Implementation of a Web-Based Wireless ECG Measuring and Recording System

Onder Yakut, Serdar Solak, Emine Dogru Bolat

***Abstract*—**Measuring the Electrocardiogram (ECG) signal is an essential process for the diagnosis of the heart diseases. The ECG signal has the information of the degree of how much the heart performs its functions. In medical diagnosis and treatment systems, Decision Support Systems processing the ECG signal are being developed for the use of clinicians while medical examination. In this study, a modular wireless ECG (WECG) measuring and recording system using a single board computer and e-Health sensor platform is developed. In this designed modular system, after the ECG signal is taken from the body surface by the electrodes first, it is filtered and converted to digital form. Then, it is recorded to the health database using Wi-Fi communication technology. The real time access of the ECG data is provided through the internet utilizing the developed web interface.

***Keywords*—**ECG, e-health sensor shield, raspberry Pi, wifi technology.

I. Introduction

ONE of the most common reasons of sudden death events is heart diseases. For the diagnosis, following-up and avoiding the heart diseases, medical devices have been developed by the engineers. The ECG is a physiological signal resulting from the electrical activity of the heart and measured by the electrodes from the body surface. Electrocardiograph is a device used to measure and motorize the ECG signal. ECG devices are utilized to get information about the physiological situation of the heart measuring the electrical activity produced by the heart via the electrodes placed to the body surface non-invasively.

In literature survey, several e-Health applications are encountered and summarized here. Baccar et al. presented a web based e-Health application serving various functions by using technological developments [1]. Shen et al. suggested an e-health monitoring system having minimum service delay and privacy preservation using geo-distributed clouds [2]. Alnosayan et al. developed a telehealth system named as MyHeart completing the discontinuity in the Congestive Heart Failure care duration while transporting the patient from hospital to the home [3]. Mukherjee et al. proposed a tele-monitoring system, developing a series of modules providing the doctors to ease the diagnosis [4]. Gjoreski et al. suggested a telehealth system using ECG sensor and accelerometer, recognizing user's activities and detecting falls utilizing the accelerometer data [5]. Maurya et al. presented a solution to health problems developing a wireless health monitoring system based on machine to machine (M2M) communication [6]. Gaxiola-Sosa et al. proposed a portable 12-lead ECG wireless medical system for the purpose of monitoring the cardiac-activity of the patients [7]. Yakut et al. developed an ECG measuring system using e-Health Sensor Shield and obtained the Heart Rate Variability (HRV) parameter utilizing the Pan-Tompkins QRS detection algorithm [8].

In this study, a modular WECG measuring and recording system is developed employing a single board computer and e-Health sensor shield. Real time ECG data is recorded to the health database using internet technologies. Real time monitoring of recorded data is provided by the use of developed web-based interface which communicates via the web services.

II. Hardware Infrastructure of WECG Measuring and Recording System

The basic components of the developed WECG measuring and recording system are shown in Fig. 1. A single board computer, a connection bridge and an e-health sensor shield are used as in the previous study [8]. The Raspberry Pi, developed by the Raspberry Pi Foundation from United Kingdom, is used as a single board computer [9]. Since the e-Health sensor shield is developed as compatible with Arduino, a Connection Bridge card is required for adapting the e-Health sensor shield to the Raspberry Pi. This card has technical specifications including 8 digital pins, wireless module, Rx/Tx pins, I2C pins, 8 channel analog/digital converters, an external power supply pin [10]. e-Health sensor shield developed by Cooking Hacks is used to measure the ECG signal taken from the body. This card is designed for biomedical researches to get various physiological data. It is connected to the Raspberry Pi via the Connection Bridge card. The Raspberry Pi takes and processes the data from the e-Health sensor shield [11]. More detail information about these three components can be found in [8].

III. Software Architecture

In the developed WECG measuring and recording system, Raspbian operating system is installed on the Raspberry Pi. An object oriented socket program is written in C++ programming language to get the ECG data from the e-Health Sensor Shield. This program is accessed by using web

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services and the patient registry. The ECG data are recorded to the PostgreSQL database. The web based interface is prepared employing PHP web programming language. Web technologies such as jQuery [12], Ajax and HighCharts [13] are utilized to improve the interactivity between users and the web interface. Therefore, a dynamic, flexible, easy to use and user friendly web interface is designed.

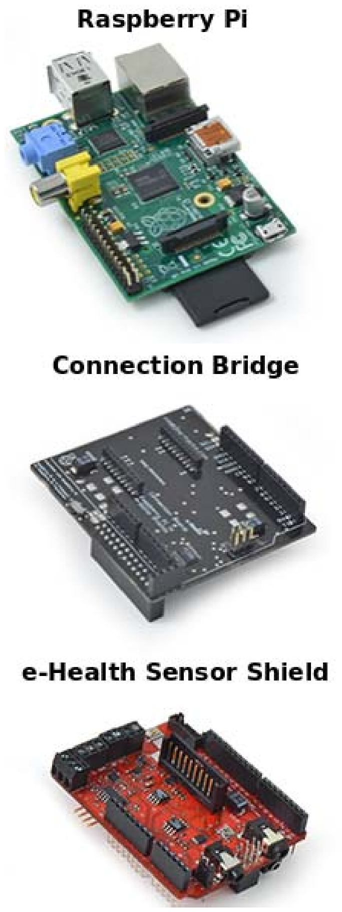

Fig. 1 The basic components of developed system [8]

IV. The WECG Measuring and Recording System

The block diagram of developed WECG measuring and recording system is given in Fig. 2. In this figure analog ECG signal, taken via the electrodes located on the patient's body, is transmitted to the e-Health Sensor Shield (e-HSS) used as an ECG instrumentation circuit. The analog ECG signal taken from the patient is amplified, filtered and converted to the digital form by the e-HSS ECG instrumentation circuit.

