Smart Healthcare System for ECG Monitoring Using IoT

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Abstract. Electrocardiogram recordings have conventionally been carried out using a oversize recording device, connected to the patients by several leads and tying them down to the bed or seat. Such gear were perfectly fitted to their purpose back then and it was great examples of the state-of-the-art biomedical electronics design. This paper aims at developing a smart product for recording the ECG and Heart rate of the person using a simple and easy wearable device. With increase in technology smaller and efficient heart rate monitoring modules can be developed. This system uses single lead, heart rate monitor module with IC AD8232 and arduino uno with help of IoT for the obtaining the electrical activity of heart and measuring heart rate. This system analyzes the PQRST wave of the heart and the frequency helps in counting heart rate. The aim of this paper is to monitor cardiovascular movements of patient and warn some entity with a message using IoT service. The whole system and the consequent hardware and software modules are sketched and results are presented for explicatory purposes in this paper. The results have been tested experimentally in lab. Real time application of this system is monitoring condition of critical patients, pregnant women and elderly people in hospitals.

Keywords: ECG; Heart Rate; IOT; Electrodes; Health Monitoring System.

1 INTRODUCTION

Today, the medical field is faced with growing public concerns and government demands for reform. The need of rapid and expert medical care can significantly improve health-care services at undermanned rural and remote areas [1], [2]. In remote regions of the country the degree of development of healthcare providing services has not reached the suitable level to effectively address the health care needs of the populations in these areas.

With the turn of the century, the chief cause of mortality in India is cardiovascular diseases (CVDs) [3]. Comparing with the people of European ancestry, CVD affects Indians at least a decade earlier and in their young midlife years [4],[5]. In India, 52.4% of CVD deaths occur before the age of 70 years [6]. The Registrar General of India reported that coronary heart disease (CHD) led to 17% of total deaths and 26% of adult deaths in 2001-2003, which increased to 23% of total and 32% of adult deaths in 2010-2013. [7] Globally, CVD led to 17.5 million deaths in 2012[9]. According to Times of India, Life report in May 19, 2016 our country faces around 2 Million heart attacks per year [9]. There is a rise in cardiac diseases like arrhythmia, heart attack, coronary artery disease every year. The World Health Organization (WHO) has estimated that, with the current burden of CVD, India would lose $237 billion from the loss of efficiency and spending on health care over a 10-year period (2005–2015) [11].

The patient monitoring system is one of the major developments because of its innovative technology. Currently, abundant research results have been achieved in the field of health monitoring systems in foreign countries. The use of advanced telecommunications and information technologies has been investigated to improve health care for past three decades Telemedicine encompasses a wide variety of technologies ranging from telephone to high-tech devices that enable health care professionals to provide their services several miles away from the point of service. With hasty technological advancement in biomedical instrumentation, telecommunications, multimedia, and internet, provision of home care to patients at remote places is becoming more popular. Also the design and development of wearable biosensor systems for health monitoring has gained lots of attention in the scientific community and the industry during the last years [12]. This system can overcome the restrictions of traditional monitoring technology. There is technological advancement in miniature bio-sensing devices, low power consumption devices, smart textiles, microelectronics, and wireless communications. The continuous advancement of wearable sensor-based systems will potentially transform the future of healthcare by enabling proactive personal health management and global monitoring of a patient’s health condition.

In principle, the technology for instrumentation and telecommunication-based health care is now in place. However, one of the challenges is how to integrate existing technologies to form a cost-effective and user-friendly health care system. The objective of this study was to take a step in this direction and develop a microcontroller based cost-effective portable tele-monitoring system for ECG and heart rate. Therefore, a system was designed, implemented and tested that is simple to install at home, and is easy to maintain. Its cost-effectiveness encourages and popularize its use. The objective of this project is to provide a solution by equipping patients with sensors that would gather basic vital parameters...
from them and subsequently transfer them to an expert wirelessly. The transmitted data will be monitored and analyzed by the expert and will be alerted should any abnormal conditions arise within the patient’s parameters hence allowing him to take prompt actions. History data could also be acquired. This idea can be extended to patients in ICUs whose parameters are constantly monitored and alerting concerned medical staffs before a pending downhill progress of the patient arises. Fig 1 shows the block diagram of this system.

In the proposed health monitoring system, ECG wave and heart rate wireless sensor was developed. The main components involved in this project are single lead, heart rate monitor module with IC AD8232, microcontroller (Arduino Uno), which are integrated with IoT technology. Firstly the data is collected from the patient such as his heart rate and electrocardiography (ECG) into a microcontroller-based board such as Arduino Uno. Here the processing and calculation and analysis of PQRST wave is done after which, secondly, the data is transferred via a wireless-technology module to a physician. The system was tested to a group of voluntary students.

The paper is organized as follows. A assessment of the related research work is given in Section II. In Section III, we focus on the description of the system architecture and on the presentation of the main components. In Section IV, related simulations and experiments of a possible application circumstances are carried out to confirm the efficiency of the proposed system. Conclusions and future work are outlined in Section V.

