Measuring ECG Signal Using e-Health Sensor Platform

Onder Yakut, Serdar Solak, and Emine Dogru Bolat

***Abstract*—**Cardiovascular diseases have a very vital importance in human being's life. Thus, measuring and processing the Electrocardiogram (ECG) signal has been a popular subject for years. In this study, physiological ECG data is measured using a single board computer card and e-health sensor platform. The e-Health Sensor Platform communicates with the single board computer, Raspberry Pi. ECG data is measured and saved as a text file to the SD-card of the Raspberry Pi. Then, this saved text file is transferred to Matlab in the computer environment. The ECG data is then processed to find the Heart Rate (HR) and Heart Rate Variability (HRV) which is used to diagnose some vital diseases. This study is the first step of patient monitoring system which we will realize in future studies.

***Keywords*—**ECG signal, Raspberry Pi, e-health sensor platform.

I. Introduction

The cardiovascular mortality is increasing with the stressful living conditions in modern hard life. Thus, measuring and monitoring the ECG signal have a vital role for the people having cardiovascular diseases. The improvements in the informatics and the communication technologies influence the medical field recently. The e-health monitoring systems obtain the continuous invasive or non-invasive physiologic data through the electrodes or sensors. This data is taken and processed for the purpose of diagnosis, treatment or both. Thus, interactive relation between the doctor and the patient or between the patient and the hospital is minimized and the patient can be monitored and followed up during his/her daily life. The doctor, the patient's relative or nurse can have the chance to observe the patient's state of health continuously. Numerous studies about this subject can be encountered in literature. Palaniappan introduces and defines the biological signals in reference [1]. So-In et al. explain the design of a continuous monitoring system measuring the ECG signal with RF (bluetooth) transmission. In addition, the mobile phone application is realized for the signal transmission [2]. Magaña-Espinoza et al. implement a wireless sensor network based home care monitoring system for following up the heart rate of the old patients. The system warns the related people in case of dangerous falls in heart rate [3]. Lee et al. develop a mobile health monitoring unit application [4]. Ghorbani et al. propose the Personal Health Service Framework (PHSF), an open architecture for developing patient-centric health applications and monitoring systems [5]. García-Sánchez et al. present a mobile gateway design providing an independent life and e-health support [6]. Orha et al. suggest a system recording the basic physiological data of the human body [7]. Philipp et al. introduce an FPGA based wireless signal processing platform for biomedical applications [8].

In this study, measuring the vital signal, ECG using e-health sensor platform is realized for the first step of the e-health monitoring system which will be realized in future studies. The single board computer, Raspberry Pi and connection bridge board are also used together with the e-health sensor shield. The measured ECG signal is transferred to the computer and processed in Matlab environment to find the HR and HRV which is an important marker of used in several other fields, such as sports science and ergonomics [9].

II. Components of The System

The system for measuring ECG signal includes e-health sensor shield, connection bridge and Raspberry Pi single board computer. The data taken using e-health sensor shield and Raspberry Pi is transferred to the computer. The basic components used to get the ECG data are given in Fig. 1.



Fig. 1 The basic components used to get the ECG data [10]

A. Raspberry Pi Single Board Computer

Single board computers are the devices commonly used in

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biomedical applications recently. These kinds of computers are generally used to take the necessary biomedical data via the various sensors and transfer this data to the data processor environment by wire or wireless. BeagleBoard-xM, PandaBoard, Raspberry-pi are various single board computers. In this study, Raspberry Pi [11], [12] is preferred for being compatible with the e-health sensor shield.

The Raspberry Pi is produced in the UK by the Raspberry Pi Foundation for teaching basic computer science in schools [11]. The Raspberry Pi hardware specifications are illustrated in TABLE I.

TABLE I [11]
RASPBERRY PI SPECIFICATIONS

CPU	700 MHz ARM11
Memory	SDRAM 256 MB (Model A) - 512 MB (Model B)
Storage	SD Card
Size	85.60 mm × 56 mm
Weight	45 g
USB Port	1 (Model A) – 2 (Model B)
Network	10/100 Mbit/s Ethernet
Power	5 V 1A via Micro USB
Video Input	15-pin MIPI camera interface (CSI) connector
Video Output	HDMI, raw LCD Panels via DSI

The Raspberry Pi uses operating systems having Linux core structure. The operating systems such as Archlinux ARM, OpenELEC, RISC OS, Raspbian, FreeBSD, NetBSD are the operating systems utilized in the Raspberry Pi. In this study, Raspbian operating system which is compatible with the e-health sensor shield is running on the Raspberry Pi.

