has already been established. The interface between our device and host (PC) can be understood from Figure 8





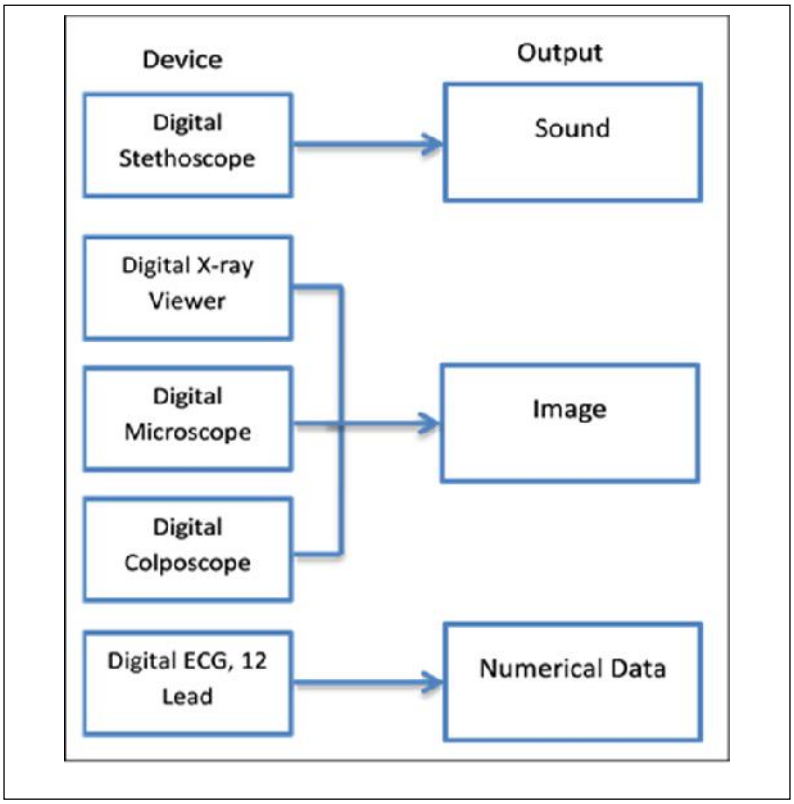


Figure 7: Outputs of Our Devices

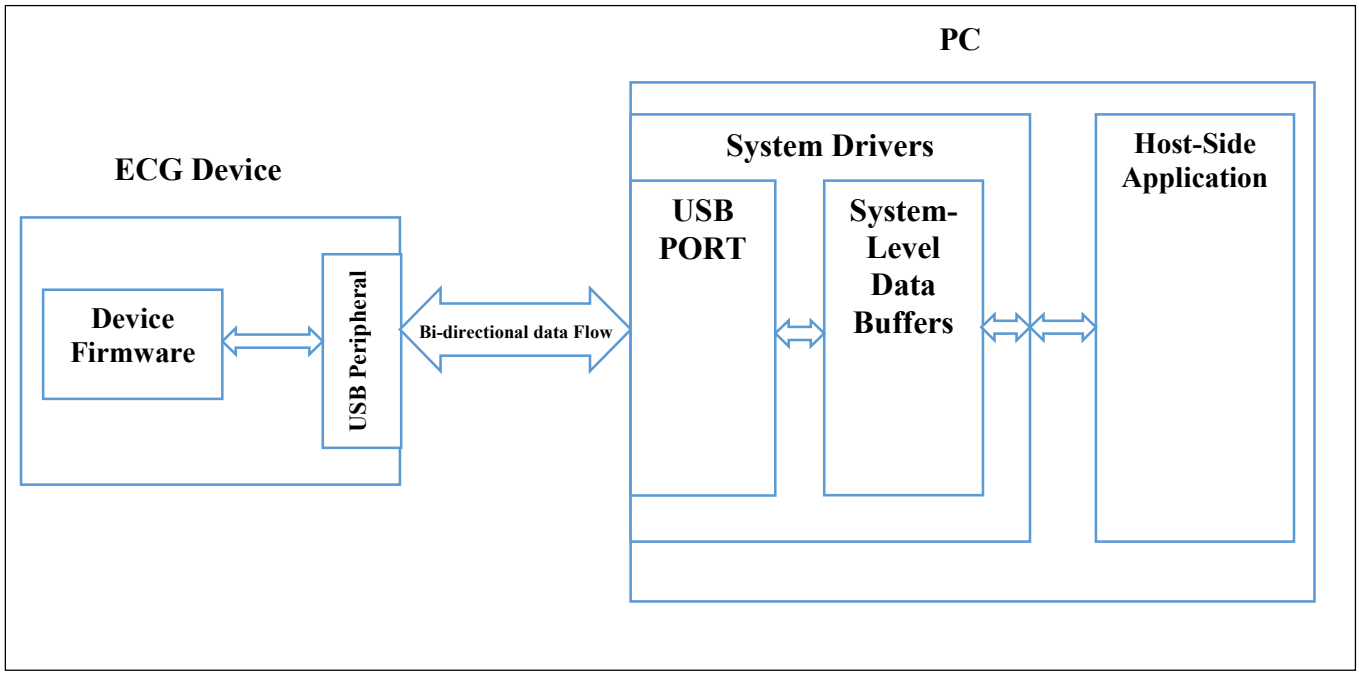


Figure 8: USB Interface between A PC and ECG Device

The challenge was to capture the data from PC's USB port. If it is possible to capture data from device anything can be done like, processing it, displaying it, storing it or sending it to remote location through internet. For capturing data from java application Java Native Interface (JNI) has been used. JNI is a programming framework that enables Java code running in a Java Virtual Machine (JVM) to call and be called by native applications (programs specific to a hardware and operating system platform) and libraries written in other languages such as C, C++ and assembly[8]. The ECG machine developed by Biomedical Physics and Technology Department of University of Dhaka is a USB Human Interface Device (HID). It has a specific Vendor ID (VID) and a Product ID (PID). These ID's are useful to find this device, establishing connection with the device and communicate with the device. As this device is a Human Interface Device we didn't need do develop custom driver for it. It can be detected by Windows operating system. JNI was used for communicating with Windows operating system's Dynamic Link Library (DLL). At first from our java code using JNI we load the intermediate library which will communicate with hid.dll. Then we search for our device using device's VID and PID. If we find our device we obtain a handle of the device and using that handle we start communication. For reading data from device Interrupt IN transfer is used. For changing leads of ECG machine Control OUT transfer is used. In Interrupt IN transfer we read 8 bytes of data in 10 milliseconds i.e. we get 800 samples in 1 second. As capturing data is a blocking function we performed it in a background thread so that it does not create any kind of problems in other tasks of java application. We get data. We process and display it. We can store the data in xml file can forward it to remote PC or we can transmit ECG data in real-time if doctor is present in remote location. For real time data transmission we used Extensible Messaging and Presence Protocol (XMPP). It is an open communication protocol for message-oriented middleware based on XML [9]. Many IM clients use XMPP protocol. Any of them can be used. We choose instant messaging service of Google Talk for authentication and data transmission. From java application developed by us we can log into a specific account. After gathering data of one lead (data of 4 seconds) it is transmitted to doctor who is already logged in in another distant place using same software. Data of 4 seconds is converted to a string and transferred. As size of data is maximum of 2 Kilobytes so it does not take much time to transmit. So doctor can see the output of the leads in real-time or we can say it near-real-time. Doctor and patient both can store

and print the output of ECG as a report. Screenshot of our software and an ECG report is given in Results section.

Web based application for telemedicine solution:

A web based application is being developed for our telemedicine solution. The purpose of this application is to maintain the whole system properly. Let us draw an image of the process of diagnosis of a patient who comes to a rural/semi-rural center. A patient comes to a health center which is run by a trained paramedic. He/she will make the patient contact with doctor who is in an expert center. After performing primary conversation with the patient and gathering symptoms the doctor can give the patient prescription or can advise for some diagnostic tests. At this point the doctor may want to listen to stethoscope sounds in real time. S/he may ask the technician at the remote centre to hold the stethoscope head at specific locations of the patient's body, facilitated by the video and audio communication. The doctor may also ask for an ECG which can be done in real time using our equipment. Alternatively, the ECG may be done later when the doctor is talking to other patients, if there are more than one technician in the remote centre. If a test has to be done in outside centres, after doing the test(s) the patient will come to health center again. The operator of the center will provide the test results to the doctor. After examining those doctor will give the patient final prescription. A web based application for this process will make the whole process a lot easier.

Now let us visualize the whole process and assume that we have web based application now. When a patient comes to a health center if s/he is new s/he will be registered by the operator. After registration s/he will be given a unique ID. This ID is necessary for patient's future diagnosis. If the patient is not a new patient s/he will give his/her ID to the operator. Operator is trained for measuring body temperature, height, weight, pulse rate, blood pressure etc. After measuring these basic measurements a new entry will be created against the ID and will be forwarded as a diagnosis request to doctor. In doctor's panel there is a list in which upcoming requests are listed serially. When doctor accepts a request s/he will make a video call to that corresponding health center. Through video call doctor will gather the symptoms of the patient as mentioned above. S/he can hear the heart and chest sound using our digital stethoscope. If necessary, real-time ECG of patient can be provided to the doctor as mentioned above. After gathering the symptoms and the diagnostic information the doctor can give the patient a

prescription/advice or give him/her some tests and tell him/her to come again. We have developed database for all medicine of some renowned company, database for diagnostic tests, database for common advices etc. So doctor can make a prescription very easily with minimal clicks. The system is designed in such way that the system administrator can insert, delete update the entries from the above mentioned entries.

After preparing the prescription doctor will send it for storage to database. Operator will fetch that prescription from database at the same time, will print it out and will give it to the patient. If the patient is given any tests s/he will have to do those. Some tests can be done in that health center. At present ECG, some blood tests (operator will be trained to prepare blood film and the captured image of the film by Digital microscope will be sent), colposcopy can be done from a health center if they have the appropriate devices. If the patient can get an X-ray done in a nearby centre, the digital X-ray view box developed by our group will be used to capture the X-ray image form the film, and will be sent. Our plan is to provide the more important and affordable devices to the centers so that tests can be done very easily. For Ultrasound B scans, image files recorded form an ultrasound scanner can be sent through the system as well.