![Fig 1. Block diagram](image)

2 THEORETICAL BACKGROUND

Based on the existing medical knowledge and methods for measuring the electrocardiograph (ECG) and heart rate the system will be designed.

2.1 Electrocardiography

Electrocardiograph is very requisite parameter for patients undergoing heart diseases. Heart disease cause adverse effect like chest pain, narrowing of blood vessels and heart attack and need to be controlled and monitored periodically. ECG is the measurement of electric potential throughout the body during heart wall contraction. The electric currents spread through the body and create different potentials at different points which can be sensed by electrodes (ECG nodes)[14]. ECG records the electrical activity of the heart over time with great detail. It is every useful in detection of heart problems. A typical ECG consists of twelve electrodes but in some cases three or five electrodes are used and the resulting measurement points provide rich information for doctors to diagnose diseases. In our application, three leads should be sufficient, since our system is designed to broadcast critical information and for portable usage. The leads used in the circuit are limb leads which are placed (using clamp electrodes) on the limbs where the least amount of flesh is present. The electrodes are bipolar and they help us take measurements from leads I, II and III. These three electrodes were measured using the heart rate module across pin LO+ and LO- and was made sure that the electrode at right leg driven circuit was always connected to the right leg as it served as the ground of the circuit without which the patient might experience discomfort.

![Fig 2. Health Monitoring Architecture](image)

2.2 Heart Rate Monitoring

Heartbeat rate can provide a lot of physiological and pathological information and is an important health indicator. Thus being an important vital sign the heart rate of the patient requires constant surveillance. One of the very important vital signs that require constant surveillance is the heart rate of a patient. Its necessity is based on understanding whether the patient’s heart is pumping enough blood. Reason of symptoms, such as an irregular or rapid heartbeat (palpitations), chest pain, dizziness, shortness of breath and fainting may be assessed. Blood flow after an injury or a blocked blood requires heart rate to be closely monitored. Similarly, diseases and medicines that may alter the patient’s heartbeat must be kept in check.
2.3 Architecture of Internet of Things Technology

So far the architecture that uses open standards has not been established for the internet of things in the world. However, the internet of things has been widely accredited by scholars as a three-layer architecture that consists of sensing layer, network layer and application layer. Fig 2 shows the system architecture of IoT. The sensing layer is used to perceive, capture and acquire the information about objects. It consists of sensing equipment such as the camera, the RFID reader, the sensor network and the EPC label. Sensing layer involves technologies such as RFID technology, control sensing technology and short-range wireless communication technology. The network layer is a fully developed layer of the IoT. It is the infrastructure and physical condition for the IoT to implement services. The function of the network layer is to reliably and safely transmit the data received and acquired by sensor devices to the cloud computing center over wireless networks and the internet. The wireless network technologies commonly used by the network layer include WLAN, 3G, ZigBee and Bluetooth, etc. The application layer is a layer in which IoT technology combines with the technologies in the fields of specific industries. It is the actual application of the front-end data acquisition of the internet of things.

In recent years, the application of the IoT in the medical field has been growing widely appreciated. In the medical field, sensing layer consists of sensing equipment. The application layer can realize applications such as sharing of health information, statistics and analysis of health information, health surveillance, remote consultation, remote diagnosis and health management and help the aged realize home-based care and intelligent care. Fig 3 shows the system architecture of the IoT for medical fields. Among the medical applications of the internet of things, the results of the application of human health monitoring system are the most prominent and significant. This is not only because of the techniques and methods of the internet of things are especially suitable for the transformation and development of human health monitoring system, but also because of this kind of system has a wide range of needs and development of space.

3 SYSTEM ARCHITECTURE

In this section, the system design is presented. In particular, a client-server pattern is adopted. A chest wearable device operates as a client and remotely communicates with a server where the logic of the presented architecture is implemented. In the following section, the experimental set up of the system is presented.

3.1 Hardware set up

This system uses a single lead consisting of three electrodes sensor pad used to obtain the electrical signals of heart. Sensor pads are attached at right arm, left arm and right leg, closer the sensor pads to heart better will be the measurement. Sensors pads needs to be replaced after every measurement of the person for better output signal. The first stage of ECG measurement circuit needs an instrumentation amplifier which provides high gain to the circuit. The electrical signals can be synthesized using heart rate module consisting of AD8232 IC which consists of high gain amplifier. The module consists of 9 pins of which 8 pins are used. 5 pins of the module are connected to Arduino and the rest 3 pin are used for reading signals from sensor pads. The electrodes are connected to arduino and the heart rate modules are shown in fig 4 and fig 5. The pins are GND, 3.3V, Output, LO+, LO- (Leads off Detect+, Leads off Detect-). LO+ & LO- are connected to the digital input of the Arduino. AD8232 is a single lead IC specially designed for heart rate monitoringAD8232 module consists of inbuilt system to extract, amplify and filter small biomedical signals even in noisy conditions. It consists of a unique instrumentation amplifier (IA) with high gain (100) and DC blocking capability, an operational amplifier (A1), a right leg drive amplifier (A2), and a mid-supply reference buffer (A3). Also it includes leads off detection circuit and an automatic fast restore circuit that will bring back the signal shortly after leads are reconnected [15].
is possible to indicate which electrode is disconnected. The AD8232 indicates which electrode is disconnected setting the corresponding LO- or LO+ pin high. The heart rate module provides a direct ECG signal when connected to the Arduino, it serially prints the PQRST wave. After obtaining ECG wave from module we take a derivative for making the signal more stable. The signal speed is lowered and provides a definite peak for every P wave in the signal. After observation and testing we find that the P wave crosses a limit which differentiates it from QRST time interval. Hence counting the number of P waves using frequency measurement we can obtain the heart rate of a person per minute.

