

Analysis of Electrocardiograph (ECG) Signal for the Detection of Abnormalities Using MATLAB

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Abstract—The proposed method is to study and analyze Electrocardiograph (ECG) waveform to detect abnormalities present with reference to P, Q, R and S peaks. The first phase includes the acquisition of real time ECG data. In the next phase, generation of signals followed by pre-processing. Thirdly, the procured ECG signal is subjected to feature extraction. The extracted features detect abnormal peaks present in the waveform. Thus the normal and abnormal ECG signal could be differentiated based on the features extracted. The work is implemented in the most familiar multipurpose tool, MATLAB. This software efficiently uses algorithms and techniques for detection of any abnormalities present in the ECG signal. Proper utilization of MATLAB functions (both built-in and user defined) can lead us to work with ECG signals for processing and analysis in real time applications. The simulation would help in improving the accuracy and the hardware could be built conveniently.

Keywords—ECG Waveform, Peak Detection, Arrhythmia, Matlab.

I. INTRODUCTION

ELECTROCARDIOGRAM (ECG or EKG) is a diagnostic tool that measure and records the electrical activity of the heart in exquisite detail. Interpretation of these details allows diagnosis of wide range of life threatening heart conditions as referred from [1] and [2]. The current is diffused around the surface of the body. An ECG is generated by a nerve impulse stimulus to the heart. The current at the body surface will build a voltage drop, which is a couple of microvolt to millivolt with an impulse variation. This is very small amplitude of impulse, which requires a couple of thousand times amplification. A typical ECG tracing of a normal heart rate (or cardiac cycle) consists of a P wave, QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. The baseline voltage of ECG is known as isoelectric line. Typically, the isoelectric line is measured as the portion of tracing following the T wave and preceding the next P wave. Electrical activity of the heart can be recorded at the surface of the body using an electrocardiogram. Therefore, the electro-cardio-gram (EKG) is simply a voltmeter that uses up to 12 different leads (electrodes) placed on designated areas of the body. Fig. 1 shows typical ECG trace as referred [2]. The electrical activity of the heart is generally sensed by monitoring electrodes placed on the skin surface. The electrical signal is very small (0.0001 to 0.003). These signals are within frequency range of 0.05 to 100Hz (Hertz) or cycle

per second. In ECG signal processing, instrumentation amplifier plays major role since signal generated by human body are very low in amplitude. High gain must be obtained with high common-mode rejection ratio (CMRR). ECG signals are very noisy, usually 50Hz. MATLAB was used to test and adjust a digital filter as referred from [3], in order to obtain a good QRS complex noise free, which represents the ventricular depolarization in the ECGs, i.e., it shows the electrical impulse of the heart as it passes through the ventricles.

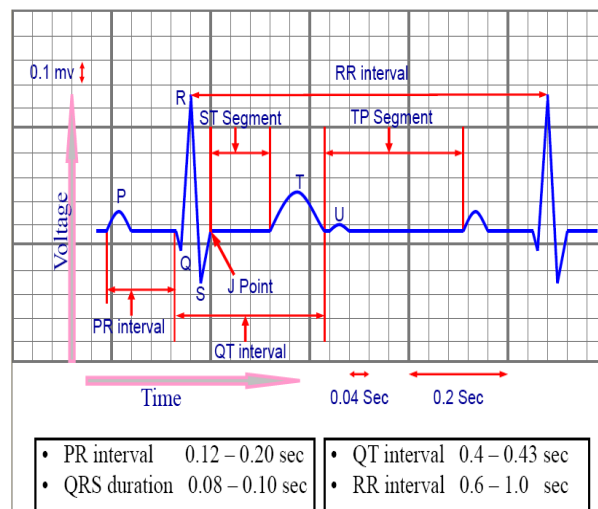


Fig. 1 Typical one-cycle ECG signal tracking

II. METHODOLOGY

The methodology of the proposed work can be predicted from Fig. 2.

