CHAPTER 7

DESIGN AND DEVELOPMENT OF A TELECARDIOLOGY FRAMEWORK FOR RURAL HEALTHCARE

7.1 INTRODUCTION

Telecardiology, a branch of telemedicine, benefits cardiac patients by enabling treatment from a distant place, either from home or from a rural medical centre. It helps cardiologists across the world to get connected and give consultations. Both cardiac patients and healthcare professionals can benefit from telecardiology (Hward et al 2001; Tsumoto 2003).

In many of the underdeveloped countries, majority of the population live in rural areas, where healthcare facilities are inefficient and inadequate. For example in India, over 80% of the main healthcare centres are located in the cities that host only 30% of the population (Sood and Bhatia 2005). This scenario reflects that only 20% of its quality healthcare facilities cater to almost 70% of the population. Hence, the rural population in general is more vulnerable than its urban counterpart. Telecardiology can therefore contribute substantially in bridging the urban-rural divide with respect to healthcare access.

7.2 LITERATURE SURVEY

The system proposed by Jose et al (2002) implements a framework that has a server providing access to remote users to advanced ECG signal processing techniques. The user can choose the signal processing technique
through his web browser window. The centralized structure of the system permits user-independent update and management of the software. In contrast to the above, Chao et al (2001) proposed a decentralized approach to reduce bottlenecks in large volume data transmission and communication between server and remote centres. This was achieved through mobile agents and Object Request Brokers which support the acquisition and filtering of ECG data at the remote sites. Mitra et al (2007) have proposed a system which uses a portable telecardiology kit at the patient site to transmit the patient’s ECG and other findings to a PC at the health centre using electromagnetic waves with a cordless phone. The PC processes the information and sends a report to the kit at the patient’s site. The distance is limited to 10km.

Even though the existing systems have certain merits and applications, they lack the involvement of expert cardiologists in the diagnostic process. The proposed web based system besides addressing this issue provides a cost effective scalable solution for bringing quality healthcare to the rural sector.

7.3 PROPOSED FRAMEWORK

The main objectives of the telecardiology framework development are (i) to build an interface which permits the physician at the rural centre to get connected to a centralized server via the internet and send locally acquired ECG files and (ii) to receive diagnosed results from expert cardiologists connected to the server via the internet. The structure of the proposed framework is shown in Figure 7.1.
Physicians at rural health centres, a centralized server and expert cardiologists constitute the framework. Personal details, clinical information and ECG acquired from a patient at the rural centre are sent to a centralized server. The server processes the ECG file to extract the lead measurements and the waveform data. The expert views the patient’s clinical information, lead measurements and ECG waveforms and submits his diagnosis for treatment. The server stores the diagnosed results and forwards the same to the respective rural centre. The physician at the rural centre can view the diagnosed results and recommendations from the expert and effect treatment.

### 7.3.1 XML-ECG File Format

Until recently, the native format for ECG files produced by the major cardiograph manufacturers has been binary files with compressed and encoded waveform data. The compression and encoding schemes were not published and easy access to the ECG waveform data by researchers and clinicians was not possible (Helfenbein and Zhou 2004). To promote the concept of open ECG format for ease of use by researches and support interoperability between devices, Philips introduced the XML ECG format in their electrocardiographs (Helfenbein and Zhou 2004; Zhou and Helfenbein 2004). XML is a W3C-endorsed standard for document markup. It is a non
presentable, data representation language. It defines a generic syntax used to mark up data with simple, human-readable tags. XML document files are essentially tree-like structures containing labelled or “tagged” elements. Both the tags and the data elements are strings of text. Hence, readily available text editors and web browsers can be used to view the data in XML documents. To parse data contained in XML documents, a variety of software libraries are available in C, C++, C#, Perl and Java programming languages. In this work, Java is used for the extraction of data from the XML file.

7.3.2 **Scalable Vector Graphics for ECG Display**

To view ECG data in a graphical format, Scalable Vector Graphics (SVG), the XML-based graphics language, is used. SVG, standardized by the W3C, is a powerful and flexible XML application language, ideally suited for display of two-dimensional graphics on a variety of display devices. Data in an XML document can be readily transformed into an SVG XML document. This document can be rendered onto a display by opening it with an SVG plug-in installed in the web browser (Helfenbein and Zhou 2004). Adobe’s SVG plug-in for Microsoft’s Internet Explorer is used in this work.