After doing the tests patient will come to health center again, provide his/her patient ID to the operator and give him the test results as well. Some test results are single numerical value those will be given as input through PC's keyboard and other complex test reports image will be captured and uploaded by the operator using a camera (The camera on the X-ray view box may also be used). These values and images of the reports will be uploaded and stored against that specific patient's ID. After uploading these, operator will send a request to the doctor. After accepting the request doctor will examine the reports and finally will give the patient a prescription. Not necessarily every patient will get the final treatment staying at his/her place. In some case doctor can suggest him/her that s/he will need to come to city or to a specific hospital or clinic for getting proper diagnosis or has to go to a specific specialist doctor. Even for this we must have a telemedicine solution.

Let us discuss about structure and process of development of our web based application. The most common structure of web based application is three-tiered application [10]. The three tiers are as follows:

(i) Presentation

(ii) Application

(iii)Storage

Web browser is considered as first tier, so no need to bother about it as there are many good web browsers available. An engine that uses some dynamic web content technology is the middle tier which is also referred as application logic. Third tier is database. The following figure shows about three-tiered web application structure (Figure: 9).

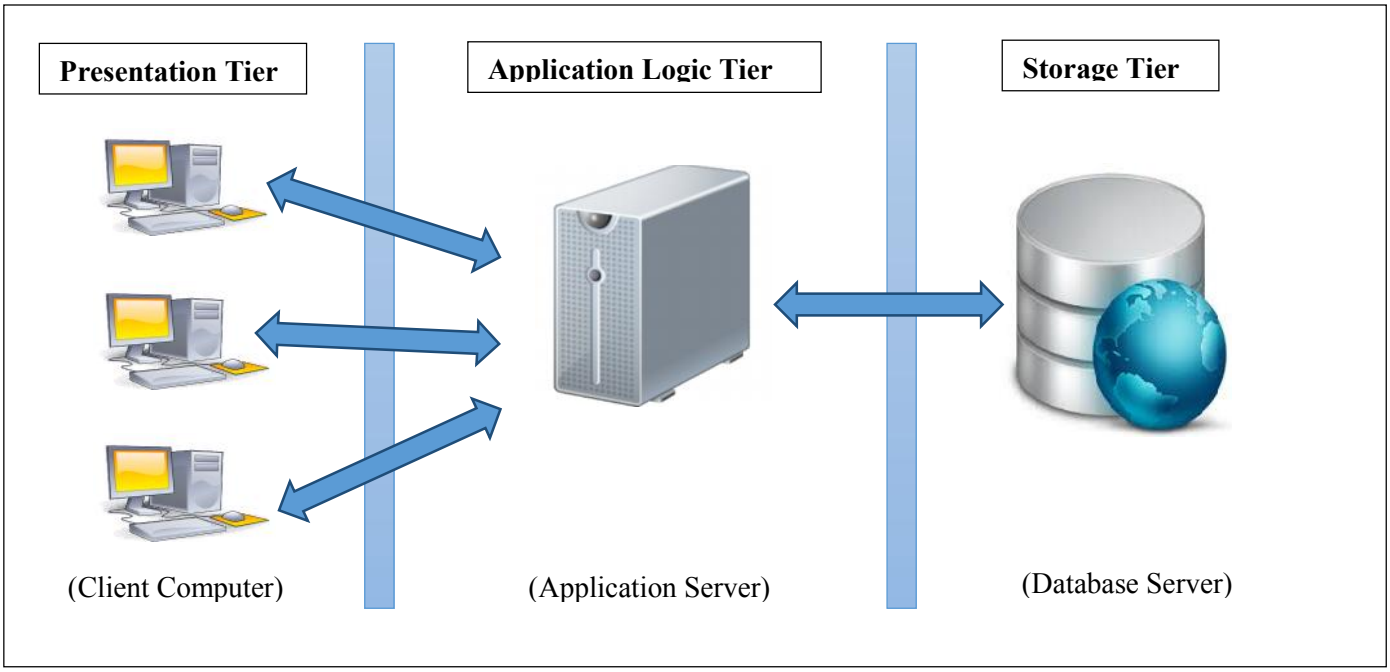


Figure 9: Three-tier Architecture of Web Application

Let's discuss about these tiers.

First tier of a web application is the content that is presented by the browser. The content can be either static or dynamic.

Second tier is application logic. This tier is for processing and generating content. We can use various kinds of server side languages for this purpose. Example of server side languages are – ASP, ASP.NET, PHP, Perl, Python, CGI, JSP/Java, Ruby on Rails etc. For our purpose we used

PHP. We used CodeIgniter web application framework. It is a framework that is used for developing dynamic websites with PHP. CodeIgniter is based on Model-View-Controller development pattern. We choose CodeIgniter for various reasons. For example PHP creator RasmusLerdorf spoke at FrOsCon (Free and Open Source Software Conference) in August 2008 noting that he liked CodeIgniter "because it is faster, lighter and the least like a framework" [11].

Let us discuss about Model-View-Controller development pattern. Model-View-Controller pattern divides a software application into three parts. These three parts are interconnected. The functionality of Model, View and Controller are as follows

- Model does the data management tasks. Classes of model contain functions that help to insert, delete, update and retrieve information from database.
- View presents information to user. Normally a view is web page but in CodeIgniter a page fragment of page like a header or footer is also considered as a view.
- Controller preforms the task of coordination between models and views. It can either send command to model for doing any change in database or can send command to view to change or show its presentation to viewer. Controller is like a hub which controls information flow in application. The following figure shows the interaction between Model, View and Controller (Figure 10).

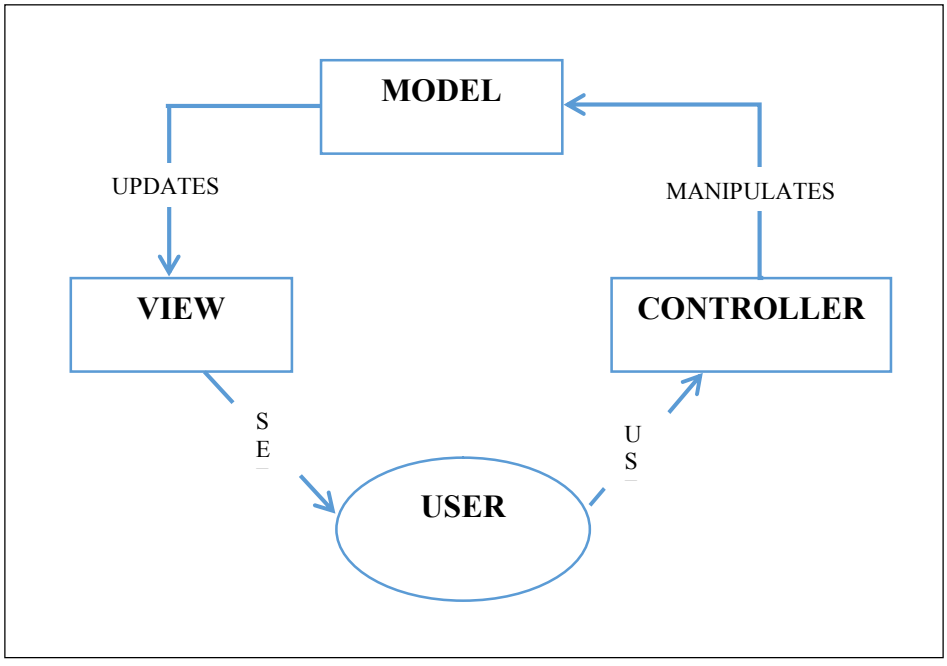


Figure 10: Interaction between MVC components

A very simple example of MVC will make it easy to understand how MVC actually works. In this example some classes and functions is used for retrieving information of registered patients and display them individually on a page.

(i) The Model:

The Model class will query for information from database. In CodeIgniter there is a folder of location application/models. Let us create a new file naming patient_model.php. After php opening tag let us create a class which will extend the CodeIgniter Model class. The class name is always begins with capital letter.

```
class Patient_model extends CI_Model{

}
```

This class will be contained with some functions. Let us create constructor first. Inside it we will load the database class for using CodeIgniter's Active Record pattern which will make it very easy to work with database.

```
public function __construct(){

     $this->load->database();

}
```

Now we will create a method that will query for patient information from database and will return it.

```
public function get_information($id){

     $query = $this->db->get_where('patient',

               array('patientID' => $id))
```

```
    return $qruery->row_array();
}
```

This method will look for information from a table named 'patient' using variable $id. After performing the query it will return the respective row of that ID.

(ii) The Controller

We have created a new file naming patient.php in application/controllers folder. Inside of that file we created a class naming Patient which extends CodeIgniter Controller class.

```
class Patient extends CI_Controller{
}
```

Now let us make a method inside the class that will handle the requests and will display the patient's information. We will load the model class from here and call the method get_information() by passing patient ID as a parameter. This method will fetch the result form model's method will store it in an array then will pass it to view for presenting.

```
public function information($id){
    $this->load->model('patient_model');
    $patientInfo = $this->patient_model ->
get_information($id);

    $data['name'] = $ patientInfo ['patientName'];
    $data['sex] = $ patientInfo ['patientSex'];
    $data['age] = $ patientInfo ['patientAge'];
```

```
    $data['address] = $ patientInfo ['patientAddress'];

    $this->load->view('show_information', $data);

}
```

(iii)The View

Let us create a file naming patient_view.php in application/views folder. Inside file we will show the patient information

```
<?php
    echo "Patient name: "+$name +"\n"
    +"Sex :"+$sex +"\n"
    +"Age :"+$age +"\n"
    +"Address :"+$address +"\n";
?>
```

So let us assume that the name of website is http://telemedbd.com. So to find the information about a patient with ID 101 we will have to enter the following URL to browser.

http://telemedbd.com/patient/information/101

After entering it browser will make a request and CodeIgniter will find for a controller named patient and the method information will be called. The ID 101 will be passed as a parameter to this function. This function will load the Model named patient_model which will perform query from database and will return respective patient's information. After getting the information the Controller will pass it to the View for presenting it.

This is a very simple example for showing how MVC pattern works. Our application is not as simple as the above mentioned example. It is very complex and contains many methods. So using MVC pattern is quite helpful for managing the tasks.