B. Connection Bridge

Connection Bridge is a special card designed for a communication between Raspberry Pi and e-health sensor shield. This card is placed to the pins on the Raspberry Pi. The connection between e-health sensor shield and Raspberry Pi is provided by locating the e-health sensor shield to the pins on the connection bridge [13].

C. e-Health Sensor Shield

e-health sensor shield is designed for biomedical researches by Cooking Hacks. It is compatible with Raspberry Pi, Arduino and Intel Galileo boards. The medical data such as ECG, EMG, airflow, glucose, blood pressure, body position, pulse and oxygen, body temperature, galvanic skin response can be measured using e-health sensor shield and related sensors. This card is generally used together with the Raspberry Pi or Arduino [14]. In addition, wi-fi, 3G, GPRS, bluetooth, 802.15.4 and ZigBee support is also provided using extra boards [15]. Thus, the patients can me monitored by transferring their medical data to the network environment.

III. THE ELECTROCARDIOGRAM (ECG) SIGNAL

The heart is an organ providing systole by producing electrical signal periodically. ECG shows the bioelectrical and biomechanical activities of the heart. Fig. 2 illustrates the ECG waveform. The ECG signal includes the waves named as PQRST at each heart beat as given in Fig. 2 [1].

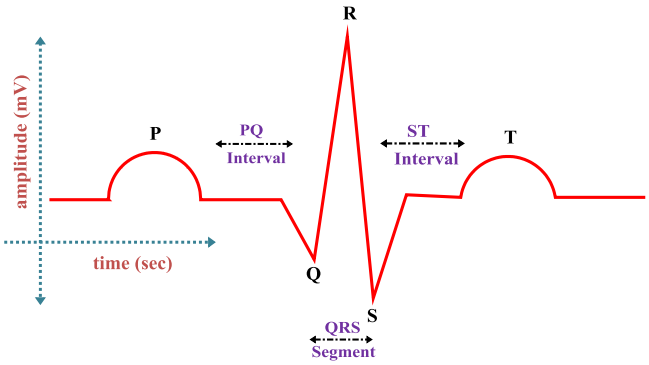

Fig. 2 The ECG waveform [1]

The ECG signal is measured through the electrodes placed on the particular areas of the body. Einthoven's triangle used for the placement of the electrodes is given in Fig. 3 [1].

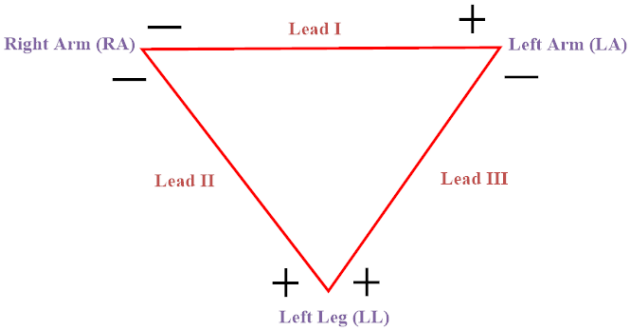

Fig. 3 Einthoven's triangle [1]

The electrodes are located on the right arm, left arm and the leg. Lead I is the potential difference between left and right arms, Lead II is the potential difference between right arm and left leg and Lead III is the potential difference between left arm and the leg in Einthoven's triangle. Left Arm (LA), Right Arm (RA) and Left Leg (LL) are used for the calculation of the potential difference between the electrodes in equations (1), (2) and (3) [1];

$$\text{Lead I} = V_{LA} - V_{RA} \quad (1)$$

$$\text{Lead II} = V_{LL} - V_{RA} \quad (2)$$

$$\text{Lead III} = V_{LL} - V_{LA} \quad (3)$$

IV. HEART RATE AND HEART RATE VARIABILITY

HR is the rate of occurrence of cardiac beats per minute. The HRV is defined as the temporal variation between sequences of consecutive heartbeat intervals. The R–R interval is described as the period between two adjacent R waves [9]. R-R interval is given in Fig. 4.

