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A Real Time Electrocardiogram (ECG) Device for Cardiac Patients

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Abstract:- Now-a-days due to rising stress levels, change in lifestyles and a variety of different issues, the number of people suffering from heart related diseases is increasing. This number would significantly rise in the next few years. As the technology enhanced, a significant paradigm shift has been observed in the biomedical industry. To tackle the heart related issues, technology can be introduced in one's life. This paper proposes a wireless, wearable ECG device capable of processing the patient's ECG in a real time environment. It is capable of comparing the ECG with threshold parameters, and if ECG of the patient is not in the range of the threshold values, the device notifies the cardiac patient's mobile phone by sending a Multimedia Messaging Service (MMS) of the changed ECG and, in turn the patient's mobile phone sends this changed ECG image to the mobile phone present at the hospital.

Keywords:- ECG, Cardiac Patient, Cardiovascular Diseases, Mobile Phone, Hospital, Wearable Devices, Microcontroller.

I. INTRODUCTION

There has been a significant increase in the number of persons suffering from cardiovascular diseases. The year 2012 noticed a huge 17.5 million deaths due to cardiovascular diseases [1]. Today, not only elder people, but a large percentage of young population also suffers from heart related diseases. Hence it becomes necessary to provide acute healthcare facilities to reduce the risk caused by these cardiovascular diseases. For every heart patient ECG test is recommended, for which patient is required to personally go to the hospital and carry out the ECG tests. This process is time consuming and requires personal, frequent visits to hospital. With the advancement in technology, wearable devices carrying out ECG tests at the patient's premises can be constructed. The device proposed in the paper is a wearable ECG device; meaning patient wears it, just like a small locket and the device performs its task of ECG monitoring in a real time environment and providing a personal ECG machine at home, minimizing frequent visits to hospital.

II. ECG SIGNAL

The ECG signal (Figure 1) is the resemblance of electrical activity of the heart represented on a graph paper with the time on the X-axis and the amplitude of the ECG signal on Y-axis (Voltage). A typical cardiac cycle of an ECG has following characteristic features:

- P-wave which is a result of contraction of heart muscles, represents atrial depolarization.
- Q-Wave is any downward deflection after P-wave.
- R-wave is a big upward deflection, also known as R-peak, after the P-wave.
- S-wave is a downward wave after R-wave.
- T-wave represents ventricular repolarization.
- QRS complex represents ventricular depolarization.

The ECG cycle starts with a P-wave and ends on a T-wave. The ECG of a healthy person has a characteristic shape and values are in the specified range. Patients suffering from cardiac anomalies have these parameters above or below the specified range [2].

A medical practitioner is able to read the ECG and can tell the cardiac anomalies related to it. Change in specific parameter of ECG is associated with specific diseases. Normally the PR-segment is less than 0.12 seconds and if it exceeds this value, it suggests ventricular escape rhythm. The elevation of the ST segment from normal baseline suggests heart attack and its depression suggests chest pain. PR-interval must be between 0.12-0.2 seconds; an increase causes heart block and decrease results in Wolf-Parkinson-White syndrome.