We have developed appropriate Graphical User Interface (GUI) using HyperTextMarkup Language (HTML) and Cascading Style Sheets (CSS). PHP can easily interact with HTML. PHP is able to generate HTML and HTML can pass information to PHP. So HTML is the presentation and PHP is the logic behind it. PHP gets information from HTML which was given as input by user activity. PHP processes it and whatever is needed to be done. Screenshot of GUI and user interaction with software will be given in Results section.

Now we will discuss about database design of our application. When we talk about database design it refers to Relational Database Design. There are many Relational Database Management System (RDMS) available. Some of them are commercial such as Oracle, Microsoft SQL Server, IBM DB2, etc. Free and open-source RDMS are also available such as MySQL, mSQL etc.

The feature of RDMS is data is being organized in tables which are also referred as relations. Rows and columns make a table. A row in a table is referred as a record or tuple. A column is referred as a field or attribute. Relationships among the tables make it possible for a relational database to store huge amount of data efficiently and to retrieve data efficiently as well.

A language named Structured Query Language (SQL) is used to work with relational databases. Designing database is more like art than designing. As every customized application is different so their database is different as well. As we developed a custom application for us so we had to design database for it from the very bottom. We tried our best to develop a consistent relational database by eliminating data redundancy and tried to ensure data integrity and accuracy which are main design objectives of database design.

For user authentication and management we used Felxi Auth. Flexi Auth is a free open source user authentication/login library for using with CodeIgniter [12]. So we did not make any table in database for user management. We used tables of Flexi Auth instead. For other task we will need tables. The Database Model Diagram of them is given in Figure 11.

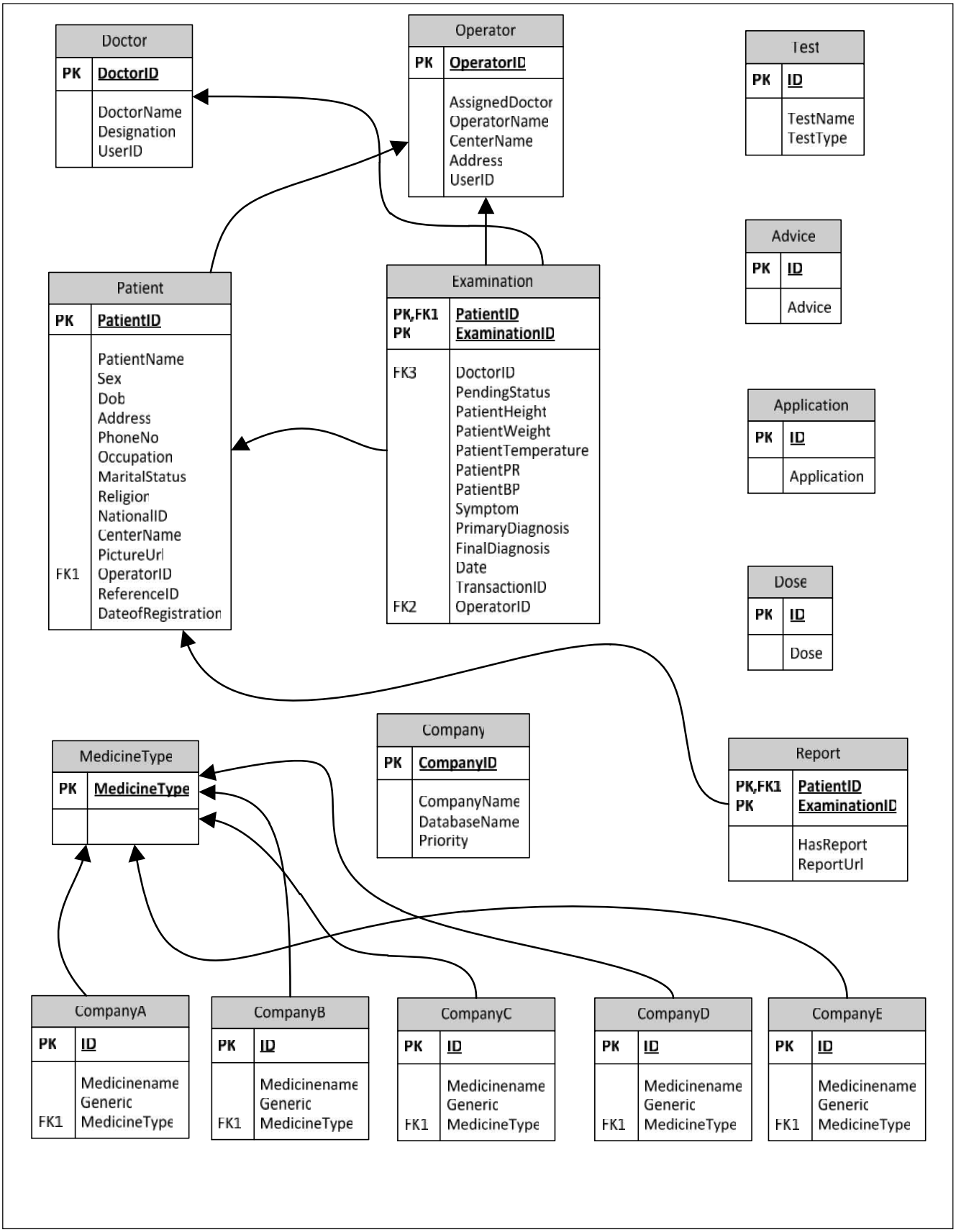


Figure 11: Database Model Diagram

In the above figure tables are shown with their attributes. PK indicates Primary Key of a table and FK indicates Foreign Key.

How we ensured user-friendliness:

One of the targets of our task was to develop a user friendly system. For developing a user-friendly telemedicine system we developed the Graphical User Interface of our applications in Bangla. As a major portion of the users of our system is Operators of Health Centres so it would be easy for them if the GUI is developed in their native language.

In second phase we took feedback from end users. By taking their feedback we altered our system to make it more user-friendly. Basically it is a dynamic process. Whenever we get a bug or problem or suggestion from users we alter our applications. Basically we developed two applications. One is for real-time transmission of ECG data and another is Web based application. We tested ECG software in field in person. So it was easy for us to find the ways to make it user friendly.

A Non-Government Organization (NGO) established a Telemedicine System using our solution. They are using the above described solution since July 2013. They established three rural healthcare centres in three Upazillas of a district and established an expert centre in the district town. For first couple of months we took continuous feedback from them. After fixing the bugs and other things now we collect feedback from them when it is needed. Since July 2013 they have served almost 500 patients using our system.

Chapter 4: Results:

In this section we will show the outputs of our system. First of all let us discuss about the ECG software. Figure 12 is an image of Graphical user interface of ECG software.

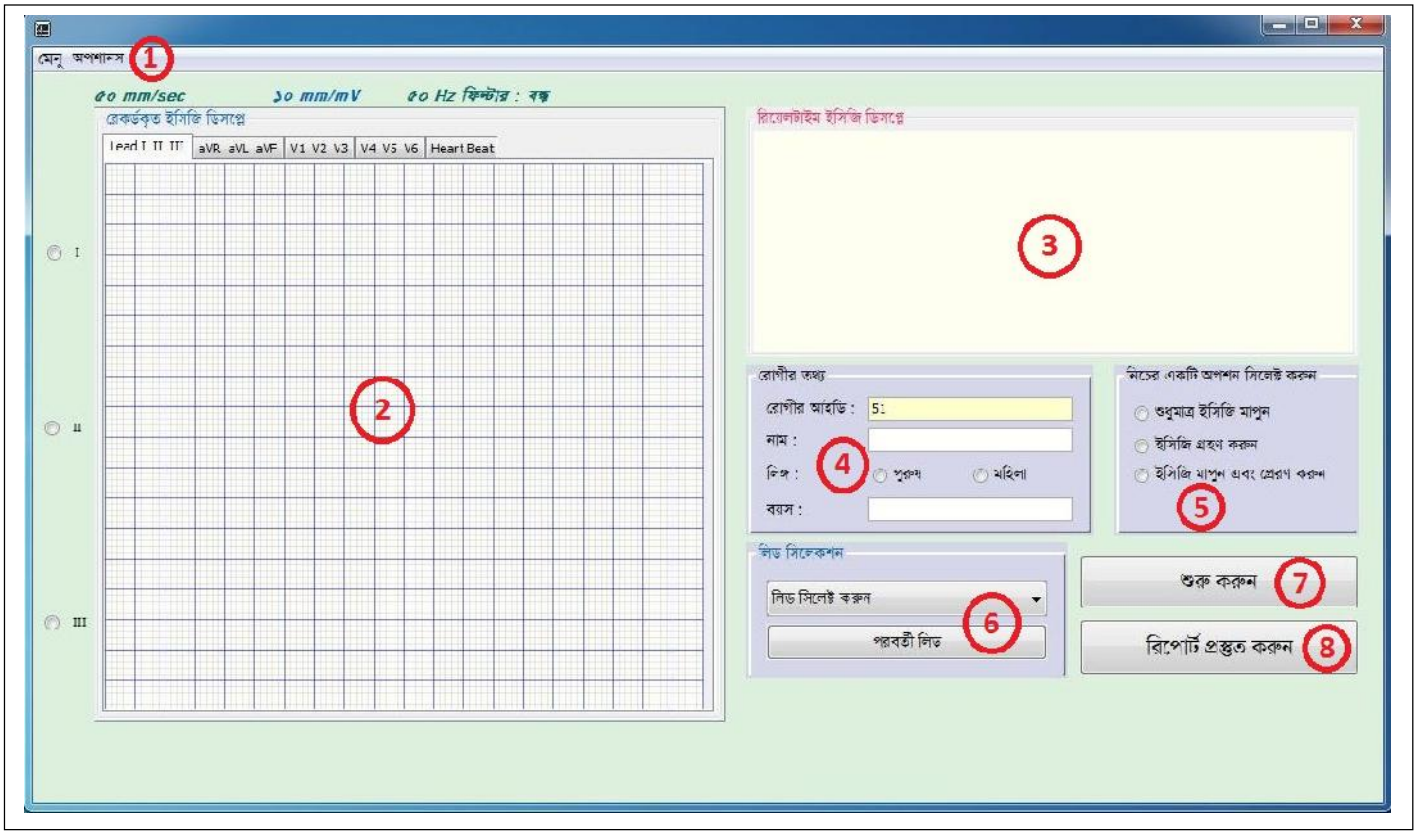


Figure 12: Graphical User Interface of ECG Software

Main parts of the graphical user interface are indicated through numbers in this figure. Let us give a short description of these interfaces. Obviously all commands appear in suitably translated Bangla on the screen.

