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XML based System for the Detection of Cardiac Abnormalities from ECG Data

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Abstract: Analyzing the QRS complex of an Electrocardiogram (ECG or EKG),it is possible to get many inferences about the working condition of heart. There are different platforms and devices available, which perform the action of ECG analysis. Access of these analysis reports are limited to closed source softwares. This paper describes a method to analyze ECG waveform from its QRS complex, detect the cardiac abnormalities present and to display the result of the analysis in a Web browser. This experiment is used to get an easier and cheap ECG analysis report to patients and also these findings will help the physicians to get a guideline about the patient's heart health.

Keywords: Electrocardiogram (ECG or EKG), Cardiac abnormalities, Savitzky-Golay Filter, Interoperability.

I. INTRODUCTION

Healthcare monitoring is becoming one of the prior concern in modern world. From an individual to the nation, healthcare is given utmost priority. United States itself spends 18% of its GDP in the Healthcare sector [1]. Cardiovascular Diseases leads the list that makes most impact in the world economy. 17 million people die every year from CVDs, an estimated 31% of all deaths worldwide [2].80% of all CVD deaths are due to heart attacks and strokes. Electrocardiogram (ECG) gives theoverall information about the heart's electrical activity.

ECG data are being monitored and analyzed all over the world using different devices. Each device has its own software, which is used to display the ECG recordings. So for each device, there will be uniquesoftwares. It is with the help of ECG, the doctors are making inferences about the health of heart. QRS detection from the ECG wave makes it possible to detect the irregularities in Heart's electrical activity. There are many algorithms proposed for QRS Detection in the past [3].Most of the algorithms require complex calculation and are notcost efficient. In this research, a systemwhich can automatically detect the heart abnormalities from the ECG data and display the output in an internet browser without any proprietary software is being presented with a simple QRS detection scheme.

II.PROPOSED WORK

The focus of this paper is to develop an interoperable system that provides an open exchange of ECG data among web browsers. This includes two stages 1) QRS detection module that used to find the peaks in the ECG signal.2) Use this information to find the cardiac abnormalities present in the ECG data.This paper concentrateson automatically detecting the cardiac abnormalities such as Bradycardia and Tachycardia. The medical standard used for research is Health level 7 (HL7) [4].HL7 provide aframework and related standard for the exchange, sharing, integration and revival of electronic health information. HL7 has more than 2300 members which include 500 corporate members who is representing about 90 percent of the information system vendors serving healthcare.

III. PROPOSED QRS DETECTION

ECGs are recorded and analyzed using different systems and in different ways. ECGcollected using the electrodes placed in patient's limbs and chest is prone to noise, which will affect the overall result of the ECG analysis.Moving average adaptive filtering may smoothen parts of ECG other than the high frequency impulse noise. So a special filter named Savtizky-Golay(SG) filter is used for the removal of impulse noise and smoothening, since they exhibits a better smoothening of signal at high frequencies. Fig. 1.illustrates the block diagram of QRS detection.

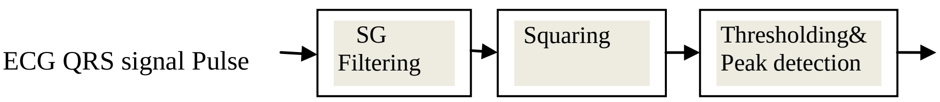

Fig.1. Block diagram of QRS detection

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A. Savtizky-Golay Filtering.

Savitzky-Golay are FIR smoothing filters (also called digital smoothing polynomial filters or least-squares smoothing filters), typically used to smoothen noisy signals with larger frequency span. In this kind of applications, Savitzky-Golay smoothing filters are superior to standard averaging FIR filters [5]. This is illustrated in Fig.2.Savitzky-Golay filter is applied to set of digital data points for the purpose of smoothing the signal without distorting the overall structure of the signal.

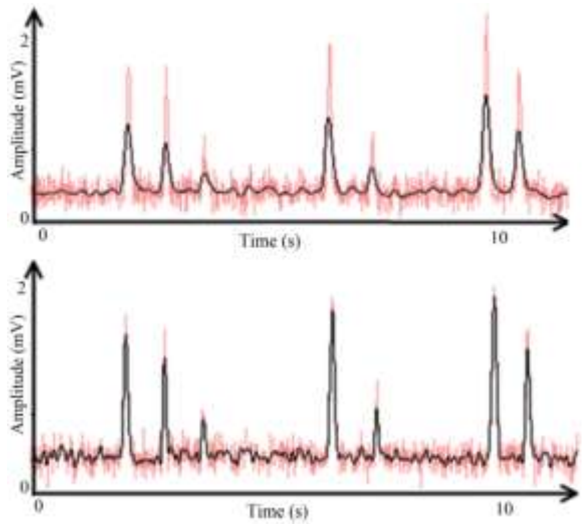

Fig.2.Filtering a signal with (a) adaptive average filter (b) SG filter

For smoothing,Savitzky-Golay filter uses least-square polynomial approximation in which a polynomial of Kis fitted to a set of input samples within a window of size Land then compute for each polynomial point within the window size. K is defined as