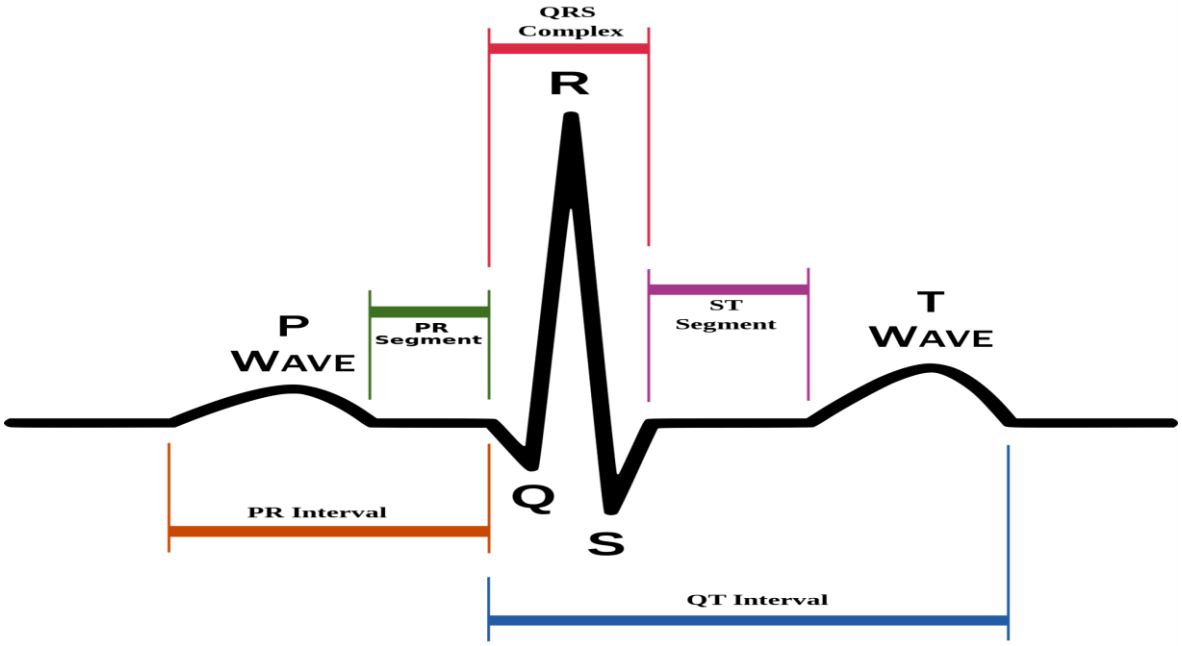

Fig. 1: Representation of a typical ECG signal of heart

III. EXISTING SYSTEMS

Existing technology includes the standard Electrocardiogram machine that records the ECG on a graph paper. For carrying out the test, the patient needs to visit the hospital personally, take an appointment for it; which is a time consuming process. But as technology boomed, there has been a significant paradigm shift in the medical industry by the introduction of wearable technology at the patient level.

A. Electrocardiogram Machine

The standard ECG machine is bulky and costly. This imposes a lot of restrictions to the patient in the sense that the patient needs to rest on a bed completely all the time until the test is completed. It usually consists of 12 lead ECG electrodes to be placed on the body of the patient. The machine then records the electrical activity of the heart and produces an ECG waveform on a graph paper. A medical practitioner then can read it and detect heart anomalies (if any) [2, 3].

Also human intervention is required to read the ECG, the machine itself cannot say if there is any heart anomaly, it just displays the heart's electrical activity. Owing to such restrictions, there is a need for an ECG monitoring system that is more intelligent, a system that works on its own in real time and provides freedom to the patients while they are they are carrying out their daily routine.

Fig. 2: Traditional ECG machine

B. Other Wearable Devices in Market [4]

Introduction of Wireless sensors has made it possible to construct small miniature sized wearable devices that can work in a ubiquitous environment. Various wearable devices currently available in the market include stress checker, heart rate checker, Blood Pressure (BP) monitors, and sugar level checkers for diabetic patients, etc. Wearable ECG monitoring devices [5, 6, 7] available in the market today are capable of detecting cardiac activities and generating resultant graphical representations as seen on clinical monitors. Thus, there is potential to exploit this availability of information in image form and consequently compare it to prior known images of normal conditions. Once the comparison is done, the equipment will be able to detect any abnormalities and hence initiate a data transfer of the abnormal signal image to the hospital.

Some of the wearable devices include:

***1) Hexoskin*:** Designed by Carré Technologies, is a hi-tech fabric shirt which consists of several inbuilt sensors and microcontrollers which can determine important information like pulse rate, step count and the rate of breathing.

2) Biopatch: Designed by Zephyr– that record ECG and transfers it to remote systems for analysis.

3) Amp Strip: The Amp Strip by FitLinxx is a device to be worn on the torso of the user. It is an efficient device which is able to monitor electrical activity of heart i.e. heart rate and its activities. This is a device recommended by fitness experts as it monitors fitness activities and stores data for analysis purposes.

4) Sun Friend: By SunFriend Corporation is wearable band that has Light Emitting Diode (LED) detecting sun's Ultraviolet rays. It consists of silicon chip that measure how is the user exposed to the sun's Ultraviolet rays.

5) Baby Monitor: The Sproutling Baby Monitor is a wearable device designed for small babies aged between 0 to 18 months. The purpose of the device is to monitor the wellbeing of an infant which is useful to parents. The device is also able to check heart rate and pulse of the baby. The device is also able to provide suggestions on sleep timing of the baby based on key milestones in the baby's development.

6) Zol Life Vest: Designed by Zol Medical Corporation is a wearable jacket that is to be used by cardiac patients. The device monitors the ECG of the patient and continuously displays it on the screen provided with it, notifies upon change in ECG so that patient can seek help beforehand; before cardiac arrest. The system is efficient but, large sized and non-wireless, patient needs to hold the ECG display monitor all the time which is connected to the Vest via a wired channel. Hence system is not completely wireless.