1. Indicates Menu bar. Menu bar contains several options like measuring new ECG, changing gain and vertical scaling, on and off 50 Hz filter etc. It also have other options

like generating report from previously recorded ECG, changing centre name, setting user name and password of gMail account, sending XML file as an attachment through an email directly from the software.

2. This is recorded ECG display. We only record one lead at a time. So previously recorded leads are displayed here.
3. This is real-time ECG display. Currently selected lead is displayed in real-time in this panel.
4. This is patient information input panel. ID of patient is generated automatically.
5. This is mode selection panel. This software can be used in three modes: i) Measurement of ECG only, ii) Receiving ECG data from a remote centre and iii) Measurement of ECG and onward transmission to doctor's end.
6. This is lead selection panel. ECG leads can be selected from dropdown combo box or by clicking 'next' lead button.
7. This is a toggle button for starting and stopping ECG measurement.
8. This button is used to generate an ECG report after finishing ECG measurement.

Figure 13 shows how the monitor display looks during measurement which also indicates the

Figure 13: ECG display and Graphical User Interface of ECG Software

graphical user interface.

For printing out the report on paper all the 12 lead ECG traces and necessary patient information are arranged as shown in Figure 14. A pdf version of this image is also stored for future reference. The raw ECG data are also saved in separate file.

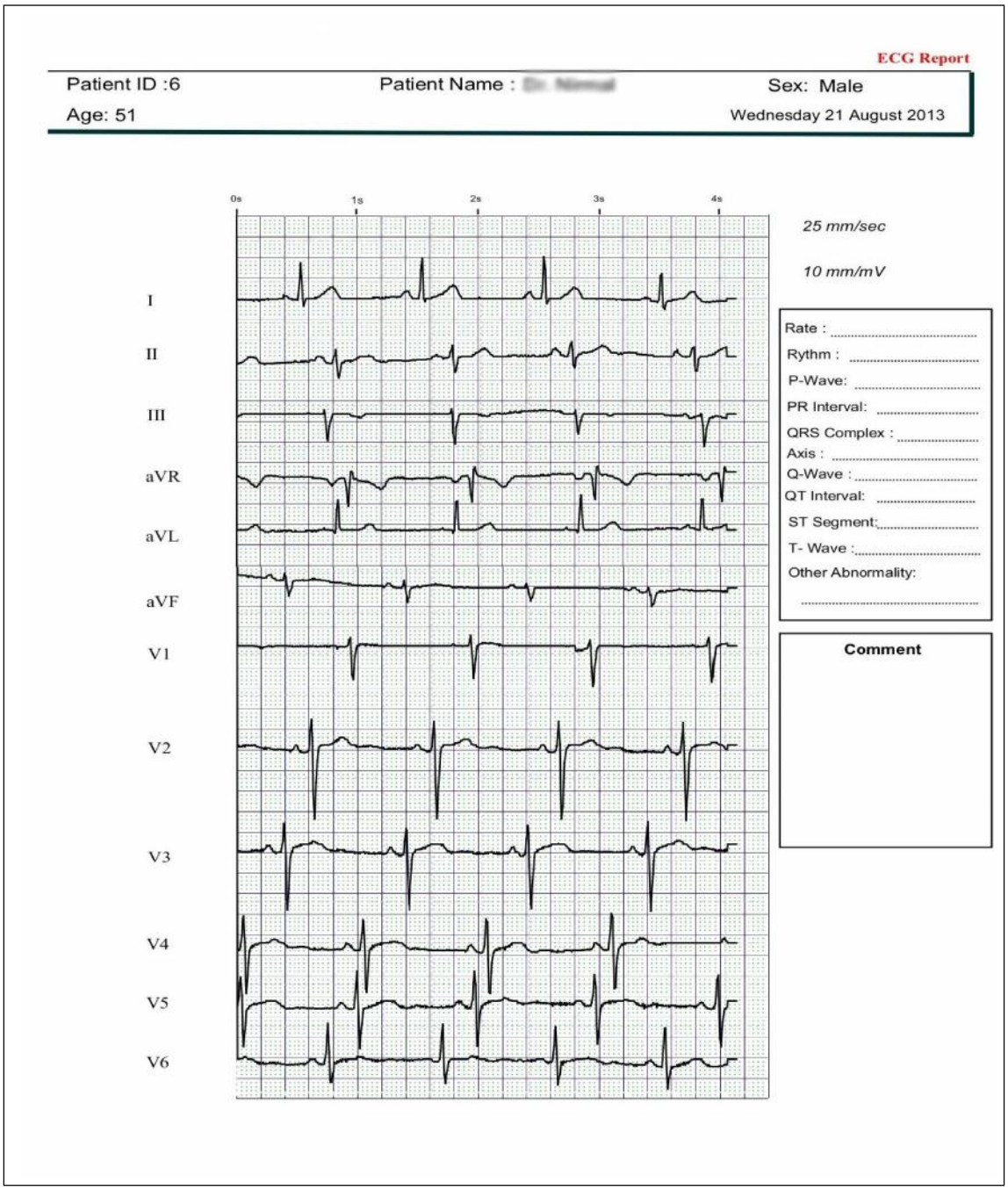


Figure 14: Sample of ECG Report

Now we will discuss about the output of web based application by showing some screenshot of that application. The following one is the home page of our website (Fig: 15). The link of our website is www.bmpt.du.ac.bd/telemedbd .

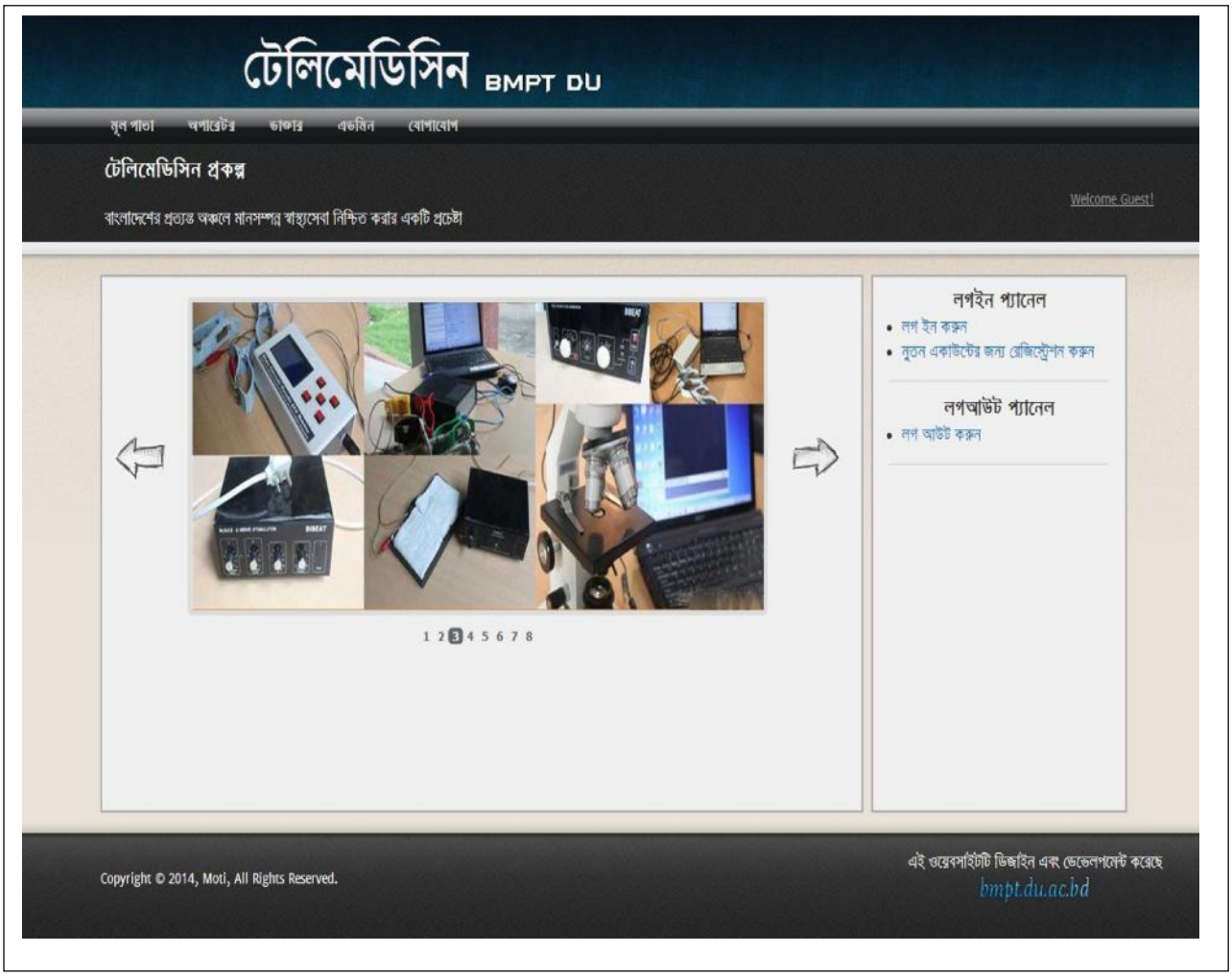


Figure 15: Home Page of Our Web Site

Right side of the page has a panel which includes login, registration and logout options. As our diagnosis process starts with patient registration let us look at the patient registration process. Patient registration is done by operator. So an operator is needed to be logged in to the web site first. After logging in he/she will navigate to the option of patient panel under operator menu in menu bar. The patient registration panel looks like as Figure 16.

Figure 16: Patient Registration Panel

The red start marked fields i.e. name and date of birth are must for registering a patient. Other fields are optional. The last field is Reference ID. Which will be used if we want to apply a family based registration. Father or mother's ID will be the Reference ID in that condition. After filling up the fields and pressing Submit button a pop-up dialogue box will indicate whether the

patient is registered successfully or not. A failure notice will appear in case of occurrence of any problem.

Sending patient information to the server

For making the process user friendly we used Ajax (Asynchronous Java and XML) for sending patient information to server. Ajax is a programming language that can exchange data with server without reloading the page and also can update part of a page without reloading that whole page. So if an operator wants to register a patient and after resubmitting the registration every time a full reloading of that page is performed it will become tiresome for him/her. So for most cases in our website we used Ajax instead of PHP's POST operation. We also used Javascript which is a client side programming language to make our application more interactive. After the registration process a Patient ID will be generated using the following rules.

