ECG Signal Based Heart Disease Detection System for Telemedicine Application

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Abstract—Most of the cardiac disorders are arise due to irregular rhythm of the heart. Irregular heartbeats leads to abnormal PQRST values which can be traced from patient’s ECG. This paper presents an automatic ECG signal processing system for detecting cardiac disorders as part of telemedicine application. The proposed system acquires ECG signal, processes it and extracts important parameters like PQRST to detect heart abnormalities. This system also includes an integrated remote transmission module by which recorded data can be transmitted over the internet to the central healthcare database system. The proposed system has been designed using Labview application software, MATLAB and C programming language and tested on ECG database obtained from MIT-BIH and synthetic ECG generated by NI DAQ device.

Index Terms—Heart disease; ECG; Virtual instrument; G-server; QRS complex; Telemedicine; DAQ.

I. INTRODUCTION

Predicting and diagnosing heart diseases such as sudden cardiac death (SAD), pulmonary diseases, AV block etc through ECG has become one of the major topics in the field of medical science and biomedical engineering. Electrical activity of the heart can be traced using ECG which appears as periodic signal. A complete ECG cycle is marked as P wave, QRS complex, T wave and sometimes U wave. Diagnosis is performed based on these extracted features. So, precise and accurate extraction of ECG signal is always essential as it provides invaluable information to the physician that helps them reach at better diagnosis decision and treatment for the patients.

According to medical terms, most of the important information can be derived from the P wave, QRS complex and T wave. These parameters are divided into PR interval, PR segment, QRS interval and ST segment as shown in figure 1. However, due to baseline wandering, power line interference, noise and amplitude of T wave similar to QRS complex create problems to separate each of this parameter properly and accurately.

Several research activities have been dealing with the detection of the above mentioned ECG parameters. Various kinds of special digital filters [1-4] have been proposed to detect ECG features. Pan and Tomkin’s proposed [5] algorithms analyze peak value to recognize QRS complex. Multiscale Wavelet Transforms [2-4] also proposed by many researchers. First derivative based Slope Vector Waveform (SVM) [7] was proposed to detect the complex points. Pattern or template based methods [6] are discussed for detection of R point. All of the proposed method [8-13,28] requires large mathematical calculation and thus computational overhead became an issue for these proposed methods.

The concept of remote healthcare system or Telemedicine has been introduced in the last few decades. Telemedicine system has gained a huge attention due to its huge potential and application [15]. As a result, the number of implemented telemedicine system has been increasing [15-17]. Generally, this system takes the patients data sent it to the central system. The central system processes the data to detect diseases (if any). A real time monitoring option is also included in some system [18-22, 25-27]. Central health system needs a good amount of time to process huge data of different patients and provide report to each patient. Real time monitoring is only available when the physician is present on the other side of the system. This scenario may increase the suffering of the patient especially with cardiac disorder if not detected at an initial stage. Detection of diseases within the system itself based on patients data can be a possible solution of the problem mentioned above.

In this paper, fast and simple techniques have been employed to extract ECG parameters and detect cardiac disorder. First simple digital filters are used to remove noise. Then Wavelet analysis has been applied for further de-noise the signal and remove baseline wandering. From the clean ECG, it is easy to extract important ECG parameters using threshold method. All of the signal processing has been done using Labview in conjunction with MATLAB and C which makes the proposed system less computationally intensive compared to the others. After successfully extract the ECG parameters, a comparison is done with the normal ECG parameters. Any mismatch will indicate abnormality in the current ECG. In addition, the proposed system also includes a web based telemedicine module which can be used for real time doctor-patient interaction and also for sending the recorded data to the central remote station for further verification.

Fig 1. Different segments of ECG [24]
II. STRUCTURE OF THE PROPOSED SYSTEM

The general structure of the proposed system is shown in figure 2. The system is divided into four major segments which are described here:

1) Data acquisition and generation module: This module takes ECG data from different sources. Sources include real time ECG data from the electrode through DAQ and from different ECG databases. In this work, ECG data are taken from the MIT-BIH[30] database and used this data to generate ECG signal through the analog output of the DAQ. The purpose of the generating ECG signal through DAQ is to include the effect of noise and interference of different sources in the signal.

