Application of Support Vector Machine Classifier on Developed Wireless ECG System

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***Abstract*—The Electrocardiogram (ECG) is a principal diagnostic instrument used to measure and record the electrical activity of the heart. The heart conditions can be detected and evaluated when the recorded ECG signals is available. The normally ECG used for monitoring and diagnosis at present hospital is expensive and stationary. With the recent advance in technology, there are possibilities to create a small sized wireless ECG system capable of processing, transmitting, and viewing ECG signal via Bluetooth technology through a smart phone to internet at low cost and at low power. In this work a small sized wireless ECG embedded system is developed to make the patient more mobile without losing the reliability of the ECG sensor. It consists of an amplifier, filtering, microcontroller, Bluetooth Technology and anroid as a platform for wireless transmission. The transmitted data is processed in the microcontroller and graphically displayed in the website.**

***Index Terms*—electrocardiogram, real time, monitoring, signal processing**

I. Introduction

In the 1856, Kolliker and Muell found that the heart generated electricity. Starting in 1903 with the invention of the electrocardiograph (ECG) by the Danish Willem Einthoven and continuing to our days with the most complex equipments. Regularly, the heart activity is very important to measure in a clinical setting using an ECG. However, the ECGs that exists today require several wired probes placed in direct contact with the skin. This requires irritating adhesives, conductive gels, and may require special treatments such as shaving the chest of the patient. Because of these factors, the existing ECGs are typically stationary devices and are not suited for long term monitoring. It is important, however, to continually monitor the heart signal of patients at risk of cardiovascular arrhythmia or other heart diseases. An ideal solution would involve a durable portable system that could be used by a patient without assistance and with a minimum of training.

The researcher of medical instruments applied in hospitals such as monitoring, diagnosis, and treatment are increasingly turning to wireless technologies, which can significantly improve the mobility and comfort of patients. Furthermore, telemedicine and remote monitoring of patients physiological data are issues that have received increasing attention in recent years. Some of the physiological signals are ECG which can be used to monitoring heart activity, an electromyogram (EMG) for monitoring muscle activity and an electroencephalogram (EEG) for monitoring brain electrical activity [1]-[8]. Among these physiological signal, ECG and heart rate are the most important to be measured. World Health Organization estimated revealed that each year more than 16 million people around the world died of cardiovascular [9]-[12].

There have been numerous attempts to develop a wireless ECG monitoring system where the patient being examined is to be free of wires. Till now this has not been available in the market. Moreover, several challenging issues still need to be improved such as how to guarantee the quality of service required for life-critical applications [13]. One of promising opportunity for wireless technologies in medical telemetry is telecardiology, which involves the transmission of ECG signals [14]-[16]. Heart function can be measured by ECG sensors worn by a patient, who may be anywhere in a hospital, in their houses or employees with risk of heart attack and the resulting data can be sent to a remote monitoring system such as smart phone. When a patient moves or is moved, these communications need to be maintained by a robust wireless link. To provide a patient with a more humane environment of their physical and physiological heath care, frequent monitoring and recording of their physiological status becomes very important [17]-[20].

Developing the wireless technologies necessary to support real-time remote cardiography. The most crucial is to guarantee the required quality of services: although conventional wireless applications are designed to

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optimize average throughput, ECG monitoring applications only require a moderate data rate, but need both an extremely high level of reliability and a guaranteed low bound on the service latency; this is because the delay, corruption, or loss of medical data can have fatal consequences. The purpose of the developed device is to transmit data about a person's heart rate in real time, using non-intrusive, low power, band-aid sized probes to a smartphone via bluetooth technology. The smartphone will either store it for later analysis or upload it for analysis in real time. The smartphone will also be able to detect when the output indicates a medical emergency, such as cardiac arrest, and call an ambulance on behalf of the patient. The software used by the application on the smartphone will be addressed by another group.