- First four characters will be taken off the first two digits of last name and the first name.
- Then there will be an underscore character and then date of birth will come in the format date, month and year respectively.
- After this there will be an underscore character again and an auto incremented value to make the Patient ID unique as it is primary key in Patient table in database.
- So if name of a patient is "AbcdPqrs" and his date of birth is 7th July 1980 then his ID will be PqAb_07071980_123 (last part i.e. 123 is an auto incremented value). We generated Patient ID using this scheme so that it will be easier for searching a patient and mining his/her data although he/she forgets the ID. As he/she will not forget his/her name and DOB so it will be easier to find the ID.

After finishing registration operator can upload a picture of the patient. It is an optional task. The display looks as in Figure 17.

For an old patient, the operator can search a patient using Patient ID and can get patient detail (Fig: 18).

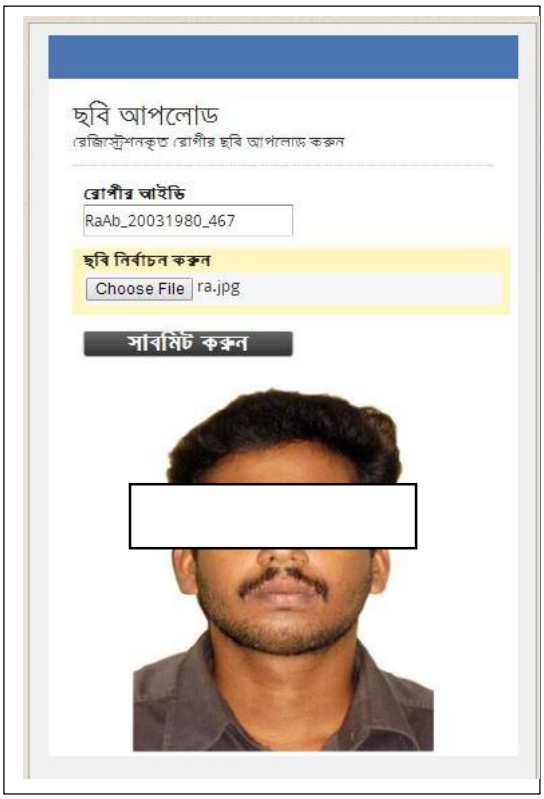


Figure 17: Patient Photo Upload

Figure 18: Patient Search Panel

For searching patient we added autocomplete functionality to the text field that is used for searching Patient ID. When operator types first two characters of the ID list of suggestions will be shown. From the list it will be easier for the operator to find desired Patient ID. Under this panel there are one text field and one submit button which are used to find and start diagnosis of a patient (Fig: 19).

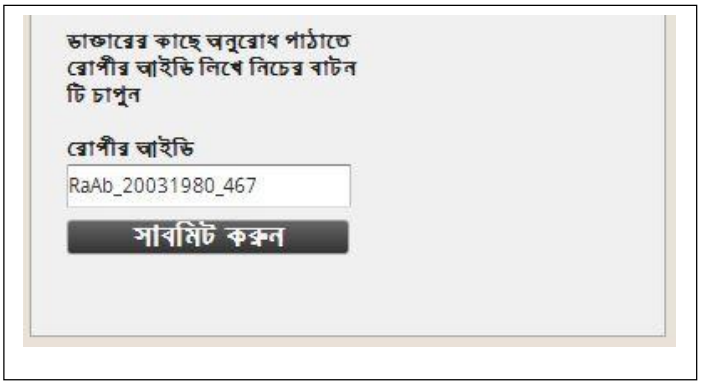


Figure 19: Start Diagnosing a Patient

After clicking the above mentioned submit button a new page will appear. Operator will fill up the page with some basic measurements of patient like height, weight, body temperature, pulse rate and blood pressure. Operator can provide some symptom of patient to the doctor though it is not necessary as it is the task of doctor to gather symptom from patient. After that Operator will press submit button. This submission will be sent as a request to the doctor. A pop up dialog box will be shown with message that the request is sent to the doctor successfully or failure message otherwise (Fig: 20).

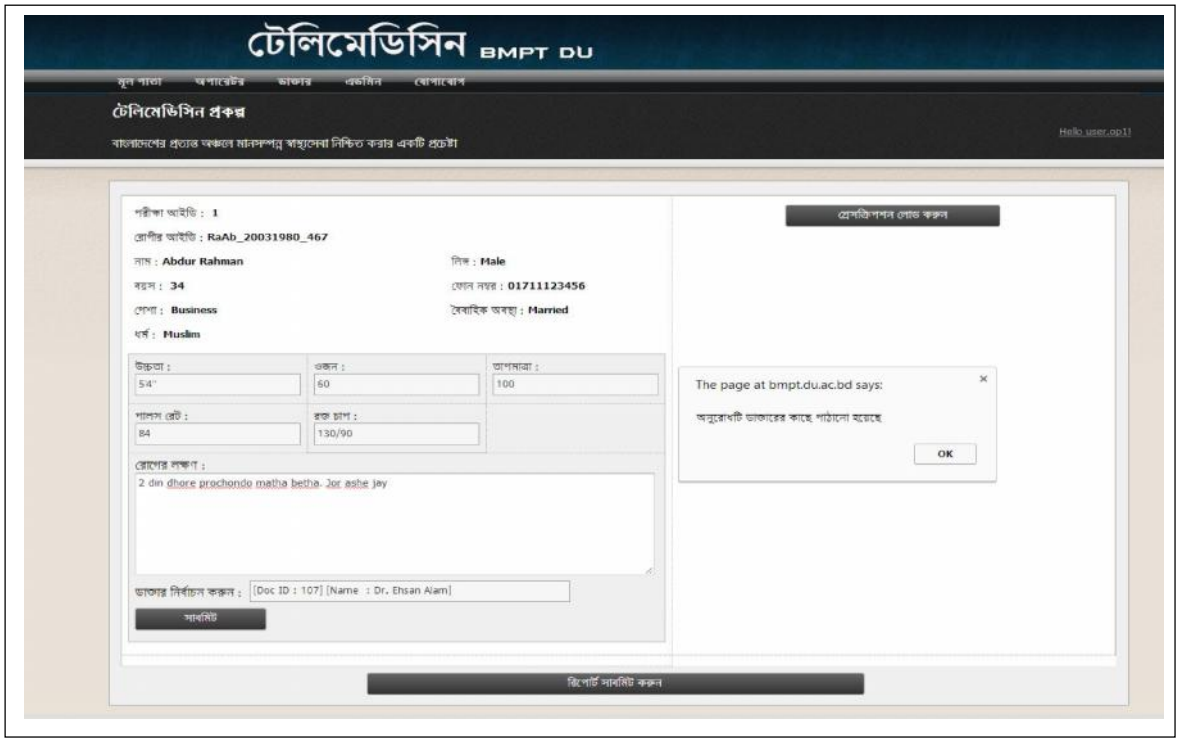


Figure 20: Forwarding Request to Doctor

This page also has option for uploading report and submitting it to doctor. At the bottom of the page there is a report submission button. After clicking it a new page will appear (Fig: 21).

Figure 21: Report Submission Page

An operator can type and submit the value of a test report. But results of all test reports are not simple numerical values. In that case operator will take pictures of the report and upload it which option is added to this page. An operator can upload any number of photos of reports but maximum fivephotos at a time.

When a request is sent to doctor through operator the respective request will be displayed in a list in doctor's panel (Fig: 22).

When doctor will click the accept request button the basic information about the patient will be shown in the right side of doctor's panel (Fig: 23).