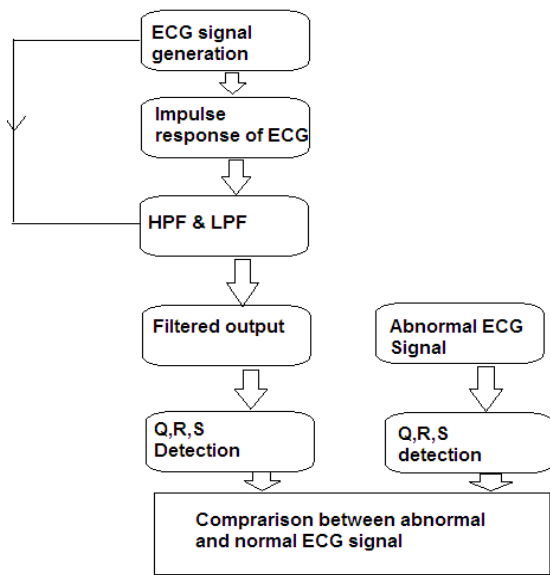


Fig. 2 Typical Block diagram of complete process

III. ECG SIGNAL GENERATION

The ECG signal is generated by the MATLAB code from real time data. The objective is to produce the typical ECG waveforms of different leads and as many arrhythmias as possible. This technique has many advantages in the simulation of ECG waveforms. Firstly saving time, secondly removing noise and thirdly Q,R,S detection in an easy manner.

A. Significant Features of ECG Waveform

A typical scalar cardiogram lead is shown in Fig. 1, the significant features of waveform are the P, Q, R, S waves, the duration of each wave and time intervals such as P-R, S-T and Q-T intervals. ECG signal is periodic with fundamental frequency determined by the heartbeat. It also satisfies the Dirichlet's condition. Hence, Fourier series can be used to represent an ECG signal. If we observe Fig. 1 carefully, we may notice that a single period of an ECG signal is a mixture of triangular and sinusoidal waveforms. The significant feature of ECG signal can be represented by shifted and scaled versions. Such one waveform is shown in Fig. 3.

- QRS, Q and S portion of ECG signal can be represented by triangular waveforms.
- OP, T and U portions can be represented by triangular waveforms.

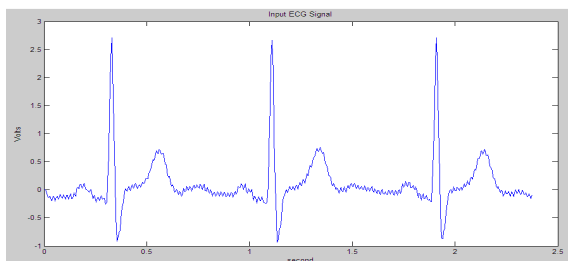


Fig. 3 Typical ECG waveform in MATLAB

The generated output signal by MATLAB is shown in Fig. 3. The specifications are default for this signal which can be changed according to the user's requirement while simulating the MATLAB code.

IV. ECG SIGNAL PROCESSING

Generally, the recorded signal is often contaminated by noise and artifacts that can be within the frequency band of interest and manifest with similar characteristic as the ECG signal itself. In order to extract similar noisy ECG signals, we need to process the basic ECG signal.

ECG signal processing can be roughly divided in to two stages:

- 1) Preprocessing
- 2) Feature extraction.

The preprocessing stage removes or suppresses noise from the raw ECG signal. The feature extraction stage extracts diagnostic information from the ECG signal referred as from [4]. Preprocessing ECG signals help us remove contaminants from ECG signals. ECG contaminants can be classified into the following categories referred as from [5]:

- Power line interference
- Electrode pop or contact noise
- Patient-electrode motion artifacts
- Electromyographic (EMG) noise
- Baseline wandering

Among these noise, the power line interference and the baseline wandering are the most significant and they can strongly affect ECG signal analysis. Except for these two noises, other noises may be wideband and usually complex stochastic process which also distort the ECG signal. The power line interference is narrow-band noise centered at 60 Hz (or 50 Hz) with a bandwidth of equal or less than 1 Hz. Usually the ECG signal acquisition hardware can remove the power line interference. However, the baseline wandering and other wideband noises are not easy to be suppressed by hardware equipments. Instead, the software scheme is more powerful and feasible for offline ECG signal processing. We can use the following MATLAB code method to remove the noise. Figs. 4 (a) and (b) represent the filtered output of noisy ECG signal.