II. Method

Development of newer and better medical instrument have been rapidly increase related to the patients population. The context for this researh is to develop a medical instrumentation for home healthcare integrated with wireless communication. This means that, patients are no longer bound to a specific healthcare location where they are monitored by medical instruments. Wireless communication will not only provide them with safe and accurate monitoring, but also the freedom of movement. For this aim, an ECG based wireless is proposed. The conceptual arrangement of a wireless ECG medical instrument is shown in Fig. 1. A challenge of the wireless communication unit is to send as little information as possible to make the communication faster, without loss of information in the ECG-signal. These purpose could be achieved when a clear ECG signals without any noise is obtained before transmission.

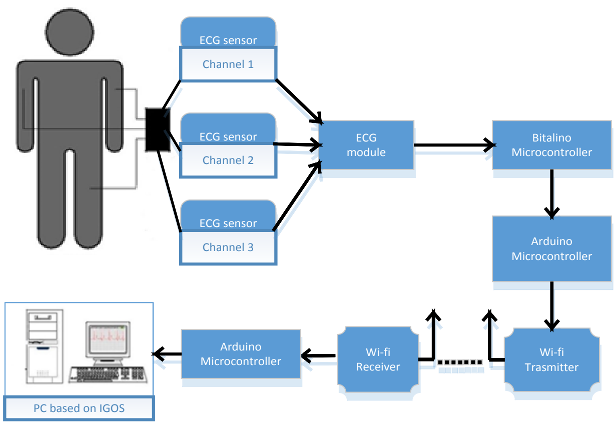


Figure 1. Conceptual arrangement of a wireless ECG medical instrument.

An advantage of wireless communications remains to provide ubiquitous connectivity, thus allowing greater physical mobility and interoperability, a number of engineering issues need to be addressed before this vision is realized. The main objective for this effort is to develop universal and interoperable interfaces for medical equipment that are: Transparent to the end user, easy to use, quickly (re)configurable.

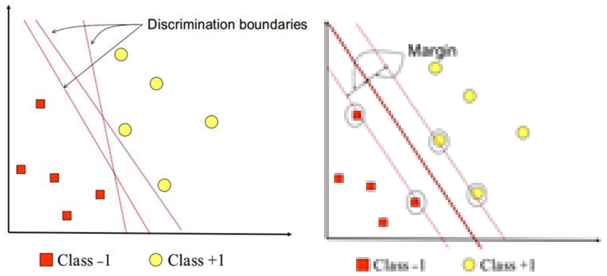
To test the reliability and guarante low bound on the service latency, the ECG signals from four subject, whose age is around 25 ± 2 years old, are recorded. All subjects were healthy both physically and mentally. Furthermore, each experiment was divided into two sessions: with and without squat jump. In the first session, the ECG signal of the fourth subject were recorded in the normal condition while the second session were recorded in a condition after doing 20 squat jump (see Fig. 2). Each subject is equipped with 3 electrodes that will measure the body information. The respective location of the electrodes is shown in Fig. 1 which are related to heart activities. Once equipped, each electrode must be covered with electrolyte gel. ECG data were collected from three Ag/AgCl electrodes embedded in the developved wireless ECG system. Then an electronic circuit will amplify this data and filter it to enhance the signal/noise ratio. After that the information will be saved in a database and the data is then sent through wireless communication to a monitoring system, where the data is analyzed, and if it is out of health limits a message is sent to notify the doctor.

Figure 2. An experiment setup.

III. Signal Processing

Cardiac signals from the heart are extremely weak (in the range of 0.025-10mV with frequencies between 0,05 and 100Hz) and are often very noisy, since it is hard to get a good contact between an electrode and the skin. For that reason, an ECG amplifier circuit is needed to amplify the signal and reduce the present noise. Signal processing is an enabling an algorithms and its application for processing or transferring information contained in many different physical formats which called as signals. Many applied signal processing for noise reductios has been proposed in the literature [21]-[26]. Wavelet denoising (one of them) is used remove noise in the form of artifacts in ECG signals recorded on while preserving the signal characteristics, regardless of the frequency content. The process of denoising (noise reduction) based on elimination or reduction of the data signal which is considered as noise. Denoising is applied by downloading the form of signal threshold wavelet with input coefficients in the discrete wavelet transform. With tresholding, wavelet transform will be able to remove noise or other undesirable signals in the wavelet domain. Then, the desired signal will be obtained after performing the inverse of the wavelet. Therefore, the concept of wavelet coefficients that represent a measurement at a selected frequency between the signal and wavelet functions are need to understand. Wavelet coefficients is calculated as a convolution of the selected signal and the wavelet function which is associated with a bandpass filter. When the signal at a high and smaller scale are analyzed, the global information of a signal called approximation and details, respectively, are obtained.

