ECG Noise Removal and its Analysis: A Review

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***Abstract*—**Heart disease is one of the leading causes of death worldwide. One of the efficient way to diagnose heart disease is the electrocardiogram (ECG). The electrical activity of the heart is translated into a waveform, which is used to find the position of the heart. The proposed work deals with the comparative study of previous work done in this field. Different researchers have used different approaches such as undecimated wavelet transform, discrete wavelet transform, fast fourier transform, neural networks analysis, digital filter(IIR or FIR) etc to achieve the result and mostly work has been done in MATLAB and LABVIEW environment. The method used have their own advantage and disadvantage. The algorithms used in previous works are complicated so there is a requirement of simple and efficient way of ECG analysis which will be helpful in detecting various problems related to the heart. ECG analysis involves three basic steps. The first step involves receiving the raw ECG signal through serial port interfacing. The received raw ECG is contaminated with various kinds of noise so the second step involves removal of these noise from the signal using digital filters such as low pass filter, high pass filter, notch filter etc in MATLAB simulink and the third step involves detection of various peaks and finding intervals between those peaks in MATLAB environment. The algorithm used in this work is very efficient and it can be easily implemented on ECG signal.

Keywords*—ECG; MATLAB; Serial interface; digital filter; peaks; intervals.*

I. INTRODUCTION

Maximum number of death in the world is caused by cardiovascular diseases (CVCs). CVCs was responsible for the death of 17.5 million population of the world according to the estimate of 2012, which comprised of 31% of world death. The threat of heart disease increases with the increasing age. The various abnormality related to the heart is shown in table1. Different test which can be done to diagnose your heart disease are Electrocardiogram, Cardiac Catheterization, cardiac computerization tomography (CT) Scan, Cardiac Magnetic Resonance Imagination (MRI).

The upper two chambers of a heart are called atria while the two lower chambers are called ventricles. The heart muscle is contracted and the blood is pumped through the heart to the lungs and the rest of the body by a natural electrical system generating their action potential. The electrical currents are created by this potential that spreads from the heart to the rest of the body.

The spread of electrical currents in the body shows different electrical potential at different locations of the body. When the electrodes are placed on the skin, it records and detects electric potential.

Table 1: Heart related abnormality and their characteristic feature

Name of Abnormality	***Characteristic Feature***
Tachycardia	Heart rate> 100 bpm
Bradycardia	Heart rate< 60 bpm
First Degree Heart Block	Long PR Interval
Second Degree AV Block	QRS Dropped
Sinoatrial Block, Asystole	Complete Drop Out of a Cardiac Cycle

Among all the test ECG is a painless and simple test which detects and records the electrical activity of the heart. ECG is the cardiac electrical potential waveform generated by the bio-potentials. The duration and magnitude of the electrical activity that is generated by depolarisation and repolarisation of the atria and ventricles is known as ECG graphic record. One cardiac cycle in ECG consists of P wave, QRS complex, T wave and in some cases U wave is also present. The ECG is used for diagnosing many diseases related to the heart. ECG is found to have most clinically useful information in the intervals and amplitude of its features i.e. characteristics waves peaks and time intervals. When an electrical sensing device is placed at suitable locations of body, ECG is obtained. The frequency range of normal ECG signal is 0.05 to 100 Hz or cycle per second. The recorded ECG signal can suffer various kinds of noise such as powerline interference(50 or 60 Hz), motion artifacts, baseline drift, electromyographic noise. Before analyzing the ECG waveform these noise has to be removed so that various peaks and intervals can be obtained accurately[1].

Lots of research has been done in the area of ECG noise removal and their analysis. Several methods are used for this purpose such as undecimated wavelet transform, discreate wavelet transform, fast fourier transform, neural networks analysis, digital filter (IIR or FIR) etc and these methods can be successfully implemented in the MATLAB or LABVIEW environment.

II. ECG WAVEFORM PARAMETERS

Typical ECG waveform is shown in the figure 1.