2) Pre-Processing Unit: This module consists of lowpass and bandpass digital filters. These filters are used to remove the noise which is added to the signal. After that Wavelet analysis is applied to make the signal noise free which is shown in figure 3 [a,b].

3) ECG features Extraction unit: When the noise free signal enters this module, it started detecting peaks/valleys [21-22] of the signal. Based on threshold method this module extract P,Q,R,S and T points. This unit also calculates R-R interval to calculate heart beat rate. For each ECG wave the threshold values are given in the table 1 and shown in figure 4.

4) Web based communication and transmission module: The unit utilizes the G-server which is included in the labview application software. With the G- server the recorded data can be sent to central system or database. In critical situation where emergency steps are required, this module can provide a real time doctor-patient communication interface.

III. DETECTION OF HEART ABNORMALITIES

Any changes in ECG parameters from their normal values reflect cardiac disorders. For example, any elongation in PQ segment and QT interval indicate heart block and congenital disorders. After the extraction of ECG parameters, this system compares the values with the predefined normal values and indicates corresponding diseases (if any) from the current ECG. Table 2 shows the normal values of ECG and Table 3 shows the abnormal ECG values with associate diseases.

Primarily, heart diseases that the proposed system can detect are enlisted below with the detection technique and Figure 5(a,b,c,d,e) shows the enlisted diseases waveform.

1) Tachycardia: Resting heart rate exceeds more than 100 bpm. But the upper limit is 150 bpm. From R-R interval the heart rate (HR) can be calculated to detect tachycardia.

2) Bradycardia: HR falls less than 60 bpm and can be detected as mentioned above.
3) **Hypercalcemia**: QTc interval time is less than 0.32 sec

4) **Hypocalcemia**: QTc interval time is greater than 0.44 sec

5) **Atrioventricular block**: PR interval is greater than 0.20 sec

**TABLE II**  
Normal ECG parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>0.06-0.11</td>
</tr>
<tr>
<td>PR Interval</td>
<td>0.12-0.20</td>
</tr>
<tr>
<td>PR Segment</td>
<td>0.08</td>
</tr>
<tr>
<td>QRS Complex</td>
<td>&lt;0.12</td>
</tr>
<tr>
<td>ST Segment</td>
<td>0.12</td>
</tr>
<tr>
<td>QT Interval</td>
<td>0.36-0.44</td>
</tr>
<tr>
<td>T wave</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**TABLE III**  
Abnormal ECG parameters and its Effect

<table>
<thead>
<tr>
<th>Abnormal parameter</th>
<th>Heart disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased HR</td>
<td>Tachycardia</td>
</tr>
<tr>
<td>Decreased HR</td>
<td>Bradycardia</td>
</tr>
<tr>
<td>Increased PR</td>
<td>AV block</td>
</tr>
<tr>
<td>Long QT interval</td>
<td>Hypocalcemia</td>
</tr>
<tr>
<td>Short QT interval</td>
<td>Hypercalcemia</td>
</tr>
</tbody>
</table>

**IV. TEST RESULTS**

When tested on both MIT-BIH database and synthetic ECG, the proposed system successfully extracted ECG parameters and detected above mentioned heart diseases which reflect a positive sign. The remote transmission module also tested successfully to ensure proper data transmission and real time doctor-patient communication. Figure 6 shows the remote monitoring system.
V. CONCLUSION

An effective and fast automatic ECG signal analyzing system has been presented in this paper. The system is flexible and the number of technique to detect diseases can be increased without any complexity. The proposed system can be very useful for an early detection of heart abnormalities which can help a cardiovascular patient from suffering. Thus, this system can open opportunity to provide medical services in the rural area where no medical healthcare center is found in the vicinity.

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