$$f_k = \sum_{i=1}^{K} Ci\ x^i (1)$$

When we computed the Peak detection accuracy of ECG signal using MIT/BIH database for different values of K&L, the best result is found whenK=3 and L=15.Although Savitzky-Golay filters are more efficient in smoothening high frequency part of the signal, but they are inferior to averaging FIR filters interm of noise rejection.

B. Squaring

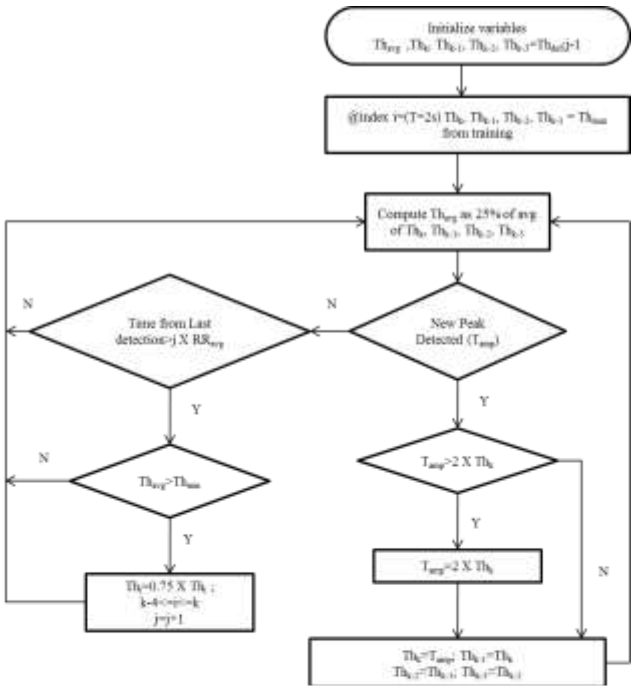

Fig. 3.Threshold routine for QRS detection.

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Since our area of interest is to find the peak of QRS complex, once the noise is removed, the signal is subjected to squaring. Squaring operation will rectify the signal, making all the peaks positive. Squaring will also enhance the high frequency part of the signal.

$$\mathrm{eno}(\mathrm{n}) \;= \sum_{\mathrm{n}=\,-\mathrm{m}/2}^{\mathrm{m}/2} \left|\mathrm{e_{sg}}\,(\mathrm{n})\right|^{2} (2)$$

$\mathrm{e_{sg}}\,(\mathrm{n})$is the SG filtered prediction error and $\mathrm{eno}(\mathrm{n})$ is the output after squaring.

C. Adaptive Thresholding

The squared signal with enhanced high frequency component are given to find the peak finding algorithm. Since the amplitude levels differ with different patients, an adaptive thresholding is carried out. A default valueis initially selected as the threshold. The flowchart for threshold routine is shown in the Fig.3. After 2 seconds a new threshold is updated asthe 25% of the average of last 4 detected peaks.

$$Th_{avg} \;= 0.25 * \frac{1}{4} * \sum_{k\leq 3} Th_k \qquad (3)$$

The intervals between two RR peaks are averaged as described in (4). For every RR_{avg} duration, we will check if a peak is detected or not. If a new peak is not detected then the threshold value is decreased to 75% of its current value.

$$RR_{avg} \;= \left(\frac{1}{4}\right) * \sum_{i=1}^{4} RR_i \qquad (4)$$

D. Peak detection

Once the signal exceeds the threshold value,the peak detection algorithm start to search for the rising edge and falling edge for a particular duration of time. There is still a chance of getting some irregular peaks which may be very close to each other. The rising and falling edge are detected by monitoring continuously the amplitudes over 3 differentpoints which is described in (5) and (6). Once they are detected the algorithm will check the presence of previous peak within the range of 35% of RR_{avg}interval. If no peak is present within this duration then a new peak is immediately declared. Peak detection and close peak elimination procedure is shown in the Fig.4.

$$\bigwedge_{j=0}^{2} eno(i-j) - eno(i-j-1) > 0 \qquad (5)$$

$$\bigwedge_{j=0}^{2} eno(i+j+1) - eno(i+j) < 0 \qquad (6)$$

III. DETECTION OF CARDIAC ABNORMALITIES.

After the QRS detection the RR interval is calculated. Then the heart Rate can be calculated and the heart arrhythmias such as Bradycardia and Tachycardia are determined from this.

