AN ANALYSIS OF BIO SIGNALS TO GENERATE ECG REPORT USING FINGER BASED SENSOR

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Abstract

Electrocardiogram (ECG) plays vital role in diagnosing large number of diseases and disorders related to heart. ECG devices are able to perform multiple parameters by analyzing the patterns of bio-signals. The state-of-art ECG machine uses electrodes attached to human body using gel. The whole process agitates the patient resulting in disturbed ECG report by producing noise due to movement, imbalanced electrodes, and heavy objects. The proposed ECG system is portable finger-based system that generates ECG report in minimum time duration with providing ease to users. The system replaces disturbing electrodes by a single bio signal identification sensor. It takes signals from one finger of patient through sensor in 7 seconds. The sensor is followed up by combination of various capacitors and buffers in order to enhance signals. The signals are then transferred to software using USB port for several medical required filtrations and overall noise removal. The result of the process is an ECG signal representing heart condition of patient. The results can be stored for future medical investigations like improvement or decline in health of patient. The proposed prototype is deployed in several hospitals for testing. The system evaluated through comparison method with current system and results are satisfactory.

Keywords: ECG, Bio-Signals, Filters, IR Sensors, Quality of Service
I. Introduction

Nowadays heart diseases are increasing very rapidly. It is due to the unhealthy diet which causes diabetes, hypertension, and heart attack. There are also other problems which results to heart diseases. All diseases related to heart can be diagnosed with the help of Electrocardiogram (ECG). ECG is an easy and simple way to diagnose any irregularity of heart. ECG machine evaluates the heart condition by interpreting electrical signals of heart muscles which is traced on a graph [I]. It is mostly available at every hospital due to its minimal infrastructure. An ECG can be performed using different techniques. One of them is wet ECG, in which 12 or more electrodes are made of Ag or AgCl pasted to the chest, arms, legs and hands, using a gel for the interface between skin and electrodes. Another technique is Capacitively Coupled ECG (CC-ECG) in which ECG signal is acquired without contact with the patient’s body. In this technique, metal plate electrode, thin layer insulator which isolates patient’s body from electrode and forms a capacitor. Different other methods are also introduced. Some of them are using sensors which are placed on different area of patient’s body. One of them is belt-type ECG system with fabric and active electrodes. Others are using bio-clothes for monitoring [II]. All methods are different from each other and produce different shapes of ECG signal. Currently most of the ECG process consists of several wired electrodes that are attached to the patient’s body and are connected by wires to the device. ECG signals are recorded on paper chart and tracing are described by wave components or segments [III][IV]. Figure 1 shows basic representation of ECG signal. The ECG is a graphical representation of heart beat i.e. Repolarization and Depolarization of heart. A normal ECG signal consists of three waves: P wave, QRS complex and T wave. A P wave shows depolarization which causes arterial contraction. The QRS complex shows ventricular depolarization which causes left and right ventricle contraction and in the end T wave shows repolarization [V].

![Fig. 1: Normal ECG wave [V]](image-url)
Most Commonly used ECG system is 12 lead ECG systems. There are other types of ECG systems are also available. The figure 2 shows ECG of a patient with 12 lead ECG machine. In this system, patient has to lie on a bed to place these gel-based electrodes on chest, arms and legs. After placement of electrodes, ECG machine started taking ECG signals and trace them on a graph paper. It takes few minutes to complete the whole process [V].

**Fig. 2: ECG of a patient**

In medical, time and accuracy are important characteristics for any medical tests. A minute delay in treating any heart disease may damage heart muscle [I]. Current ECG systems are not user friendly and time consuming. Due to which systems are now moving towards automation, less time consumption and permanently save users information systems.

**II. Literature Review**

In paper [I], authors introduced a wearable ECG sensor that monitors long term arrhythmia. The objective was to evaluate signal quality and R to R coverage of the proposed system compared with 3-lead Holter. In first trial person is monitored for 24 hours with OM Signal system and 3-lead Holter together. Signal quality was evaluated by finding differences in P-QRS-T wave. Signal accuracy was measured by Bland-Altman analysis [VII]. In paper [VIII], the authors had proposed energy-efficient wearable ECG system which consisted of two phases neural network and diagnosis based adaptive compression. It maintained the high accuracy and reduced the consumption of power in ECG process. In paper [IX], ECG classification algorithm was proposed to monitor heart conditions on wearable devices. An architecture of proposed solution consisted of wavelet transform and multiple Long Short-Term Memory (LSTM) neural network. The proposed algorithm was lightweight and accurate during cardiac monitoring of an individual. In paper [X], authors had developed an implantable ECG monitoring system which evaluates ECG signal, temperature and voltage level of rechargeable cell inside a device. Information that has been transferred can be checked by users using PC program or mobile application. The wireless charging technology emits use of lead wire. The proposed
wireless technology whose power transfer efficiency was approximately 30%. The implantable device was reduced by integrating coil and antenna into a size of 34mm x 14mm.