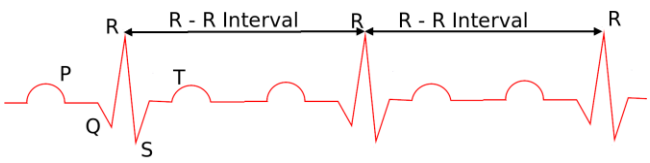

Fig. 4 R–R interval between two adjacent R waves [9]

R-R analysis is used autonomic neuropathy diagnosis for diabetic patients. HRV analysis has been utilized in several diseases such as hypertension, cardiac insufficiency, heart transplantation, angina pectoris, arrhythmias, brain death, sleep apnea, head injuries [16].

V. Pan & Tompkins QRS Detection Algorithm

Pan-Tompkins Algorithm is a real-time algorithm used for detection of the QRS complexes of the ECG signals [17]. The block diagram of the algorithm steps is illustrated in Fig. 5. This algorithm is based on the digital analyses of slopes, amplitude, and width. The ECG signal is passed through a special digital band-pass filter composed of one high-pass and one low-pass filter to lessen the noise. Afterwards, the filtered signal is passed through the derivative block to obtain the slope of the ECG signal followed by squaring and window integration processes. Then, the threshold is used to increase the detection sensitivity. [17], [18].

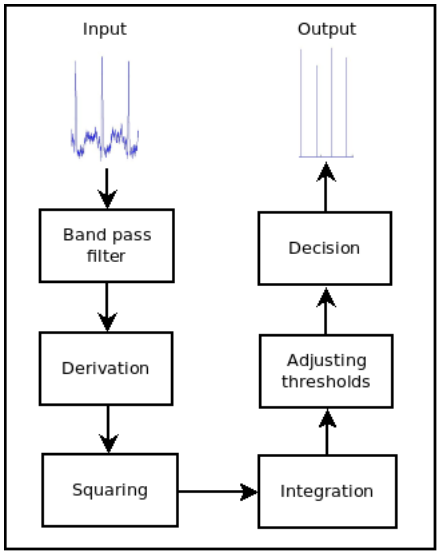

Fig. 5 the block diagram of the Pan & Tompkins algorithm [18]

VI. Measuring The Ecg Signal

In this study, e-health sensor shield is connected to the Raspberry Pi via the connection bridge board. The Raspbian operating system runs on the Raspberry Pi single board computer. C or C++ programming language is used to get the ECG data through the e-health sensor shield.

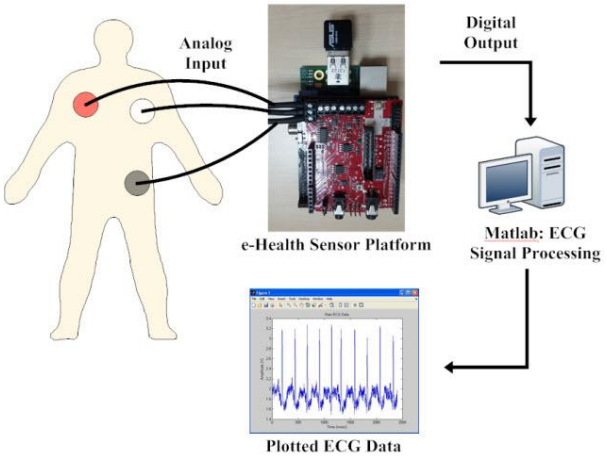

Fig. 6 The block diagram of the ECG measuring system

In this ECG measuring system, the electrodes are placed on the patient as seen in Fig. 6. In this Fig., the electrode placement corresponds to Lead I in the Einthoven's triangle. The ECG signal taken from the patient by the electrodes is transferred to the e-health sensor shield. e-health sensor shield amplifies, filters and converts the analog ECG data to the digital form. The digital ECG data is taken by the code written in C++ programming language running on the Raspbian operating system installed on the Raspberry Pi. This taken data is saved as text file and this text file is transferred to the Matlab environment running on the computer. The Matlab environment enables us to process the ECG data.

VII. Obtained Results

The ECG signal is measured through e-health sensor shield and Raspberry Pi and transferred to the Matlab environment. The measured raw ECG signal is shown in Fig. 7.