A. Heart Rate Calculation

Once the RR interval is found the heart rate can determined using following equation.

$$Heart\ rate = \frac{60}{RR\ Interval}\ (bpm)(7)$$

B. Bradycardia

In normal condition or at rest the heat rate for most of the people is in between 60 to 100 beats per minute. For some people heart rate at rest will be less than 60 bpm. Being a heart rate lesser than 60bpm indicates a condition called bradycardia. Bradycardia, which indicates a problem related to heart’s electrical system. There aretwo main reasons for bradycardia: 1) when the heart’s natural pacemaker stops working normally and 2) When the electrical pathways of heart are disrupted. In severe cases, the heart rate will become very less and it result in a condition where heart is unable to pump enough blood to different parts of the body.

C Tachycardia

The Irregular heart rate more than 100 bpm at rest result in a condition called tachycardia. In a person having tachycardia the lower and upper chambers of heart will start to beat faster. When heart beat rapidly increases, it will not be able to pump blood to all part of the body efficiently. Tachycardia usually don’t show any symptoms, but it increases the risk of sudden cardiac arrest, stroke etc.

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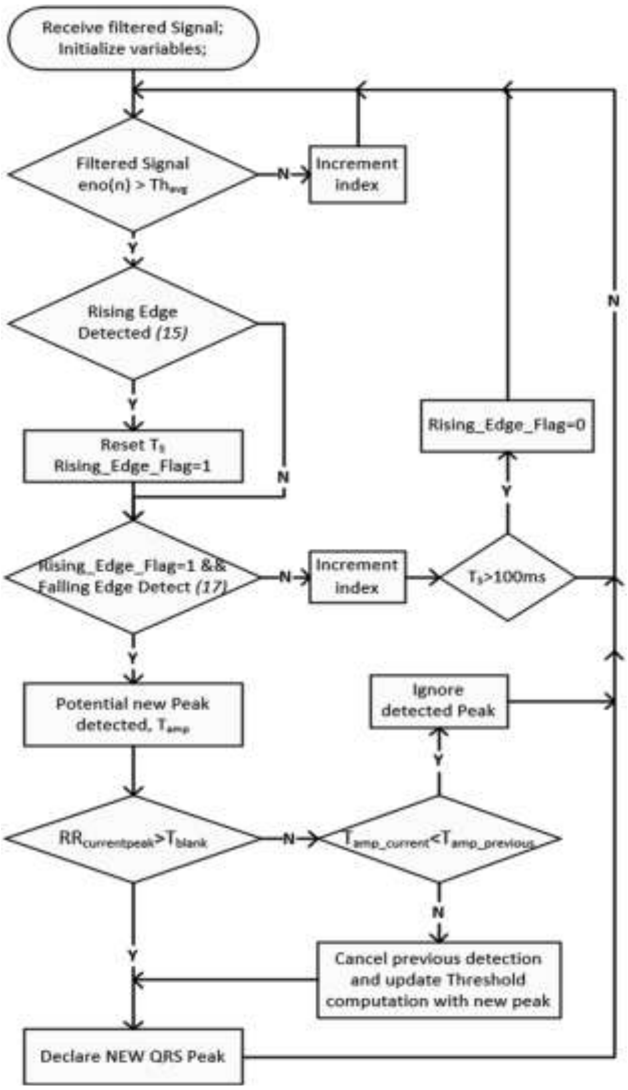

Fig.4.Peak detection of QRS Segment

IV. SOFTWARE FRAMEWORK

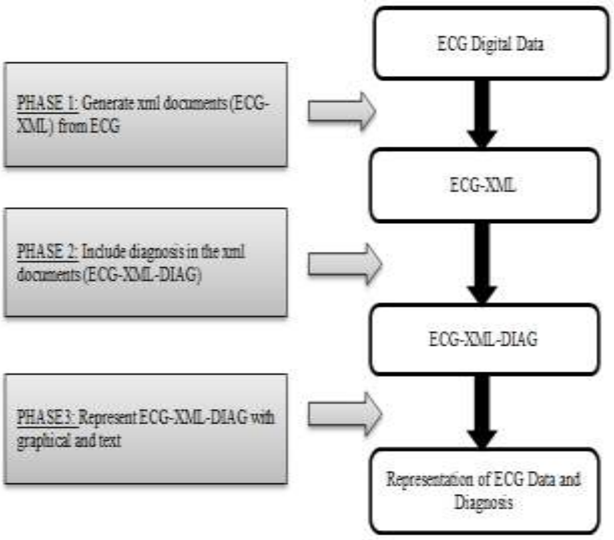

Fig.5.Block diagram of Software Framework

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To display the output in a common platform suchas the internet browser we need to convert the input ECG data into a common data format that can beexchanged in between various computing platforms. Extensible Markup Language (XML) is used for displaying the ECG analysis result in an internet browser. Flowchart for the software development framework is shown in the Fig.5.