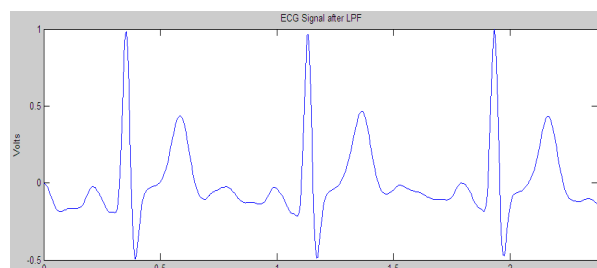


Fig. 4 (a) Typical Low pass filtered output of noisy ECG signal

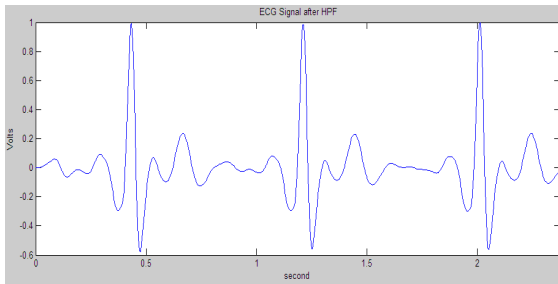


Fig. 4 (b) Typical High pass filtered output of noisy ECG signal

A. QRS Complex Detection

The detection of the R-peaks and consequently of the QRS complexes in an ECG signal provides information about the heart rate and the conduction velocity. It also bears the information about the condition of tissue within the heart as well as various abnormalities. It supplies the evidence for the diagnosis of cardiac disease. For this reason, it has drawn considerable attention in the ECG signal-processing field. However, the presence of the noise and time-varying morphology makes the detection difficult. Fig. 5 shows the peak/valley detection from original ECG signal. The peaks and valleys (especially Q, R and S points) become more distinct after this analysis. After extracting the feature of QRS complex detection, we can analyze the feature with others methods. For example, we can perform heart rate variability (HRV) analysis on the R-R interval signal to demonstrate the state of the heart and the nerve system.

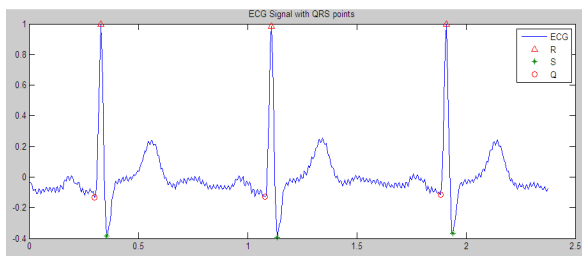


Fig. 5 Typical peak representation of normal ECG signal

B. Abnormal ECG Signal (ARRHYTHMIA)

An arrhythmia (ah-RITH-me-ah) is a problem with the rate or rhythm of the heartbeat. While an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm. A heartbeat that is too fast is known as tachycardia. A heartbeat that is too slow is known as bradycardia. Most arrhythmia are harmless, but some can be serious or even life threatening. During an arrhythmia, the heart may not be able to pump enough blood to the body. Lack of blood flow can damage the heart, brain, and other organs. Fig. 6 shows arrhythmia representation of the heart and Fig. 7 shows peak representation of abnormal signal.

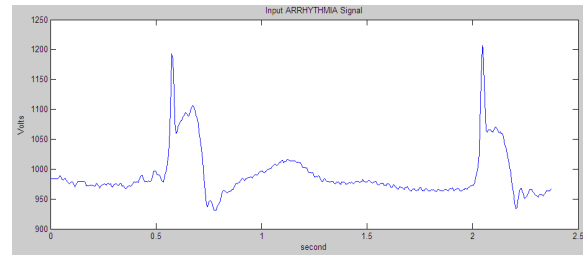


Fig. 6 Arrhythmia signal (Abnormal ECG signal)