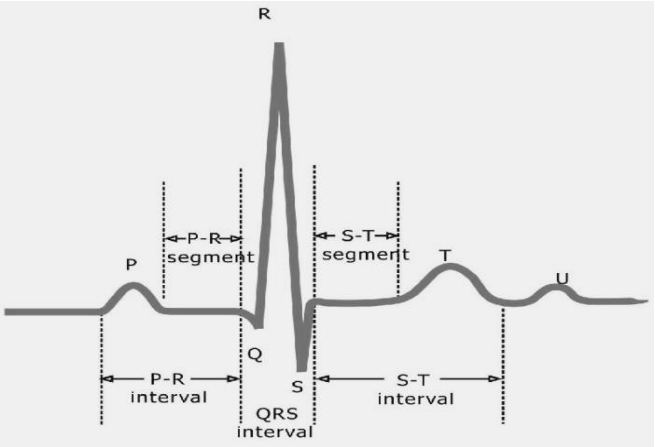

Fig.1: Typical ECG waveform

A. PQRST Intervals: P wave, QRS complex and a T wave are the part of a typical ECG tracing of normal heartbeat. U wave is normally found in 50% to 75% of the graph.

B. P Wave: The atrial contraction is caused by P wave in which both the atrias contract simultaneously. A heart block is determined by its relationship to QRS complexes. Arrhythmia is indicated by an irregular or absent P waves. The atrial disorder is indicated by the shape of the P wave.

C. QRS Complex: Ventricular depolarization is represented by QRS complex. It is larger than P wave because of greater muscle mass of ventricals. Its normal duration is 0.08-0.10 seconds. Its duration, amplitude, and morphology are useful in diagnosing cardiac arrhythmias, ventricular hypertrophy, MI, electrolyte derangement, etc. Q wave greater than 1/3 the height of the R wave, greater than 0.04 sec are abnormal and may represent MI.

D. T Wave: The repolarization of the ventricles is represented by T waves. The absolute refractive period is the gap between the QRS to the apex of T.

E. PR interval: The starting of P wave to the initials of QRS complex measures the PR interval. 0.12 - 0.20 sec is its normal duration which represents its atria to ventricular conduction time. The first degree heart block is indicated by a prolonged PR interval while an accessory bundle is indicated by a shorting.

F. QT interval: The beginning of the QRS complex to the end of the T wave measures the QT interval. The heart rate is determined by the QT interval which is usually about 0.42 seconds.

Table 2: Standard value of various peaks in ECG [2]

	Standard value
Heart rate (avg.)	60-100 beats/min
P Peak (lead I)	0.03-0.15 mv
Q Peak(lead I)	<25% of R Peaks
R Peak(lead I)	0.5-2.5 mv
T Peak(lead I)	0.1-0.5mv
QRS Interval(lead I)	0.09 sec(approx.)

Table 3: Standard Duration of various waves in ECG[1]

	Standard duration
RR Interval	0.6 sec to 1.2 sec
P Wave	80 msec
PR Interval	120 to 200 msec
QRS Complex	80 to 100 msec
ST Segment	80 to 120 msec
T Wave	160 msec
ST Interval	320 msec
QT Interval	Up to 420 msec (in heart rate of 60 bpm)

G. ST segment: It connects the QRS complex and T wave and has duration of 320 sec.

III. NOISE IN ECG

The noise and the artifacts generally contaminate the recorded signal which can be within the frequency band of interest and manifest with similar characteristic as the ECG signal itself. Processing is done to extract basic ECG signal from noisy ECG signal. There are two steps of ECG signal processing:

1) Preprocessing and 2) Feature extraction.

The Preprocessing stage removes or suppresses noise from the raw ECG signal. The diagnostic information from the ECG signal is extracted at the feature extraction stage. There are following types of ECG noise [3]:

A. Power line interference
B. Baseline drift
C. Patient-electrode motion artifacts
D. Composite noise

A. Power line interference

It is one of the main source of noise. The Electromagnetic Interference (EMI) from 50/60 Hz powerline noise influences the ECG signals which is carried by the data cable from the patient to the display devices. The tiny features and the signal quality is affected by the noise which can be critical for clinical diagnosis, monitoring and signal processing.