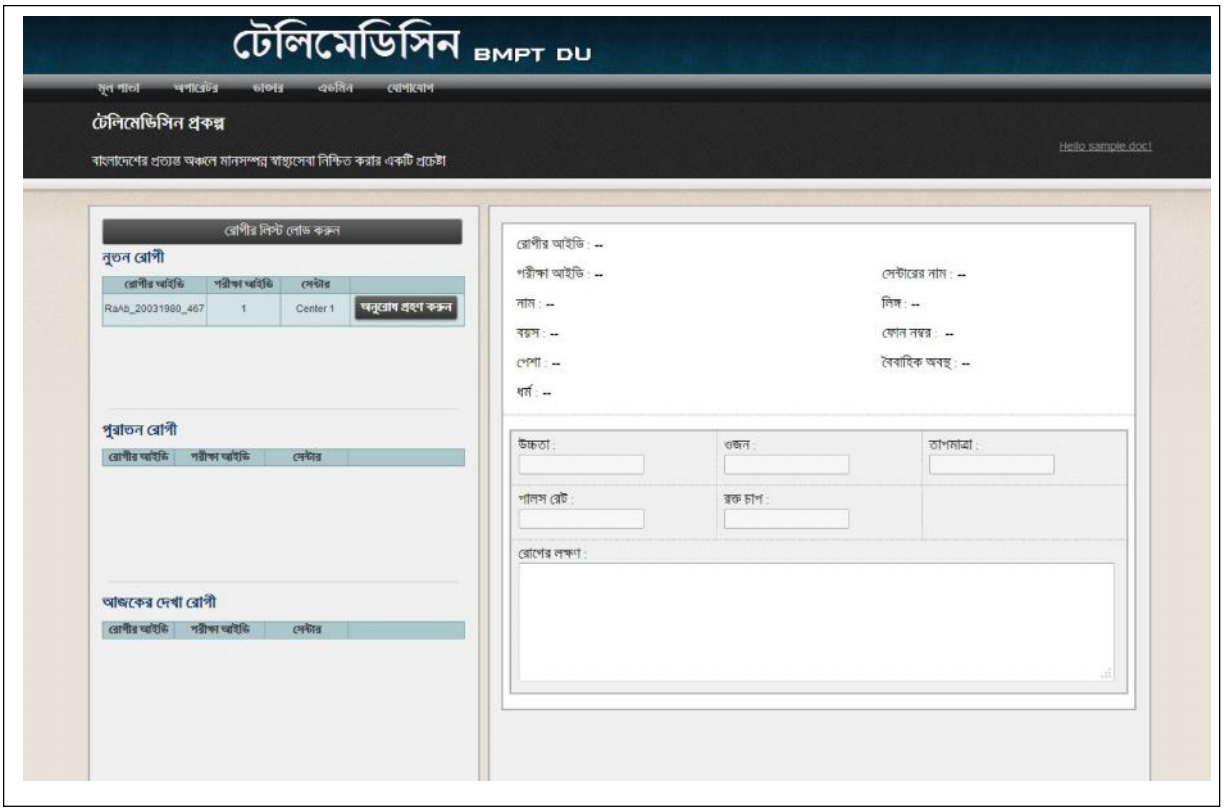


Figure 22: Doctor's Panel

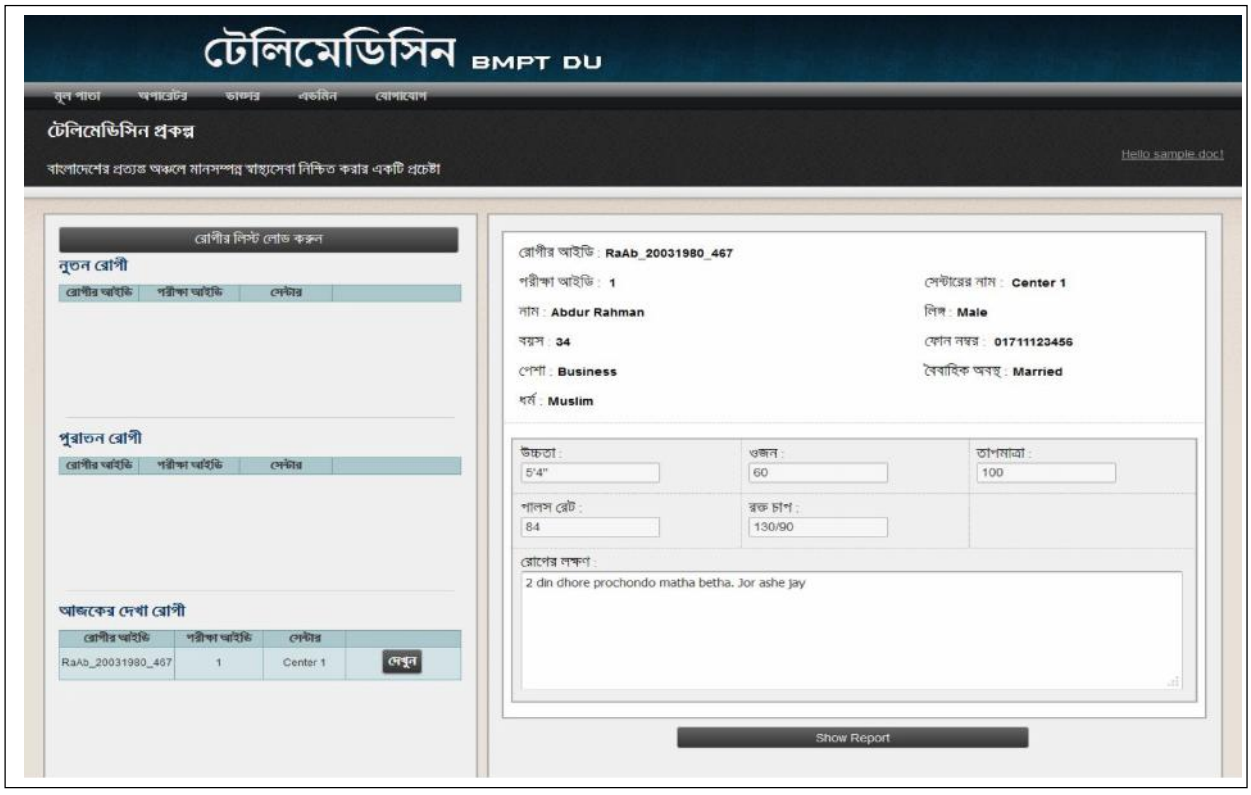


Figure 23: Doctor's Panel

In this situation doctor will call to the respective operator using Skype. Then he/she will talk with the patient listen to patient's problems, gather symptoms etc. Then doctor will make a prescription for the patient using prescription maker. We developed a user friendly prescription maker through which a doctor can make a prescription with minimal mouse clicks. After clicking the button for loading prescription panel, Prescription panel will be loaded (Fig: 24)

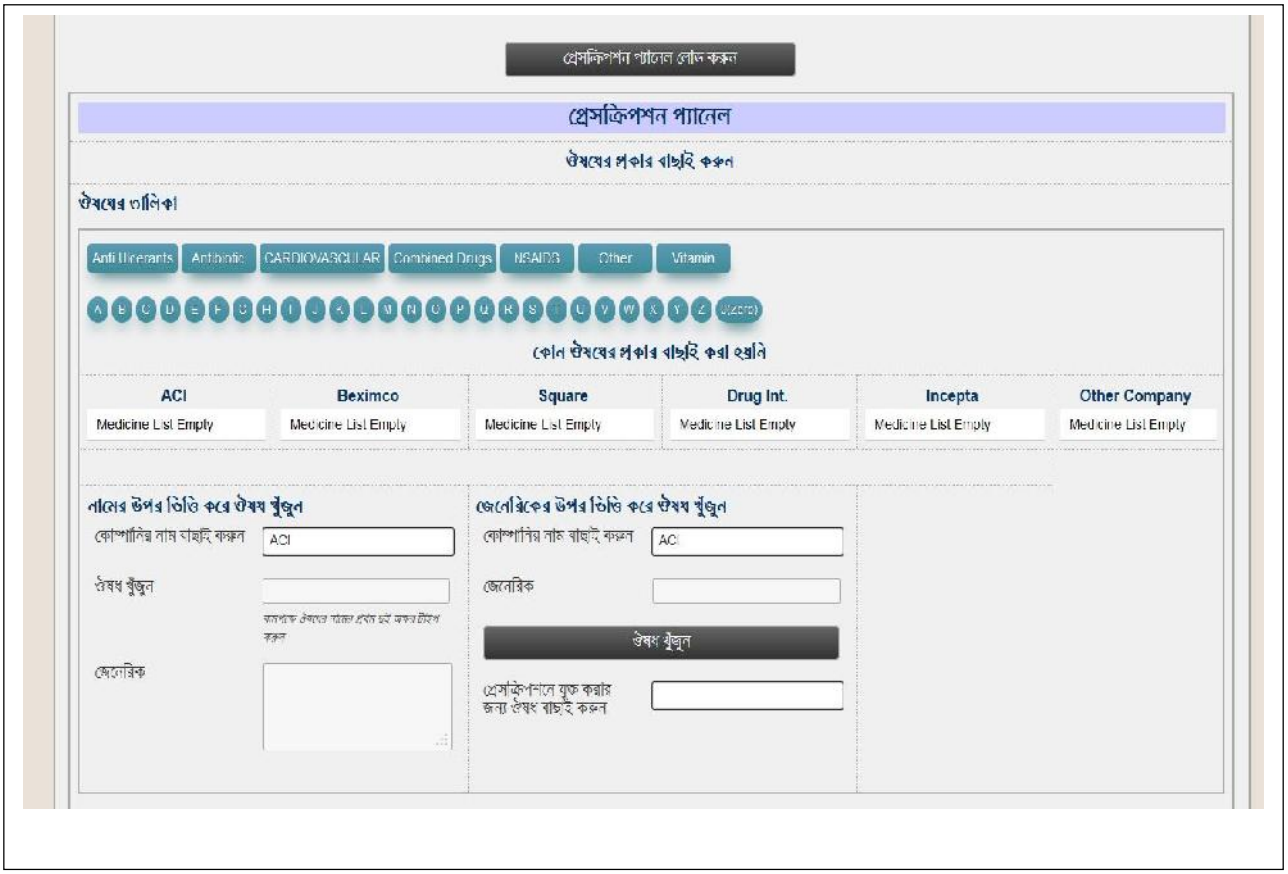


Figure 24: A Part of Prescription Panel

There are three options for finding medicine from this panel. Doctor can choose a medicine type and the can load the list of that type of medicine alphabetically or doctor can find the medicine using medicine name or can find the list of medicine using generic names. After selecting a medicine a dialogue box will pop up with options for dose selection, input for days and application selection (Fig: 25).