Raspbian OS is running on the Raspberry Pi. The screen output of the e-HSS socket program is shown in Fig. 3. Real time ECG data in digital form is taken from e-HSS using a C++ based object oriented socket program. Then, it can be recorded to the local or remote database or cloud platform. In this study, real time ECG data is stored to the PostgreSQL, remote database server. The e-HSS can perform its wireless internet communication via the WiFi access point.

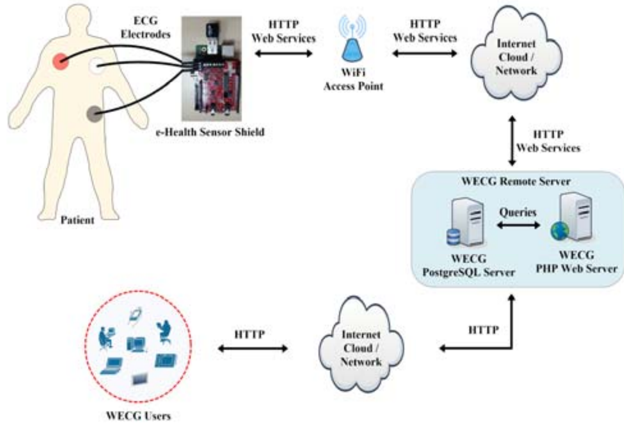

Fig. 2 The block diagram of the WECG measuring and recording system

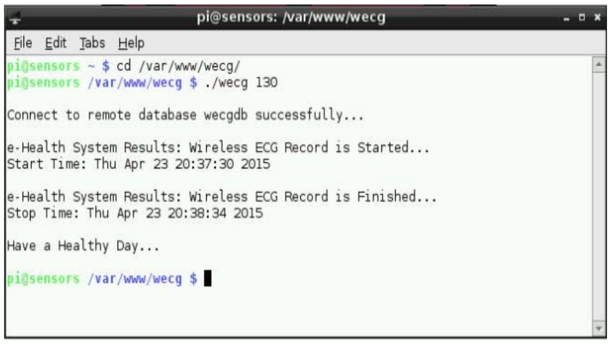

Fig. 3 The screen output of the e-HSS socket program

Web service which is developed using PHP web programming language, evaluates Remote Procedure Call (RPC) requests, realizes the related processes and returns the results of the RPC requests as response. The ECG data obtained from the e-HSS is accessed and taken by the developed socket program and real timely stored to the PostgreSQL database in the WECG Remote Server. The web server provides the communication with the developed socket program activating it and organizes the results and provides feedback when the ECG recording ends. For real time monitorizing the ECG data using the developed web-based interface, the PHP web server runs on the WECG Remote Server. Clinicians can access to the WECG measuring and recording system with their user name and passwords through a desktop PC, a laptop, a smart phone or a tablet having an internet connection. They can register the patient to the system, monitorize the real time ECG data, store it to the database, and analyze reaching the old ECG recordings.

The flowchart of the WECG measuring and recording system is presented in Fig. 4. When a clinician logs in the system with his/her user name and password, he/she has two main paths to follow and these paths are grouped in two different colors in Fig. 4. The clinician locates three electrodes to the patient's body according to the Einthoven triangle, registers the patient's information to the system and starts the ECG recording. The real time graph of the ECG recording is plotted on the web interface. The ECG recording is limited in one minute for experimental studies in this study. It ends in one minute and the results of the e-HSS are shown on the web page.

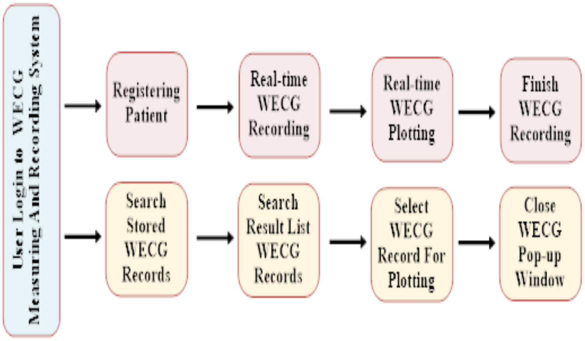

Fig. 4 The flowchart of the WECG measuring and recording system web interface

When the clinician wants to analyze new or old ECG data, he/she can search it using the patient's name and file number on the WECG PostgreSQL Server. The ECG results of the patient are listed in detail. The clinician selects the desired ECG recording according to the recording date and plots the ECG data on the web interface.