In paper [XI], a system had developed which contains Capacitively Coupled ECG (ccECG) and radar signals. It allowed for the extraction of heart rate (HR) and respiration rate (RR). In addition, signal quality and confidence indicators had been introduced. Sensor fusion methods were performed with quality based ccECG, confidence-based radar HR source selection. The proposed system and algorithm were tested on five individuals during office work. Errors had been decreased by the combination of system and algorithm.

In paper [XII], a system was developed to acquire 12-lead ECG. Four sensors had been used to form a network. These sensors had used short cables, preamplifications, close to the patient and supplied three bipolar voltage leads. 12-lead ECG could be reconstructed by the sensor network at 1.5 T and 3T as compared to previous systems. The system would help to improve monitoring of patient. In paper [XIII], the authors had developed a mobile based patient monitoring system. This system consisted if four sensors: ECG module, blood pressure sensor, temperature sensor and pulse oximeter module. All these four sensors combined into one system with the help of Arduino. All the data sent to Wi-Fi module which was uploaded on cloud.

In paper [XIV], authors had developed a patient monitoring system that automatically displays patient’s health condition by using different sensors. The processing of data was held by Raspberry Pi and information was saved to IoT cloud. All the patient’s information was checked by doctors/nurses/relatives and in addition, a notification was sent to them in critical situations. In this paper, authors had proposed a cascaded PCA Network (CPCANet) which was based on a principal component analysis network (PCANet) for identification of an individual ECG. There were three phases of CPCANet. In first phase, ECG signals were normalized. In second phase, the R-peak in ECG signals were detected and then signals were converted into two dimensional images as input of CPCANet. The proposed method was good in performance and effectiveness as compared to the conventional algorithms [XV].

In paper [XVI], author introduced capacitively coupled ECG electrode to monitor heart rate. Guard rings reduce noise for two electrodes that were produced on a polyamide substrate. The operational amplifications (op-amps) filter ECG signal and R peak in the ECG. The detection of ECG signal was done from ECG databases and real signals from human subjects. The comparison of heart rate and its variability with the other existed systems, devices, and sensors were done and achieved good results. Op-amps were used to increase high performance from weak bio potential. In paper [XVII], author presented a near field dielectric plethysmography (DPG) heart rate sensor that obtained data by contracting and expanding blood vessels with giga hertz-frequency at fingertip. Analysis, frequency and variability of signal showed the DPG robustness for heart rate detection. In paper [XVIII], an ECG biometric system’s performance had been assessed. Digital filters removed noises from signal at preprocessing stage to improve signal quality. To enhance the feature extraction, Pan Tompkins approach had been used for the detection of ventricular complex (QRS). Different classifiers were used to extract features. The performance of various
approaches had evaluated by making use of Sensitivity, Efficiency and Specificity, Receiver Operating Characteristic (ROC), Equal Error Rate (EER) curve.

III. Motivation

There are different types of ECG system that have been evolved. The conventional ECG system uses gel on body for interface between skin and electrodes. These electrodes irritate skin when pull off from the body. In addition, it takes more time and patient should not move during ECG process. The above-mentioned electrodes may get results in inaccurate report of ECG [V].

In this work, proposed system is a finger-based ECG system to generate the ECG report of patients that recurs to Infra-Red sensor for taking bio-signals from one finger and hardware setup for data acquisition through micro controller chip. Signals filtration and normalization must be performed to obtain the required ECG waveform. Filtration of bio-signals are performed by polyester capacitor and potentiometer at hardware level. Further filtration and normalization performed by Engelese Zeelenberg algorithm at software level to get invariant ECG waveform. The motive of system is to provide ease to the users without time consumption in ECG process and its result. ECG reports are saved into database as well and two ECG reports comparison is also provided through Euclidean distance.