B. Baseline drift

A sinusoidal component at the frequency of respiration added to the ECG signal represents a baseline drift. It is mainly due to the respiration of amplitude of around 5% of frequencies around 0.15 and 0.3 Hz. The detection of ECG signal is difficult due to the drift.

C. Patient-electrode motion artifacts

The patient movement or loss of electrode contact causes motion artifacts while the alteration in the electrode skin impedance with electrode motion causes transient baseline change.

D. Composite noise

Composite noise is the combination of all the above mentioned noise.

IV. RELATED WORK

Detecting heart problem on time is very important otherwise it can be dangerous and life threatening. Lots of research has been done in the field of ECG analysis using different techniques. Every technique has its own advantage and disadvantage. Comparison of digital filter and wavelet transform approach in MATLAB and LABVIEW has been done. Digital filter doesn't give accurate result for non stationary signal. Wavelet is superior to the conventional Fast Fourier Transform method in finding the small abnormalities in ECG signals but Wavelet is not suitable when high reliability is needed [4]. Undecimated Wavelet Transform (UWT) has been used for diagnosing the signal. The invariant translation characteristic, better noise reducing capacity and better peak detection is found in UWT, but computationally UWT based method is less efficient[5][6]. The study and analysis of ECG waveform is done for detecting abnormalities present in P, Q, R, S and T peaks. Comparison between conventional filter and adaptive filter is also done which gives the result that Adaptive filter is more convenient **but** it amplified the S-peaks in some cases [7].

Identification of various type of noise which corrupt the ECG signal has been done. Digital filters such as high pass, low pass, notch filter and band pass are used to suppress the noise. These filters are stable but always have some ripples. Moving averaging filter are used for smoothing out the signal and removing powerline noise [8][9].

Software digital filters are implemented in order to effectively eliminate the noise from the ECG signals and comparison between FIR and IIR filter is done. For ECG signal processing FIR filter is preferred due to its linear phase property. But for the FIR filter higher order is required [10] Digital FIR filters with Kaiser Window has been designed, which is used to remove the interferences or the artifacts in the waveform. Here these filters are used to filter the raw noisy ECG signal. Results are found out using FDA tools [11].

The effect of various filtering stages on the noisy ECG signal has been examined to approximately estimate the order of each filter stage to get the required quality. By increasing the order of the filter system the signal to noise ratio improves but at the same time number of components increases and so more power dissipation [12].

MATLAB implementation of LMS (least mean square), RLS (recursive least square), NLMS (normalized least mean square) algorithm has been done and their results has been compared in noise removal application [13]. This paper deals with the overview of all the filters such as IR, notch, adaptive filter etc used to remove baseline drift from ECG signal. It also includes the comparative study of all type of digital filters which are used to get noise free signal [14]. The method of estimating ECG parameters has been discussed which includes three steps. First step uses discrete wavelet transform (DWT) technique to remove low-frequency component. Second step also uses the same method DWT to denoise the signal which consists of three procedures such as signal decomposition, thresholding of DWT coefficient, and finally the signal reconstruction. The third step is the feature extraction of the processed ECG (PQRST) signal [15].

The development and evolution of ECG feature extraction system has been proposed which is based on multi-resolution wavelet transform. The result of two wavelet transform filters (D4 and D6) on the signal are compared, filters are of different length. Wavelet filter having scaling function close to ECG is chosen. First the noise is removed by corresponding wavelet coefficients at higher scales and then detection of QRS complex is done in order to find various peaks of ECG [14]. Method of analyzing ECG signal and its feature extraction has been discussed. Peaks of the ECG signal are identified by using Fast Fourier Transform and the various diseases are identified by using neural networks method [16].

V. PROPOSED WORK

The above discussed techniques for ECG analysis involve complicated algorithms so this work is proposed which involves quick and simple method for ECG analysis. ECG analysis can be divided into two steps namely Preprocessing and feature extraction. Preprocessing removes noise from recorded ECG signal and feature extraction extracts useful information such as position of various peaks and their intervals.