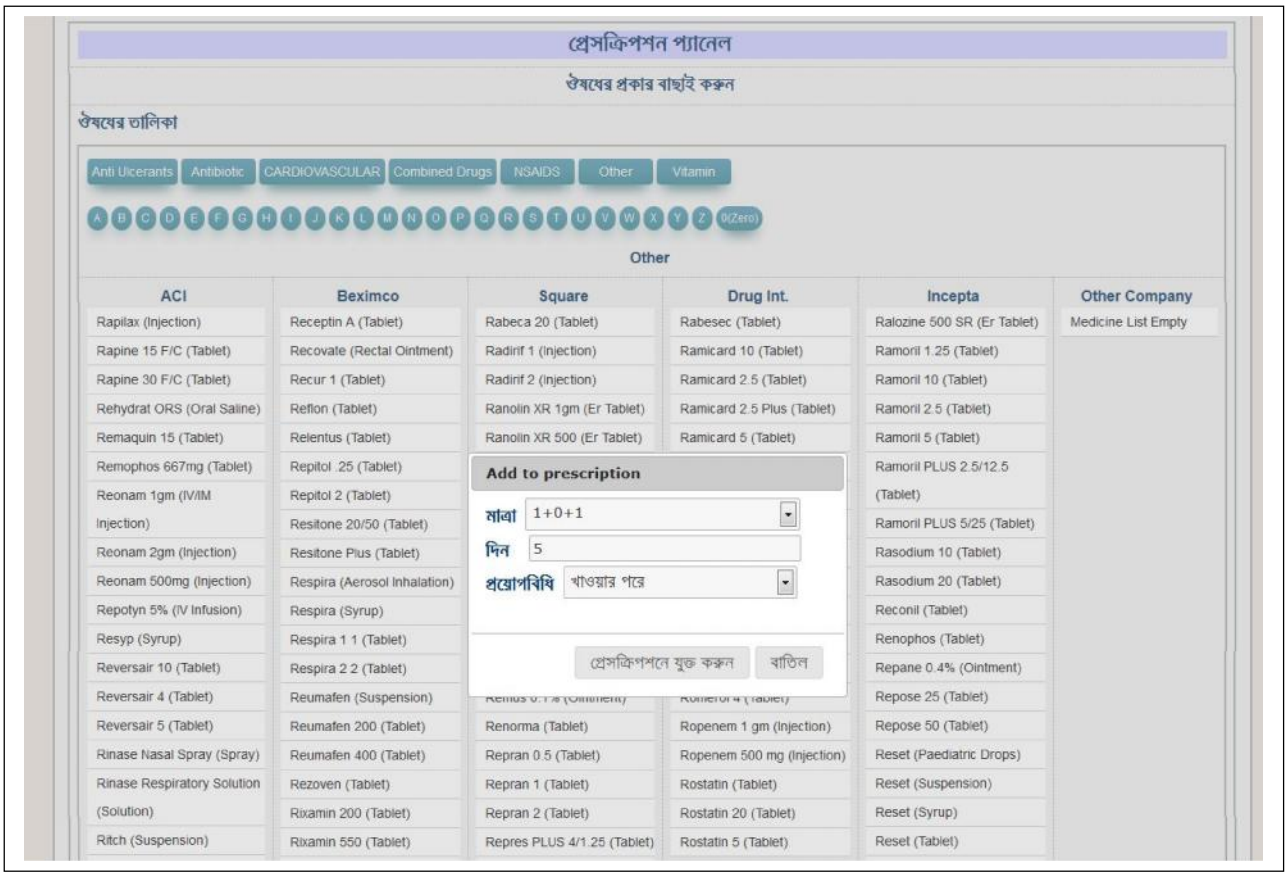


Figure 25: Pop up Dialogue box After Medicine

After clicking the affirmative button the name of the medicine, dosage, day(s) and application

Figure 26: A Portion of Prescription Panel

will be added to a text area (Fig: 26)

Beside this, options for adding tests and advices are provided. The doctor can choose from these in the form of a list by mouse click and add to the text area as well. After finalizing the prescription doctor will send the prescription either as primary or final prescription. After clicking the respective button a confirmation message will be shown to the doctor that the prescription has been sent successfully (Fig: 27).

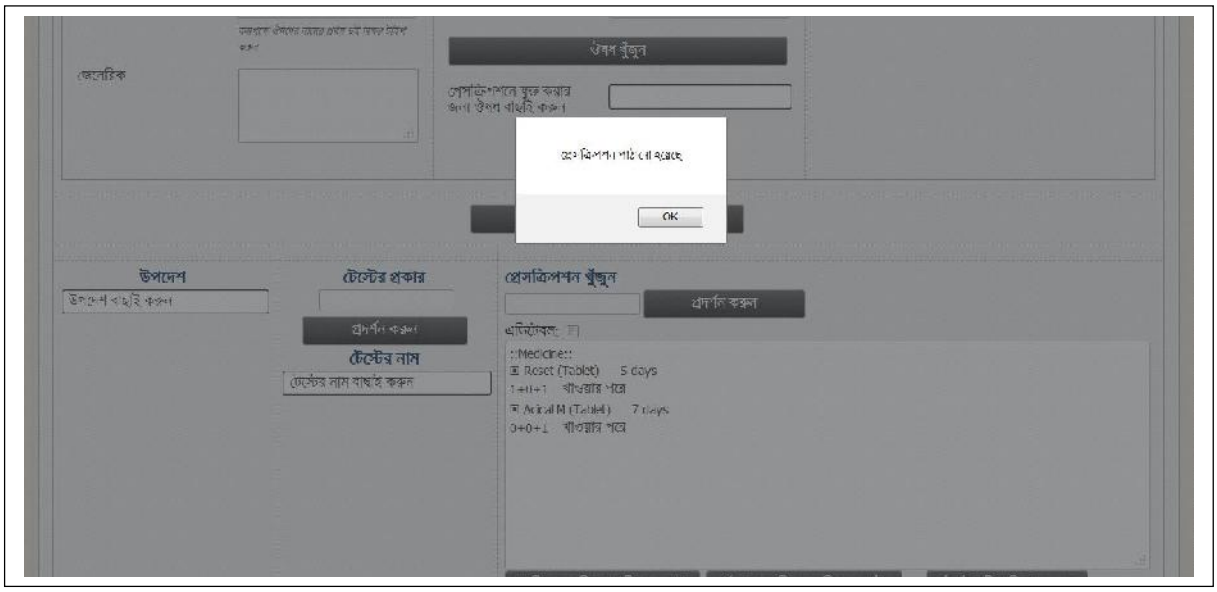


Figure 27: Confirmation Message for Sent Prescription

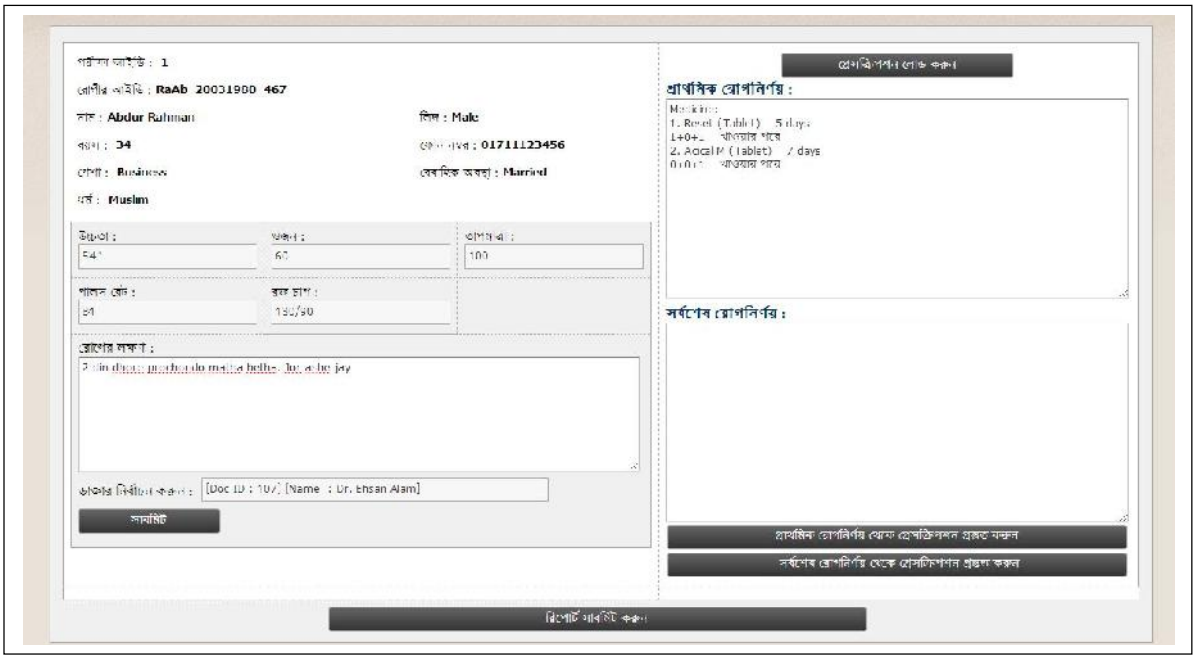


Figure 28: Prescription Is Available in Operator's End

Now the prescription is available in operator's end. Operator can load the prescription panel for seeing the prescription (Fig: 28)

For printing the prescription the operator will click the respective button. A new page will appear where a prescription will be prepared as a report (Fig: 29)

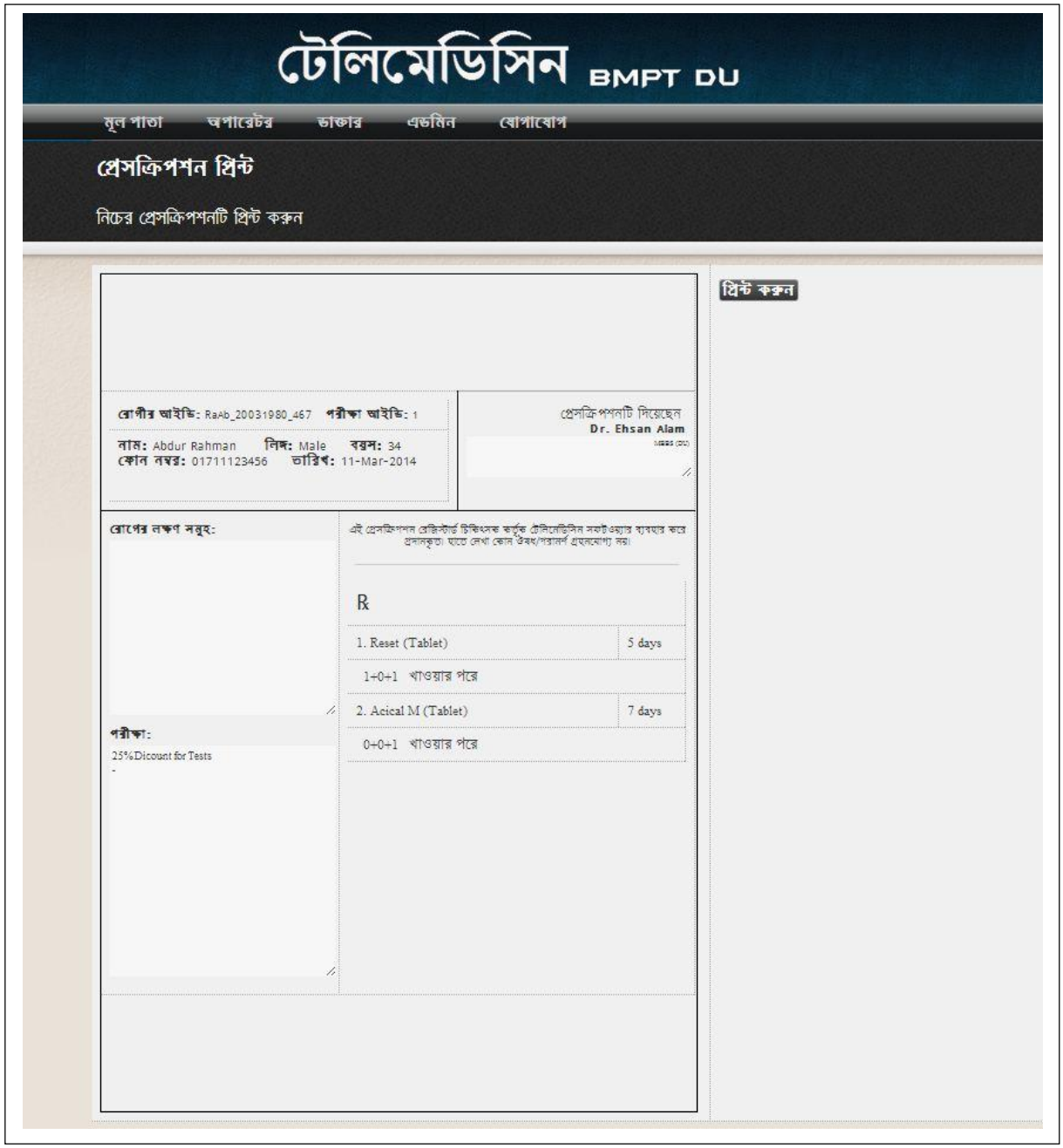


Figure 29: Print Prescription Page

After clicking the button for printing this prescription will be printed and provided to the patient. A scanned image of a printed prescription is given in Figure 30.