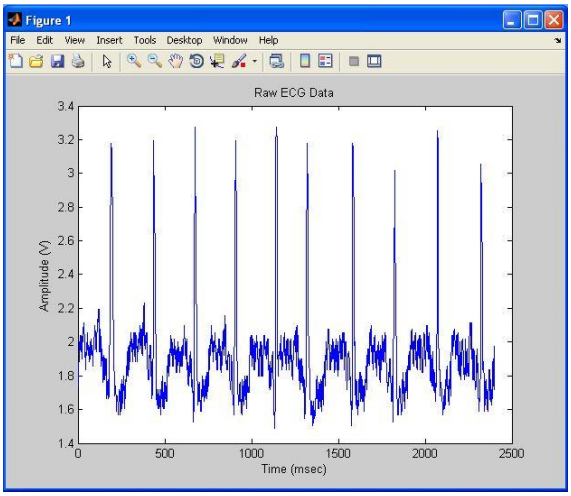

Fig. 7 Plotted raw ECG signal measured from the patient

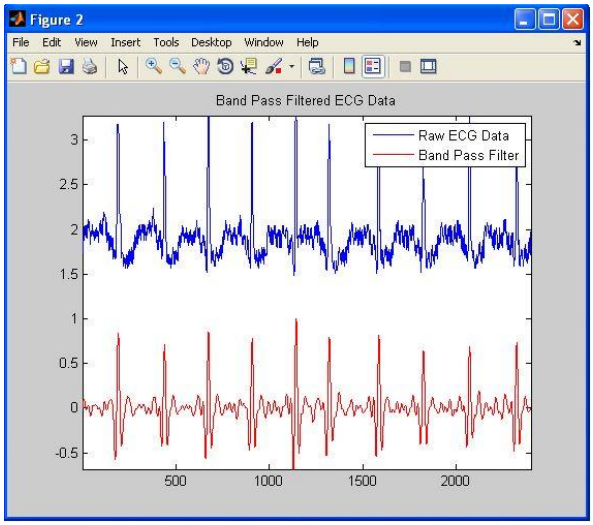

Fig. 8 Band-pass filtered ECG signal

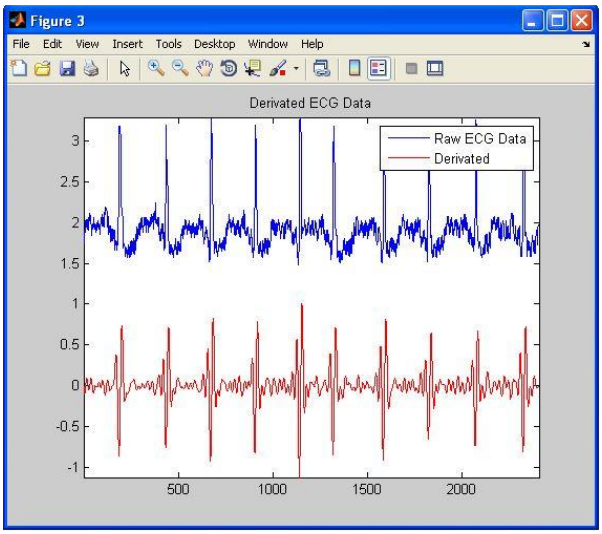

Fig. 9 The output ECG signal of the derivative block

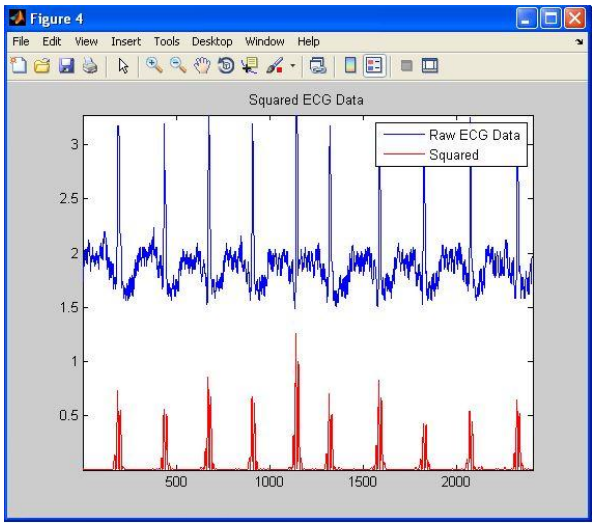

Fig. 10 Squared ECG signal

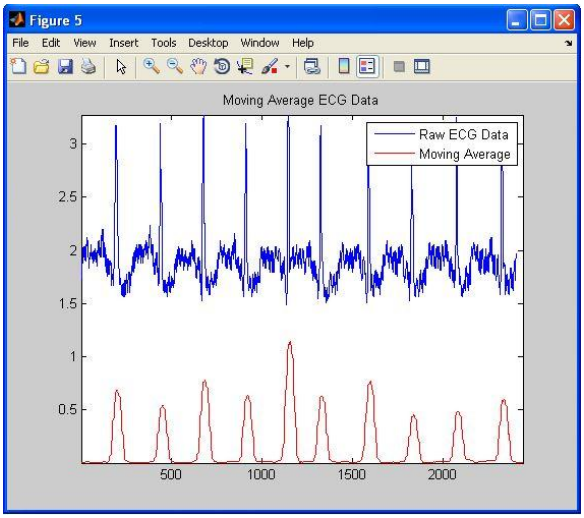

Fig. 11 Raw ECG signal versus the output signal of the integration block

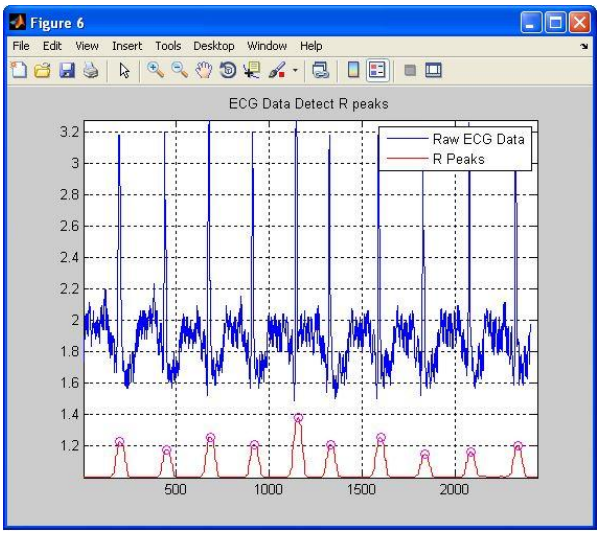

Fig. 12 Raw ECG signal versus the detected R peaks

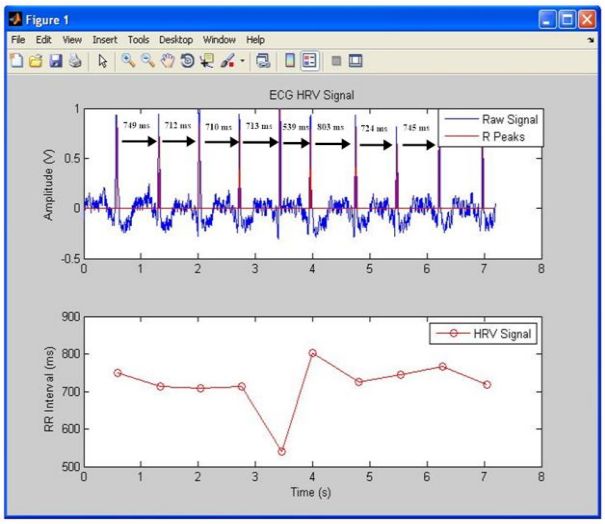

Fig. 13 Raw ECG signal versus the detected R peaks and the HRV signal

The measured ECG signal is processed to get the R peaks and the HRV values using the Pan-Tompkins QRS detection Algorithm. The ECG signal is processed step by step using the block diagram given in Fig. 5. The first step is passing the raw ECG data through the band-pass filter to reduce the noise. The output of the band-pass filtered ECG data is seen in Fig. 8. This filtered ECG data is applied to the derivation block to get the slope of the signal. The output signal of the derivation block is shown in Fig. 9. Then the signal is squared as depicted in Fig. 10. Fig. 11 illustrates the output of the integration process. Fig. 12 shows the detected R peaks. Finally, Fig. 13 gives the HRV values, the graph of the R-R interval.

VIII. Conclusion

In this paper, the ECG signal is measured using e-health sensor shield with the Raspberry Pi, single board computer. The measured ECG data is taken to the computer and processed to obtain the HRV values in Matlab environment. The Pan-Tompkins QRS detection algorithm is used to find the HRV. And satisfactory results are obtained as seen figures above. In this study the ECG signal is both measured and processed in Matlab. Web based patient monitoring system using this infrastructure is planned in future studies.

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