IV. Methodology

![System Diagram](image)

Figure 3: Block Diagram of proposed system

Figure 3 depicts the system framework. At the hardware level, sensor is used to take bio-signals from subject finger, amplify and filtrate the signal and transfer it to software by USB data cable. MATLAB is used for the implementation of software. At software level normalization, filtration, mean subtraction, pattern recognition and classification are held for signal. Database is also implemented to store or retrieve the data. Group of functions are implemented to retrieve data from the database.
IV.i. Proposed Prototype Hardware

Advancement in bio-signal sensors leads to wearable, wireless technologies for gathering ECG signals [XVI-XVIII]. Still, current systems are used in many medical hospitals for ECG process. In these systems subject’s body contact is needed i.e. hands, legs and chest area for pasting gel to stick wired electrodes.

The presented system which takes signal from finger through sensor and generate an ECG report on screen. That report can be store in database as well as in other format, also it can be print and send to others through mail.

Proposed system is depicted in figure 2, which shows Infrared sensor (IR) for receiving signals from the finger. Received signals are transferred to two passive filters and one active filter for filtration of noise from the signal. As signal is very minute ranges from 5Hz to 25Hz is amplified by potentiometers and buffer. Then signals are transferred to USB-Microcontroller chip (PIC 18F4550) for digitizing the signal by analog to digital converter (ADC) and transmit it to processor to transmit it to internal USB handler convert signal into serial data. External USB is connected to software for transmission of data.

IV.ii. Proposed Prototype Software

When data is transmitted by hardware device to software system, software ask for its port name, baud rate and samples. Once the information is delivered, start capturing data from hardware device. Now it goes through different phases of the algorithm which are discussed.
IV.ii.a. Normalization and Filtration

First a raw signal is captured and plotted. This noisy signal is normalized through amplitude normalization. The amplitude normalized signal is plotted and send it for digital filtering of the signal through low pass filter. This results in remove of high noise (50 Hz) from signal. Raw signal and filtered signal are depicted in figure 3.

Fig. 5: Normalization of noisy signal

Fig. 6: Normalization of noisy signal
IV.ii.b. Mean Subtraction

The filtered signals are resized by throwing first 100 samples and last 100 samples for better signal wave. The original signal is subtracted from the mean of the signal for defining a line.

IV.ii.c. Pattern Recognition

In this step, find first R peak of the first signal and declare it first index then find another R peak and declare it second index. Full first signal is formed after finding indexes. Now process is repeat for second signal. When two waves are formed, R to R averages of both signals are taken and show result in a single wave which is rearrange to be in P-QRS-T signal form.
IV.ii.d. Classification

Classification is performed using Euclidean distance, which takes two reports from the database and classify the distance between those reports. A real time ECG report is also classified with the available ECG report from database. ECG reports are passing through the following classifier for distance calculation:

![Fig.9: Euclidean distance ECG wave result of two reports](image)

V. Experimental Results and Discussion

The evaluation of the proposed system is done by taking ECG of 33 subjects from the existing electrode-based system and the proposed system. Compare the results of proposed system with existing system which shows that 28 reports are same and 5 reports are different. On the basis of these results, we can determine the accuracy and performance of the proposed system. The proposed system is 85% accurate to generate an accurate ECG report.

Table 1: 10 comparison ECG results of patients

| Patient No. | ECG1 (Hospital System) | ECG2 (Finger-based System) | Comparison Result |
|-------------|------------------------|---------------------------|-------------------|
| 1           | Time taken: 6 minutes  | Time taken: 10 seconds    | ECG report results are same |
|             | Report: Normal         | Report: Normal            |                   |
| 2           | Time taken: 5 minutes  | Time taken: 8 seconds     | ECG report results are same |
|             | Report: Normal         | Report: Normal            |                   |
| 3           | Time taken: 7 minutes  | Time taken: 9 seconds     | ECG report results are same |
|             | Report: Normal         | Report: Normal            |                   |
| 4           | Time taken: 5 minutes  | Time taken: 10 seconds    | ECG report results are same |
|             | Report: Abnormal       | Report: Abnormal          |                   |
VI. Conclusion

This system provides ECG report in real time through taking bio-signals from finger. Our goal is to provide ease to users by eliminating gel electrodes. We devised a framework that only needs contact with the patient’s finger and show ECG result on system screen that can be store, print and sent to others through email. Moreover, system is evaluated through comparison method and confusion matrix which shows that 85% of ECG reports are correctly identified. Future work is focus on introducing classification of ECG results as well as making fully mini portable system. It will be easy operable by users without any guidance.

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