4 RESULT AND CALCULATIONS

The paper aims at getting the desired ECG signal and calculating the heart rate from the PQRST wave. Measured signals are displayed on the computer by Arduino, and serial plotter and serial monitor help in obtaining the desired data. The system was tested on a volunteer and the reading and ECG wave was observed on the computer display. ECG wave is observed in two conditions; in normal condition and after some workout sessions. From the fig 5 and fig 6 the change in waveform can be seen. The time between two P waves is calculated and hence calculated the frequency of the Wave. For achieving more accuracy derivative of the observed wave is calculated, is shown in fig 8. The heart rate monitoring was a follow up to the system for obtaining the electrocardiograph. After obtaining the electrocardiograph, the Arduino Uno was programmed to obtain the heart beat rate of that particular reading.

3.2 Software Setup

This project uses ARDUINO 1.8.1 software. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Using Arduino boards simplifies the interfacing of hardware and software needed to run the system efficiently. The choice of using Arduino boards makes the system framework easy to maintain and makes it possible for adding new features in the future easily. The Arduino boards consist of digital and analog input/output (I/O) pins that may be interfaced to various other extension boards (shields) and circuits. Programs are written on Arduino is called sketch and language supported by Arduino is C and C++ structure coding. The code consists of only two functions that are void setup and void loop. Void setup is used for initialization of the code, variables, input and output. The loop function helps in running the program until the Arduino is turned off or reset. The main working and calculation of program is written under the loop function, which helps in giving continuous output. The program uses LO+ and LO- that features ac and dc detection modes optimized for either two or three-electrode configurations, respectively. As we are using 3 electrode configuration dc leads off mode the AD8232 checks each input individually, it
the same volunteer. The heart rates of different volunteer are shown in Table 1. Test result shows that the proposed device’s readings are very close to manual calculation. During the test conducted, data was acquired from sensor through serial communication of Arduino. The data can also be accessed remotely, through the website.

![ECG of a Person with Exercise](image)

**Fig 7. ECG of a Person with Exercise**

![Derivative of ECG of Fig.6.](image)

**Fig 8. Derivative of ECG of Fig.6.**

The time interval between two P waves can be found out using the arduino code. For obtaining the beats per minute (BPM) following equation is used.

Pulse Rate = 60/Time Interval.

For 1st sample time interval = 0.628

Pulse rate = 60/0.628

= 95.54 equivalent to 96

For 6th sample time interval = 0.544

Pulse rate = 60/0.544

= 110

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| 5 CONCLUSIONS |

A large number of heart monitoring systems are available in the market, however most of these systems tend to be large in size and are not convenient to use on a regular basis. The disadvantages of previous heart monitors have led us to consider a new system that can monitor heart rate without limitation due to time or location of the patient. This system should be able to record and send the heart rate data to doctors either upon request or when an abnormal condition is detected. This is particularly convenient for elderly and disabled patients who have difficulty in traveling to see their doctors. Instead of going to the hospital, the proposed wireless monitor will provide doctors with the ability to remotely monitor and diagnose patients while pursuing normal daily activities. The project could also be applied to battlefield health monitoring. Military doctors usually treat battlefield casualties immediately if there is no medical station nearby. By means of wireless sensor network, the doctor could set up a local wireless network and receive the vital signs of many casualties at the same time, in order to determine which patient needs treatment the most. With the internet of things as the medium that connects individuals, households and hospitals into a whole, the health monitoring system into which sensors are embedded is connected with the background data processing system to establish a data acquisition and analysis platform, in order to accurately acquire and analyze the various data about human health in real time, master human health conditions and transmit the acquired data to healthcare workers in real time. As promising technologies such as the IoT are steadily applied to medical health monitoring, in future such system will develop into an
intelligent, networked and multi-functional one achieving effective interaction between patients and hospitals and better understanding and self-management of chronic diseases. It adopts the small volume, low power consumption, portable and wearable design, the system can monitor and process a number of data on the health indicators of wearers (such as blood pressure, blood sugar, blood oxygen ) in real time, evaluate their health levels and realize intelligent early warning of health when health conditions undergo anomalies, in order to provide more timely and effective health monitoring and medical services.

REFERENCES


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