IV.RESULTS AND DISCUSSIONS

An interoperable system that detects the abnormal condition of the heart such as Bradycardia and Tachycardia are detected with more than 90% success rate. There are various algorithms available for QRS detection in ECGs. Since dealing with the Human life directly,all QRS detection algorithms maintains accuracy about 99%. Out of these PanTompkins algorithm is the popular and most commonly used for QRS detection [5]. Both our algorithms and Pan Tompkins algorithm are evaluated using a standard data base of two channel 48 half-hour ECG recordings, named MIT-BIH database [10]. Theparameters used for evaluating these algorithms are error rate (ER), sensitivity(Se) and positive predictivity (+P), as described in (8), (9) and (10).

$$ER\ (\%) = \frac{FP + FN}{Total\ QRS} \quad (8)$$

$$Se(\%) = \frac{TP}{TP + FN} \quad (9)$$

$$+P(\%) = \frac{TP}{TP + FP} \quad (10)$$

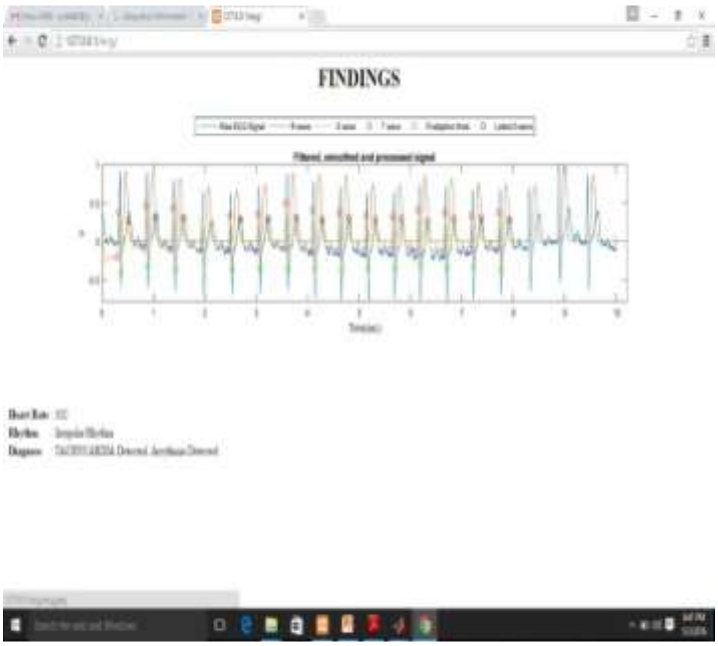

Fig. 6.The experimental result

True positive (TP) occurs when R peaks are detected correctly by an algorithm. False negative (FN) occurs when an actual peak in the annotation file is not detected by the algorithm. False positive (FP) correspond to detection of a false beat. Table I shows the overall comparison of Pan Tompkins and the proposed algorithm.

The proposed QRS detection algorithm in comparison with Pan Tompkins algorithm has lower computational complexity and error rate.

TABLE I COMPARISON OF ALGORITHM

Methods	Total QRS	FN	FP	ER (%)	Se (%)	+P (%)
Pan Tompkins	109508	277	507	0.72	99.74	99.53
Proposed Algorithm	109508	395	201	0.54	99.64	99.81

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The proposed QRS detection algorithm need only fewer filters compare to Pan Tompkins algorithm. As there is a need of proprietary software to display the ECG recordings, depending on the company which build the ECG machine, the result done of this research can be shared in any computing platforms and can be viewed in an Internet browser makes it cheap and readily available. The output of the research is shown in the Fig.6.

V. CONCLUSION

The developed interoperable system that automatically detects the abnormal cardiac condition such as Bradycardia and Tachycardia provides the structure to display the ECG analysis result in an open source such as Internet Browser. This system can be used as an aid to doctors for the diagnosis of ECG. Since there is no need for the proprietary software to view the result of ECG analysis, it will be more cost efficient. Fast diagnosis result and the ability to openly exchange the patient’s diagnosis report anywhere increases the overall healthcare. Since the ECG report can be viewed by the doctors anywhere in the world using an internet browser the system provide a smart and fast Healthcare.

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BIOGRAPHIES

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