V. Web-Based Interface Designed for WECG Measuring and Recording System

The web pages of web interface developed for WECG measuring and recording system are introduced in this section. The web interface is designed in a dynamic PHP based structure that providing easy for use. Visual and structural novelties are gained to the web interface using jQuery framework. Therefore, the interactivity between the user and web interface is increased to a high level. The web interface gets the user, patient information and ECG data connecting to the PostgreSQL database management system using relational database model and SQL language in its structure.

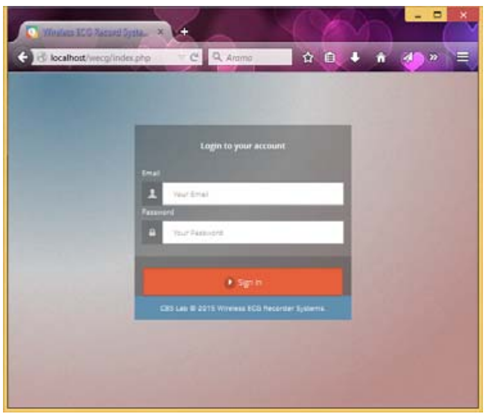

Fig. 5 The login page of the WECG web interface

The login page of the WECG measuring and recording system, which the clinicians use for signing in with their user name and passwords, is shown in Fig. 5.

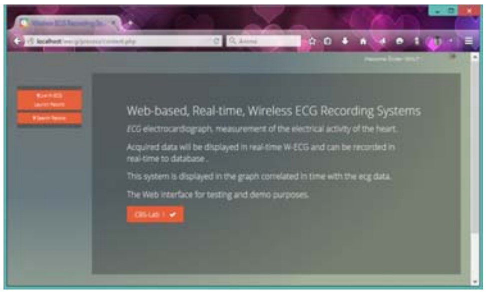

Fig. 6 The welcome page of the WECG web interface

After the clinicians sign in the WECG measuring and recording system web interface, they meet the welcome page given in Fig. 6.

The clinicians click the button "Live WECG Launch Record" for starting the wireless ECG recording after they locate the ECG electrodes to the appropriate places on the patient's body. Then they enter the patient's information to the dialog page shown in Fig. 7 and click "Save Changes & Record" button to register the patient's information and start the ECG recording. Real time ECG graph is plotted and shown with the patient's information on the same web page together as illustrated in Fig. 8.

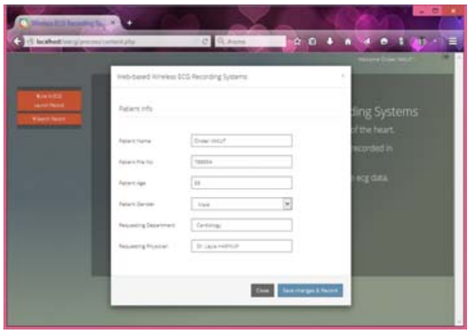

Fig. 7 The patient registration page of the WECG web interface

Fig. 8 The real time patient ECG recording page of WECG web interface

After the wireless ECG recording ends, the real time ECG graph stops being plotted. The information about the ECG recording which e-HSS socket program returns is shown on the web page as seen in Fig. 9. The system is ready for use to measure and record the wireless ECG data at any moment.

The clinician can search new or old ECG recording of a patient on the database by clicking the “Search Record” button. The used search page is seen in Fig. 10. The clinician can access the stored ECG recordings of the patient as a list by searching with the patient’s name, surname and file number. He/She can plot his/her desired ECG recording as a pop-up window which is illustrated in Fig. 11 by clicking the “Plot ECG Record” button. Furthermore, she/he can also plot more other recordings in new pop-up windows for comparison.

Fig. 9 The result page of the socket program after the system stops real time ECG recording

Fig. 10 Search result list of the WECG web interface

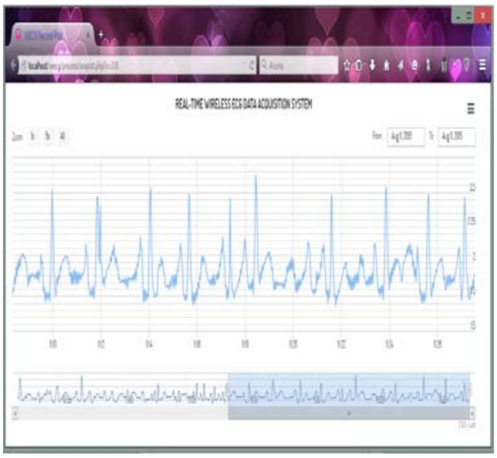

Fig. 11 The plotted pop-up window of the searched ECG recording

VI. Conclusion

In this study, a web-based wireless ECG measuring and recording system is realized. The developed system has a modular structure including both hardware and software sections. This designed system as an e-health application is ready for use including the specifications of being portable, compact, easy to use, user friendly and real time. With this study, it is aimed to support the clinicians while diagnosing, treating and following up the patients. In future studies, it is planned to design a decision support system used for automatic diagnosis of the heart diseases by processing the recorded ECG data.

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