Classification is aimed to categorize feature extraction results based actual heart activity. Among many classification algorithms, Support Vector Machine (SVM) is chosen due to its accurate result and fast computation time [27]-[29]. SVM have become extremely successful discriminative approaches to pattern classification and regression problems. In other words, SVM is a technique used to obtain the most probable hyperplane to separate two classes. It is done by measuring the hyperplane's margin and determines its maximum point. Margin is defined as distance between the corresponding hyperplane and the nearest pattern from each class. Moreover, this nearest pattern is called support vector. Meanwhile, SVM can also be used to separate non-linear data as displayed previously in the following literature [27]. These explanations are well illustrated within Fig. 3. Fig. 3a displays several discrimination boundaries while Fig. 3b shows the most probable hyper-plane.



(a) (b)

Figure 3. SVM is a method used to obtain the most probable hyper-plane.

Suppose we have a set of training data $\{(x_1, z_1), \cdots, (x_N, z_N)\}$. The decision function $f(x)$ has the form:

$$f(x) = \operatorname{sgn}\left(\sum_{i=1}^{N} z_i \alpha_i k(x, x_i) + b\right) \tag{1}$$

where $\{\alpha_i\}$ are embedding coefficients and $k(x, x_i)$ is kernel that is represented by the dot product, i.e.:

$$k(x, x_i) = \langle x, x_i \rangle \tag{2}$$

where $\langle .,. \rangle$ denotes the dot product. The optimal decision function is computed by the following quadratic programming:

$$\text{maximize } J = \sum_{i=1}^{N} \alpha_i - \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j z_i z_j k(x_i, x_j) \tag{3}$$

subject to $\alpha_i \geq 0$, $i = 1, \cdots, N$, and $\sum_{i=1}^{N} \alpha_i z_i = 0$. More details on SVM can be found in [30], [31].

IV. Results and Discussions

The system has been tested on four healthy volunteers subject aged around 25 ± 2 years old and it functions normally. The ECG signals are recorded using developed system and processed using wavelet denoising algorithm in real time. Fig. 4 is illustrated the standard heart waveform. This is useful because if the ST elevation and the ST depression can be early detected then the myocardial infarction (heart attack) information and the conditions such as Digoxin Toxicity and Hypokalemia will be available to the patients and doctor [32]. Fig. 5 to Fig. 9 show the recorded using developved system (raw data, filtered, and extracted) for the normal and squat subject, respectively. Fig. 5 and Fig. 6 show the recorded and filtered ECG signals (normal and squat subject) for one session (about one minute). Fig. 7 and Fig. 8 show the seven second recorded and filtered ECG signals. It is clear that the peak amplitude (QRS) number of squat subject (15 peak) is higher than normal subject (10 peak). Fig. 9 indicates that the transmitted ECG signals of both conditions subject (normal and squat) conform with the standard heart waveform. All processed signal in this paper were taken from subject 2. All signals from all subject and different conditions of wireless ECG recording signals are in the standard form of ECG signals such as given in Fig. 4.

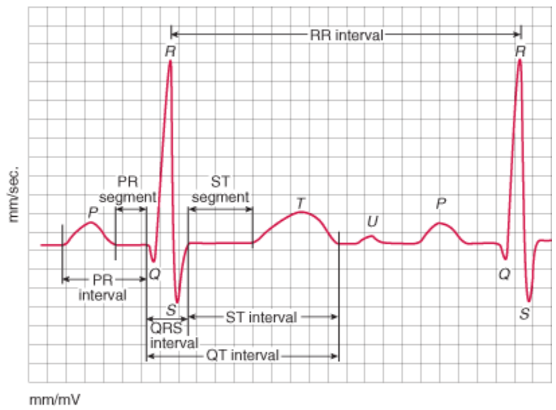


Figure 4. The standard of heart waveform [33].