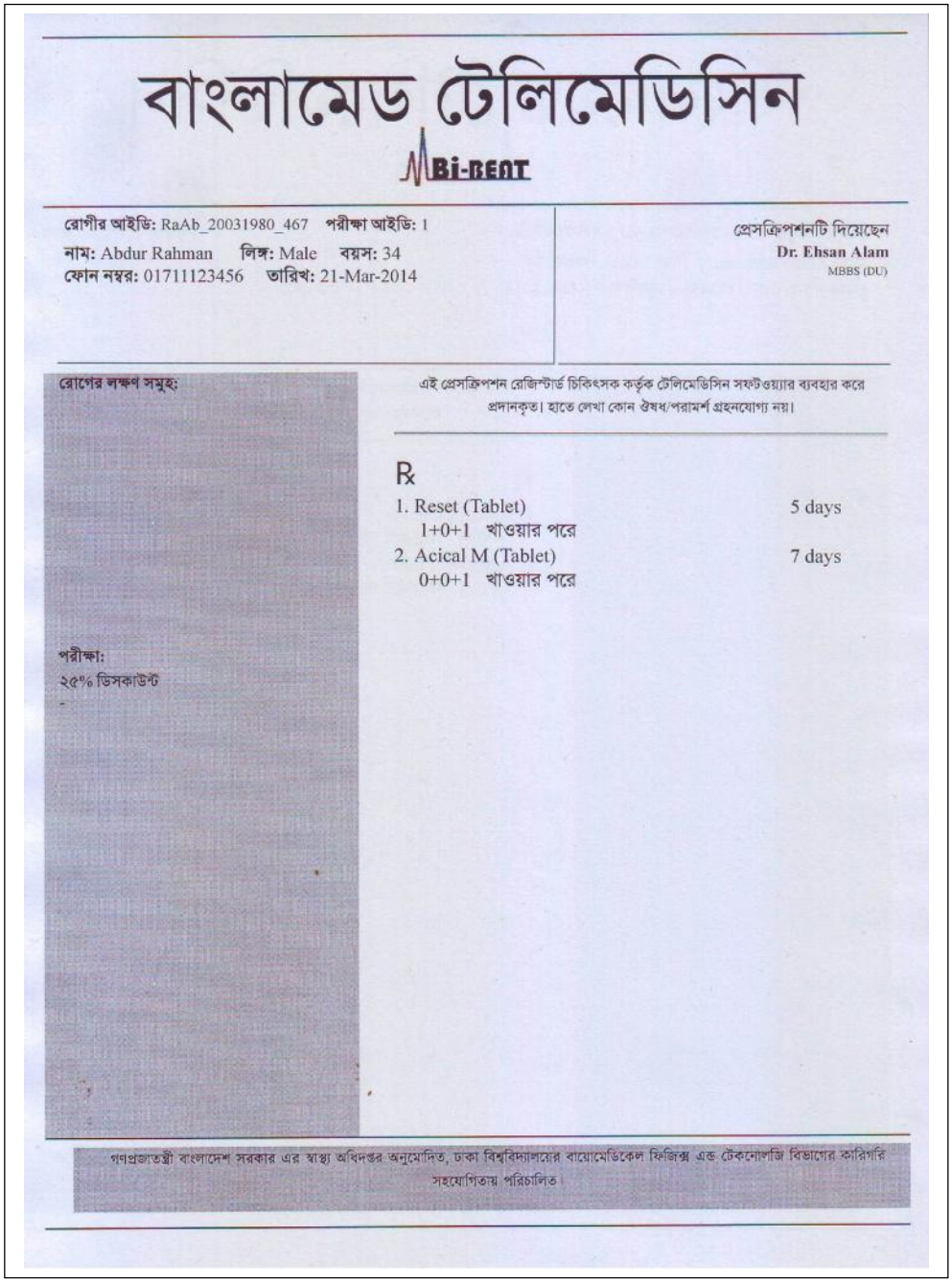


Figure 30: Scanned Image of a Printed Prescription

There are other options in this application which are related to web admin which are not illustrated here. An admin can add, delete, update medicine name, type generic etc. He/she can also add/delete/update test type and name, medicine dose, application. Surfing patient database option is also given in this application. Admin can see all patients' info. Operators and doctors can see the patients' info which is related with them.

The results of this work can be applied to any telemedicine system with appropriate modifications.

Chapter 5: Discussion

Providing health service to the citizen of our country has always been a challenge. It is quite hard for the people of rural areas of our country to get in touch with qualified physicians. It is possible to improve this situation using Information and Communication Technologies (ICTs) in health sector. We may not have sufficient number of doctors staying in rural areas due to various reasons but it is possible to take their services to the rural areas using appropriate telemedicine system. We tried to establish a system which will be best suited in socio-economic condition of our country. If we put our solution to this sector where not much effort has been given so far there is no doubt that it will boost up the health sector of Bangladesh. As mentioned before, some attempts are going on in telemedicine using video-conferencing only, or using expensive foreign equipment. It is possible to establish a system using foreign machines and software but a question lies there that are we capable of running that system for long time? Most foreign equipment are not suited to our environment and abnormal power supply conditions and are likely to go out of order frequently. Repairing such equipment remote from its country of manufacture also poses an almost impossible task, in view of the expenses involved. So we tried to find a solution which is easy to use, robust, sustainable and of course maintainable. Although some may have the notion that local equipment may not last long, but it is the other way round if it is designed by knowledgeable local experts. Our design will keep the local conditions in purview, so will last longer. Besides, repairs will be possible at much less cost since spares and expertise will be available locally. In the beginning we have started with 5 devices and appropriate software for those. Many medical devices are necessary but our department consulted with experts to choose the 5 mentioned. Some of them were developed from scratch while the others were improvised using easily available products and materials. We did not develop some common devices like thermometer, blood pressure meter as they are of low cost and easily available. Their data can be transferred easily by manual typing through telemedicine software.

While developing the User Interface of software Bangla language was chosen as it is our mother tongue. It will be easy for the operators of rural health care centers to operate the software if the

user interface is developed in their native language. The software was developed in English as well. So we have two versions of same software.

Java programming language was chosen for developing ECG software. One of the main reasons behind choosing Java programming language is NetBeans Integrated Development Environment (IDE). IDE is software application through which anyone can write and debug programs. NetBeans is a free and open source IDE for developing software in Java programming language. Actually it is not a big deal to choose a specific programming language. It mainly depends on the how a developer feels comfortable in that specific programming language. Basic of all programming language are almost same. So Java has been used it does not mean that C# couldn't be used.

The same reason applies for developing web based application. PHP was used for front end of the application and MySQL was used for back end i.e. database management. PHP and MySQL combo is very much popular in developing web based application. Most of the hosting providers support PHP and MySQL hosting so it was easy and reasonable for choosing PHP and MYSQL for developing web based application.

Software for ECG was developed first for the telemedicine system. At first transmission of data between computers were done using unique IP addresses. If two PCs have unique IP addresses then it was possible to transfer data between them. But we know that we don't get unique IP address from internet providers. A unique IP address is shared and divided into many private IP addresses and distributed between the users. For this reason in the beginning we had a plan to establish radio linked connection between the rural and expert centres, but the solution was not economically viable. So we had to find a solution that could be well suited in current infrastructure. To suite with existing solution we changed the transmission process of ECG data. Rather than using Real IP address we used Extensible Messaging and Presence Protocol (XMPP). Many IM clients use XMPP protocol. Any of them can be used. We choose instant messaging service of Google Talk for authentication and data transmission.

The next thing was developing a web based application for our telemedicine system. Developing a web based patient management system was pretty much straight forward. We worked with an NGO in building this web based application. Though patient management system development is straight forward but we took suggestions from the NGO as they will be the user of the system. We also kept it in our mind that we should develop a system which can be used by anyone not only the NGO we worked with. Implementing a system in real life is always crucial and challenging. Every system contains bugs. Feedback from the NGO was very much useful for solving the bugs contained in our system. After implementing the system in 3 rural centers connected with one urban center we solved some major bugs and made some alterations for making our system more user-friendly and robust. Working with such group has both positive and negative aspect. Sometime the NGO claimed something that is needed for them but will not be appropriate if we want to develop a system that will be well suited to any user. So after having some meetings and conversations we came to optimal solutions. The feedback from the users was very important in developing the final system. Working with them it was possible to establish a system and implement it in real world. The NGO mentioned already served almost 500 patients using our system which is a good achievement for both our groups.

We developed a system, but it is difficult to say that a system is complete. There is always room for improvement. We will like to incorporate more diagnostic devices with this telemedicine system. Based on importance more diagnostic devices will be incorporated with this system. At present different devices in our system use different operating software. Some of these use numerical time series data while some use image data as provided by the respective manufacturers. It would be best to develop a unified software in future for all devices rather than using different software for different devices. There are always scopes for making the software more user-friendly. It is always an ongoing process.

The existing system is based on personal computers which are quite well spread in Bangladesh. However, we can make our system portable and mobile by simply developing smart phone applications. Low cost smart phones and tablets are easily available in our country. So if we will develop smart phone application then it will be possible to provide door to door service.

We tried to develop robust and easy to use telemedicine system. We started our journey. We hope that one day whole Bangladesh will use our telemedicine system. We are not narrowing our system using it only in our country; we plan to translate the user interface into other language so that this system can be used in any part of the world.

Rooftop is not our limit. If we look above we will see sky. This is sky which is shared by every common people of the world. So our limit is the sky.

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