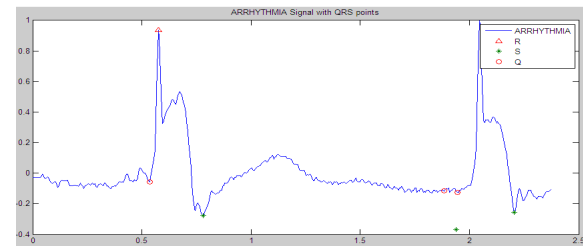


Fig. 7 QRS complex representation in abnormal signal

V. COMPARISON BETWEEN DIFFERENT PROCESSING TECHNIQUES

Though, the non-adaptive filtering is faster than the adaptive filtering methods, based on some optimum value gives the best results as referred [6]. Though Adaptive filtering amplified the S-peaks in some case, it does not give any serious distortion effects onto the signal. However, this approach is more convenient than the conventional filtering techniques, which highlights the details of the ECG signal with optimal time-frequency resolution.

VI. COMPARISON BETWEEN NORMAL AND ABNORMAL ECG SIGNAL

In normal ECG, the time interval between R-R is 0.6-1 second, in case of fast heartbeat the time interval is less than 0.6 second which is known as sinus tachycardia; in case of slow heartbeat the time interval is more than 1 second which is known as sinus bradycardia. By referring Fig. 8 (a) we can say that the R-R interval for normal case is between 0.6-1 second and from Fig. 8 (b) we can say that the R-R interval for abnormal (Arrhythmia signal) case is greater than 1 second that is known as sinus tachycardia abnormalities. Table I highlights the difference between peak value of Q, R and S which are negative, positive and positive which represent normal ECG signal but from Table II we can say that the difference of peak value of Q, R and S are positive, positive and negative which represent the sinus tachycardia signal (Arrhythmia signal).

TABLE I
NORMAL ECG SIGNAL

	VOLTS	VOLTS
Q PEAK	-0.1303	-0.1147
R PEAK	0.9996	0.9838
S PEAK	-0.3843	-0.3926

TABLE II
ARRHYTHMIA (ABNORMAL ECG) SIGNAL

	VOLTS	VOLTS
Q PEAK	-0.0555	-0.1246
R PEAK	0.9355	1
S PEAK	-0.2767	-0.2585

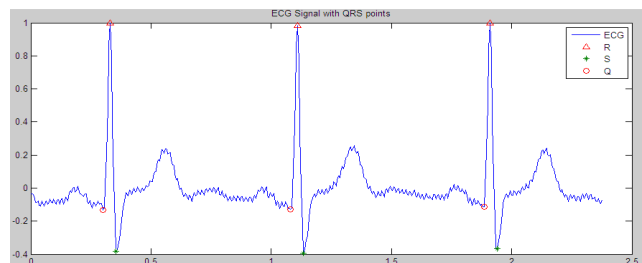


Fig. 8 (a) Representation of normal ECG signal with peak

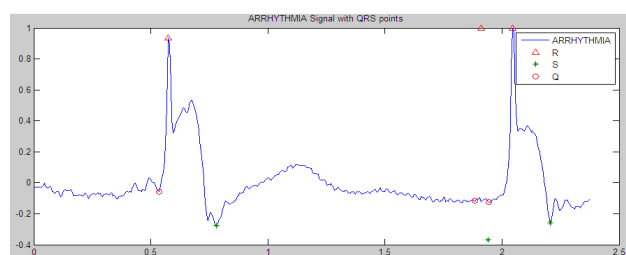


Fig. 8 (b) Representation of abnormal ECG signal with peak

VII. CONCLUSION

MATLAB has immense effect on ECG signal processing. It is so useful and handy that everyone can monitor his/her heart condition simply utilizing the power of MATLAB. The above discussed examples and techniques can be utilized for real time experimental/lab purpose. One of the crucial steps in the ECG analysis is to accurately detect the different waves namely P, Q, R and S depicting the entire cardiac cycle. The methodology is definitely a new approach to detect points and nonstandard shapes present in the ECG signals. This proposed work could be continued to further improve the algorithm to detect abnormalities and implement this system to find deposits of arrhythmia in the heart by using calculations of intervals between impulses of two different signals in real time. For processing and design of detection algorithms, MATLAB is used, in which they were implemented as mathematical signal processing operations and statistical analysis of test results.

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