7) Fit Guard: By Force Impact Technologies is a device which has in built acceleration sensor, which detects the head movements. The sensor can record movements of head which help to determine the impact and severity of head injuries. This device is used by athletes.

8) Zio XT-Patch: Designed by Irhythm company, is a wearable device that monitors hearts electrical activity and sends data to the hospital via a wireless medium. The device records data for fourteen days and sends it to the hospital. Major disadvantage of such a system is that the entire data is accumulated over a period of time and is sent for analysis purposes. Hence the device stores the data over a period of time and does not work on a real time basis.

Fig. 3: Wearable devices available in market

IV. PROPOSED SYSTEM

The proposed system is meant to serve the chief purpose of informing the medical staff about the ECG of the cardiac patient as when required. The device is to be worn in a similar manner like a locket Figure 3 shows architecture of the proposed system.

A. Description of System Architecture

The system consists of three module: ECG device, the cardiac patient's mobile phone and mobile phone / computer at hospital. The patient keeps wearing the device which continuously, keeps on monitoring the patient's ECG in a real time environment. The device consists of microcontroller and ECG sensor that perform the task of ECG monitoring on a continuous basis. ECG leads are to be used to acquire the ECG from the patient. The microcontroller unit is to be designed by ECG detection algorithms. Along with it, the device hardware has a Bluetooth module for data transmission to the patient's mobile phone. Finally the computer terminal at hospital, where the ECG of the patient can be received.

B. Working

The storage unit consists of the threshold ECG which is the ECG at the healthy state. The hardware on device includes a circuitry for storage of standard ECG signals, subroutines on a Microcontroller to perform predefined tasks of comparing the ECG signals and also to communicate with the mobile device via a Bluetooth interface. Microcontroller is to be designed with detection algorithms like P-QRS-T detection algorithm, that detect various characteristics of ECG i.e. the P-wave, QRS complex and T-wave [8, 9, 10].

The ECG is a pseudo-periodic signal in the sense that the cardiac cycle repeats according to heart rate. However, the heart rate may not remain constant. The components of cardiac cycles appear in a regular sequence P-QRS-T. The R peak in the QRS complex is the dominant feature of the cardiac cycle, which can be distinctly recognized from the sharp edges and high amplitude as shown in Figure 1. Therefore, it is relatively easy to locate the QRS complex in the ECG even in the presence of low frequency noise (like the baseline wandering due to respiration) and hence this is used for determining the current heartbeat. The QRS detection forms the basis of most ECG analysis algorithms [8].

The current heart rate may be determined by calculating the time period between the two consecutive R peaks. Moreover, specific ECG parameters can be derived using the R peak locations. In morphology based QRS detection approach, morphological operators like opening and closing are used to enhance the particular shape of the QRS complex. The QRS complex contains abrupt positive and negative peaks, therefore, using a peak-valley extractor, the QRS complexes are enhanced and the other parts of the signal such as P and T waves as well as noise are suppressed [9].

Peak-valley (PV) extractor is a morphological operation used for mapping smooth parts of a signal to the corresponding zero amplitude at segments to extract peaks and valleys in the signal. In PV extractor, a smoothed signal is derived from the opening followed by the closing of the input signal by a horizontal structuring element.

After processing the ECG signal, it is compared with existing ECG plots using the detection algorithms and if the ECG parameters are not in range of specified threshold value, the device transmits the ECG image to the cardiac patient's mobile phone which in turn sends a MMS of that ECG image to a dedicated mobile phone at the hospital. The patient's mobile is to be designed with an android application that immediately sends the modified ECG to the hospital upon reception from the ECG device (hardware).

Patient mobile phone numbers will be mapped in the database at the monitoring center. Thus, it will clearly identify which incoming ECG signal belongs to which patient. Once this is done, the medical staff can prescribe a further course of actions.