A. Recording ecg signal

ECG signal is to be recorded from ECG card through serial communication. In laptops COM port is not available so one of the USB port will be converted to com port for this purpose and then data will be received through COM port. ECG signal will be received in MATLAB simulink. In this case baud rate of 9600 bps will be used and the data bit will be chosen as 8 bit, data bit is the number of bits to be transmitted over the serial port and the signal will be saved as a MATLAB file which can be used further in the next step.

B. Preprocessing

Filter circuit in MATLAB simulink will be designed to remove various noise in recorded ECG signal. The signal received from serial communication block will be used as an input in the filter circuit. Among all, the most significant noise

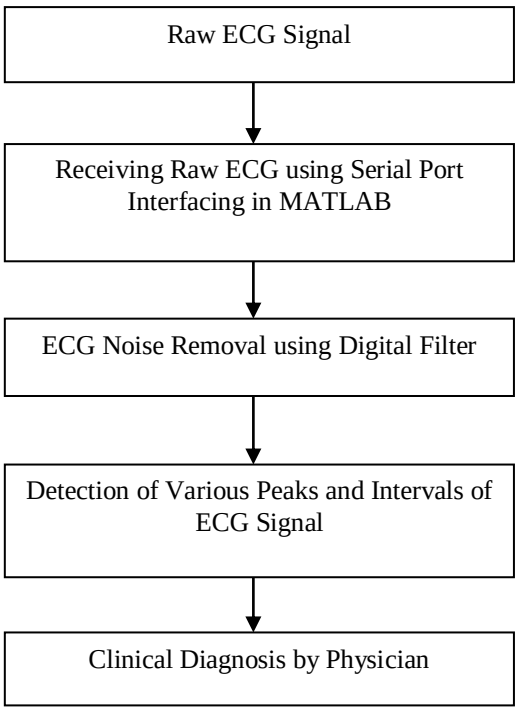

Fig.2: Methodology of the work

is the power line interference and the baseline drift, they strongly effect the ECG signal analysis.

In this case two butterworth notch filters of order 10 will be used, one of 50 Hz and another of 100 Hz having bandwidth of 2 Hz to suppress power line interference (50hz,100hz). An equiripple FIR high pass filter of 100 order and cut off frequency of 1hz to suppress baseline drift (0.15-0.3hz). Equiripple low pass filter of 400 order and cutoff frequency 150 hz will be used because all the useful information lies within 150 frequency range. The performance of the filter circuit will be measured by PSNR (peak signal to noise ratio). The output of the circuit will be saved as MATLAB file which can be further used for feature extraction [17].

C. Feature extraction

Detection of QRS, PR, RR, ST intervals and amplitude of various peaks of ECG signal will be performed in MATLAB. The algorithm involved in this will be that the whole of the ECG signal will be divided into positive and negative halves. Bracketing will be done of consecutive nonzero positive part and the local maxima will be detected in the selected portion of the waveform. Maximum among 5 local maxima will be the R peaks and accordingly remaining peaks will be detected as P,Q,R,S,T are always in the same sequence. The intervals are detected by measuring the distance between various peaks. Similarly negative portion of the signal is also analysed.

VI. CONCLUSION AND FUTURE SCOPE

Detection of heart problem and its treatment on time is very important otherwise it can be life threatening and can even cause death. One of the efficient way of measuring the condition of the heart is ECG. The proposed work is very simple and effective method for ECG analysis. This work involves various steps initially ECG signal will be received through serial port interfacing and then noise will be removed from the signal and at last detection of various peaks and intervals between them will be calculated. Filtration of raw ECG signal will be done in MATLAB simulink using different digital filters according to the range of frequencies to be removed and their order will be decided depending upon the amount of accuracy required, while the peak detection and calculation of various interval will be done in MATLAB editor.The ECG signal will be divided into positive and negative halves. Various peaks will be detected by finding local maxima and minima of the signal and then setting minimum threshold limit for them. The result obtained can be used for clinical diagnosis by the physician and will be very helpful in finding various abnormalities in the heart.

In future improvement can be done in this project such that ECG signal can be transmitted to distant place via mobiles or internet for further storage and investigation if required [18].

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