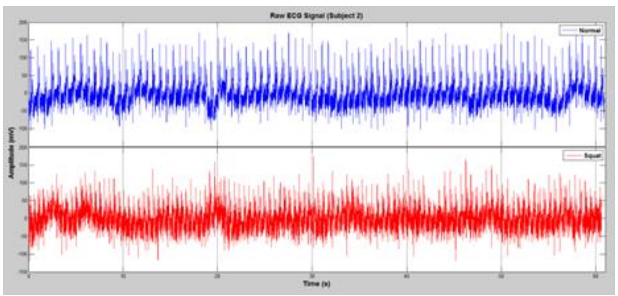


Figure 5. Recorded ECG signals of normal and squat subject.

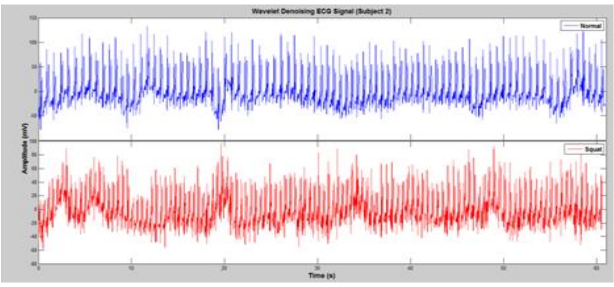


Figure 6. Filtered ECG signals of normal and squat subject.

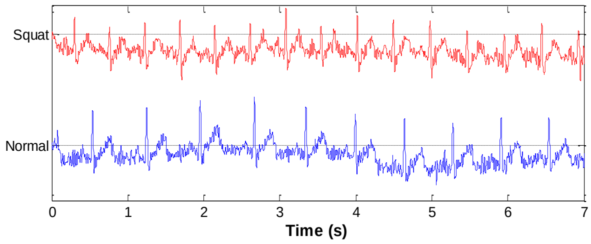


Figure 7. Recorded ECG signals of normal and squat subject: Comparison of peak amplitude (QRS) number between squat and normal subject.

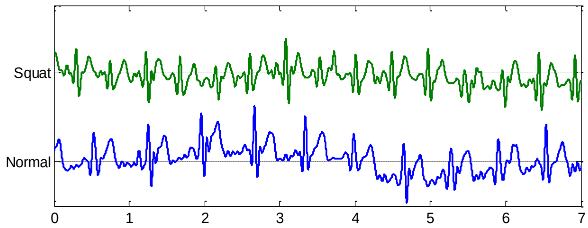


Figure 8. Recorded ECG signals of normal and squat subject: Comparison of peak amplitude (QRS) number between squat and normal subject.

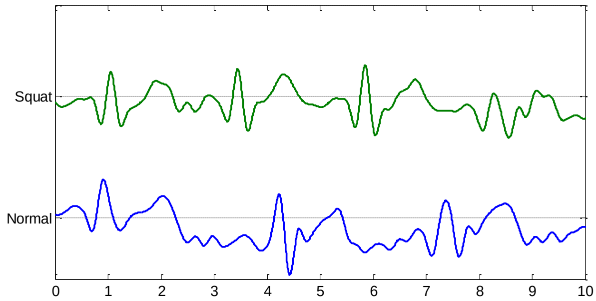


Figure 9. Filtered ECG signals of normal and squat subject.

V. Conclusions

In this paper, we presented the development and implementation of an wireless ECG system that consists of mobile physiological examination device and wireless base station. The equipment developed in this project meets its requirements. In the different tests we could see that all the information we sent through wireless communication arrived correctly to the computer and we could reproduce the signal without any problem. The speed of the communication was enough to receive all the information, and the noise levels were below the theoretically calculated. This project achieved its objectives, but there are some points where it is possible to improve some details. Therefore, our system can adapt to the requirements of many different environments and can be upgraded by using new technologies.

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