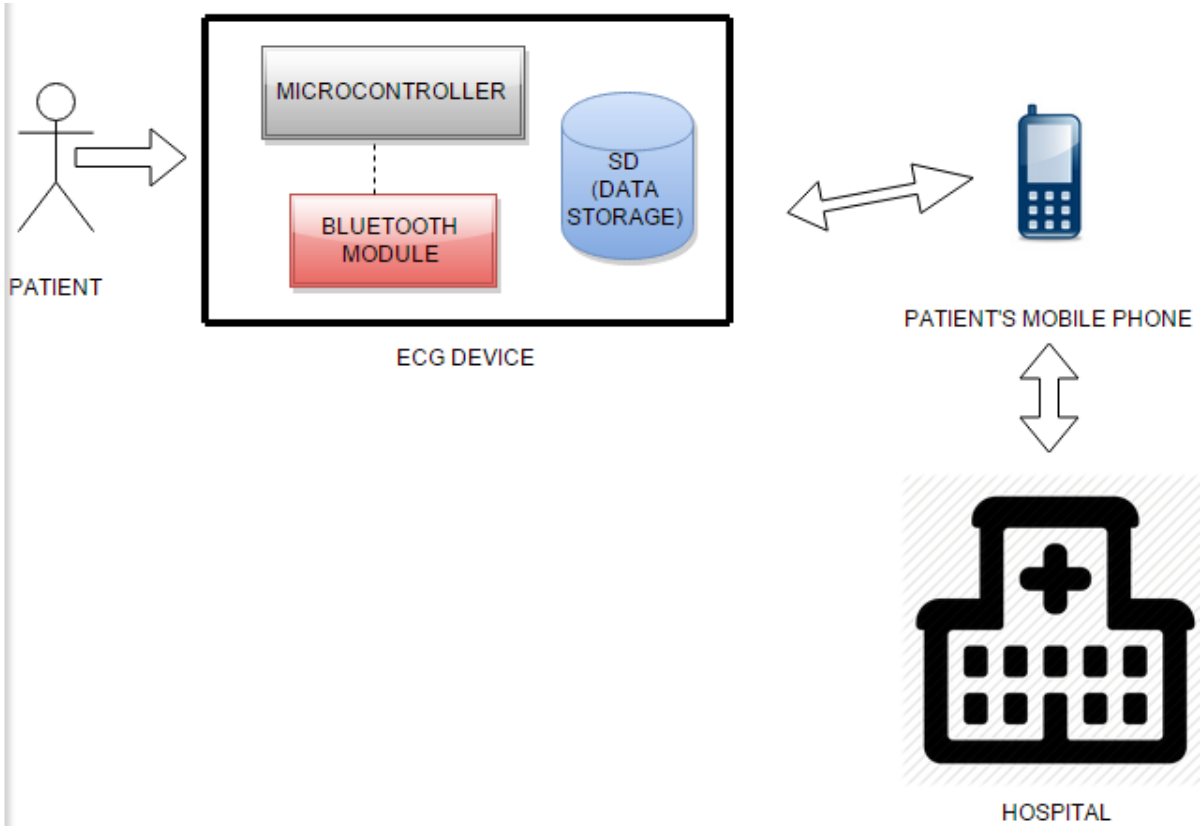

Fig. 4: Architecture of the Proposed System

C. Advantages of Proposed System

The system proposed in this paper is efficient as compared to other wearable ECG devices. Also, a lot of groups have developed wearable devices, but the device proposed, has not been developed, yet. It has some major advantages as compared to current wearable devices:

- The system implementation is simple and feasible.
- The equipment for monitoring ECG is compact, not bulky and can be manufactured at low costs.
- Requires lower processing capabilities and consumes less power.
- Storage memory required is also negligible.
- Multiple parameters of the ECG wave can be detected.
- Image accuracy is maintained throughout the transmission.
- Real time transmission enables better monitoring and attention towards the patient's condition.
- No involvement of the patient is required, even if patient is in an unconscious state.

V. CONCLUSIONS

With increase in the percentage of cardiac patients every year, it becomes necessary to provide acute health care services. Technology can be introduced in one's life in the form of wearable ECG device. The device proposed in this paper adheres to this requirement.

The proposed system is meant to serve a host of patients. Each such patient is given a wearable device with his/her standard ECG signals set to as baseline for any analyzing purpose. The device is worn by the patient while he/she performs daily routines. The system is meant for post hospitalization monitoring; the device is programmed with comparison operators to detect abnormalities in the current ECG signal feeds received from the patient. On comparing the standard ECG signal and the recent ones taken from the patient; all that remains to be done is perform a few detection algorithms and derive conclusion as to whether the patient is suffering any cardiac disorders.

Thus the system has a great scope and high potential in the biomedical industry for cardiac patients and provides them with their own personal doctor, at their hand. He/she can have their ECG graphs monitored while carrying their daily errands, thus saving a lot of time and frequent visits to hospital.

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