7.4 **IMPLEMENTATION**

7.4.1 **Graphical User Interface**

The graphical user interface on the web page provides the access for the user to upload and send the ECG file to the expert. The interface has been simplified for the user to navigate through the website. Various navigation tabs such as User, Expert, Contact Us, About US and Help are provided in the home page as shown in Figure 7.2.
7.4.2 User Authentication

To prevent unauthorized use, access to the system is restricted to authorized users (physician and expert) who have a login and password defined in the server. All actions including login and log out are maintained in the database. The Message Digest (MD5) algorithm, intended for digital signature applications, is used to generate a digital signature. The passwords for physician and expert are maintained in the database in the form of digital signatures. This algorithm takes a message of any arbitrary length as input and produces a 128-bit message digest of the input. MD5 algorithm is considered to be very safe since it is an irreversible algorithm. An MD5 hash is typically expressed as 32-digit hexadecimal number. MD5 is used in a wide variety of applications, and is also used to check the integrity of files (Rivest
Hence, this algorithm has been chosen. A second level of authentication has been provided through entry of the area code by the client. The login, password and area code are entered in the User login page.

7.4.3 ECG File Transfer

After authentication, the user is permitted to upload the patient’s ECG file. A File browser dialog box is presented to the user to select a patient’s ECG file. A click on the submit button, shown in Figure 7.3, transfers the file to the server. Here the store and forward type of ECG transmission is employed (Alvaro 2006). A confirmation message is displayed to inform the user that the file has been received in the server.

Figure 7.3 Screenshot of patient’s ECG file upload page
7.4.4 Processing Techniques

The XML ECG file consists of two parts. The first part contains the patient’s personal details and numerical values of wave features of different leads along with tags providing the information to what each value denotes. The second part contains the compressed and encoded form of the ECG that should be used to display the ECG waveform. The XML ECG file is processed in the server by software written in Java. The numerical values of the lead measurements in the XML ECG file are extracted in the server. A Java applet which can be embedded in the web browser is used for this purpose. The applet displays the extracted details in the form of a table that can be easily interpreted by the expert. A screenshot of the extracted lead measurements of lead aVR from an XML ECG file is shown in Figure 7.4.

![Patient Information]

Figure 7.4 Screenshot of lead measurements of aVR lead
The Philips XML to SVG converter software, downloaded from Philips website (Philips 2004), is used to convert XML ECG files to XML SVG files, which could then be used to view ECG waveforms on any PC with a SVG plug-in enabled web browser (Helfenbein and Zhou 2004). This SVG converter is placed in the server. A screenshot of a patient’s ECG displayed by the system is shown in Figure 7.5.

![ECG Waveform Screenshot](image)

**Figure 7.5 Screenshot of a patient’s ECG waveforms**

### 7.4.5 Expert Diagnosis

For diagnosis, an expert has to login with username and password. A welcome page permits the expert to select a patient’s XML file and view
the details of the patient. From the patient details page, Figure 7.6, the expert can either view the numerical values of the ECG or view the patient’s ECG waveforms.

![Screenshot of Patient Details page](image)

**Figure 7.6 Screenshot of Patient Details page**

The expert is also provided with a text area to enter his diagnosis and recommendations for treatment and submit by clicking the send report button as shown in Figure 7.7. The submitted report is encrypted using the AES (Advance Encryption Standard) algorithm and transmitted. At the rural centre, when the user wishes to view the results, this report is decoded and displayed.
SUMMARY

The design and development of a web based telecardiology framework for diagnosing cardiac patients in the rural areas was presented in this chapter. This framework facilitates patient diagnosis by an expert via the internet, in a centralized way, without the need to run programs on the local stations. The physician in the rural hospital needs to have only a PC with a web browser installed and a network connection. The developed framework, in addition to providing patient’s personal, clinical and ECG lead information permits the expert to view the ECG waveforms facilitating conventional diagnosis. Any portion on the waveform can be zoomed for a detailed view.
Further, patients’ diagnostic results are stored in the server which can later be retrieved at the rural centre for reference.

The system was configured both in the LAN and in the internet environments and found to work satisfactorily. The system was demonstrated to cardiologists who commended the work stating that this is a useful contribution to the field of medicine. Implementation of this framework by hospitals with rural centres can change the way healthcare is delivered in cardiology for rural patients.