Heart Rate Monitoring and PQRST Detection Based on Graphical User Interface with Matlab

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***Abstract*—An electrocardiogram (ECG/EKG) is an electrical recording of the heart and is used in the investigation of heart disease. This electrical activity of the heart translates into line tracings on paper. The spikes and dips in the line tracings are called series of waves. This series of waves consists of six different waveforms, are discernible, and are differentiated as P, Q, R, S, T and U. The most of earlier method of ECG signal analysis for detecting PQRST was based on DSP technique for example (Wavelet Transform and Fast Fourier Transform) and Artificial Neural networks. While this work proposes a simple and dependable method to detect the P, Q, R, S and T values of an electrocardiogram (ECG) signal. This method is based on finding a mathematical relationship between the highest values (peaks and valleys) of the ECG waveform and time. In this proposed method is exemplified by designing a graphical user Interface (GUI) by using MATLAB for detecting PQRST by using simple mathematical algorithm to get PQRST values and draw these values on ECG wave at the same time. This program will be devoted to the purposes of scientific research instead of clinical diagnosis.**

***Index Terms*—GUI with MATLAB, QRS complex analysis, heart rate detection, ECG leads, ECG extraction and methods.**

I. Introduction

The electrocardiogram, or ECG, is the most common test used to assess the heart. The ECG is vastly used because it is capable to screen for a variety of cardiac abnormalities, ECG machines are easily available in the most of medical facilities, and the test is simple to perform, (risk-free and inexpensive). From the ECG tracing, the following information can be identified [1]:

- The heart rate.
- The heart rhythm.
- Whether the heart muscle has become abnormally thickened.
- Whether there has been a prior heart attack.
- Whether there may be coronary artery disease.
- Whether there are “conduction abnormalities” (abnormalities in how the electrical impulse spreads across the heart).

All of these traits can be significant and important.When the ECG indicates a heart attack or possible coronary artery disease. Extra testing is usually done to entirely determine the kind of the problem and determine the best treatment. (These tests often include a cardiac catheterization and stress test.) An echocardiogram is often ordered when the heart muscle is thickened in order to look for possible valvular heart disease or other abnormalities. It is easy to know through Changes in the electrical pattern of the electrocardiogram may give clues to the reason of fainting, or may indicate potential heart disease. An electrocardiogram is a graphical record of bioelectrical signal generated by the human body during cardiac cycle [2]. It is Possible to obtain useful and important information through the chart of the ECG that relates to the functioning of the heart through the baseline and waves representing the voltage changes of heart during a period of time [3]. The ECG is very important and has a particular value in the next clinical cases [4]:

- Myocardial Infarction (heart attack).
- Pericarditis.
- Electrolytic transformations
- Auricular and ventricular hypertrophy.
- Arrhythmias.
- Cardiac medicine effects, especially digital and quinidine.
- Generalized suffering affecting heart and blood pressure.

This paper presents a software package. The software has been developed for the purpose of scientific research rather than clinical diagnosis. In this paper, a MATLAB program includes standardized graphical user interface (GUI) for the analysis of P, Q, R, S and T values. All of the parameters are computed from the ECG recordings. Loading ECG recordings from any source of data as text or binary files and excel files. The paper is structured as follows: Section II givesa brief review of the ECG extraction methods. Section III summarizes continuous of the ECG waveforms and leads. Section IV focuses on the software which analysis ECG signal to get P, Q, R, S, and T values. Section V presents the results that have been achieved in this paper. And finally conclusions are drawn in Section VI.

II. ECG Extraction Methods

The recording of Electrocardiogram (ECG) signal plays an important role in the early diagnosis of heart disease which is after that studied and analyzed using a microcontroller. Through analyzes of ECG may be obtained on the measurements of the rate and regularity of heartbeats in addition to the size and position of the chambers, the presence of any damage to the heart and the effects of drugs or devices used to regulate the heart. Diagnosis of cardiovascular disease by using Electrocardiogram signals, this can be achieved either through the connected the sample of the ECG signal with a normal healthy signal, characterizing the normal ECG signal using basic logical

Manuscript received September 10, 2014; revised November 21, 2014. Heart Rate Monitoring and PQRST Detection Based on Graphical User Interface with Matlab.

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DOI: 10.7763/IJIEE.2015.V5.550

decisions, or more complicated algorithms to handle in depth the heart disease [5]. In recent years, many studies and mathematical analyzes have been developed for the exertion of analyzing the ECG signal; all of these studies or techniques and algorithms which have been proposed during the last decade includes Artificial Neural Network, Fuzzy Logic methods, Digital Signal Analysis, Genetic Algorithm, Support Vector Machines, Hidden Markov Model Self-Organizing Map, Bayesian, Slope Vector Waveform (SVW), Discrete Wavelet Transform (DWT) and Difference Operation Method (DOM) [6]-[11]. All of these methods above have been dealing with the PQRS complex detection for ECG signals. For examples, Slope Vector Waveform (SVW), in this method proposed an algorithm to detect ECG QRS complex and evaluate RR interval. Through this technique provide quickly and accurately search for the R location, RR interval and QRS complex duration, and gives excellent results ECG feature extraction [12].While the Discrete Wavelet Transform (DWT) method states to extract the relevant information from the ECG input data in order to perform the classification task. Their proposed work includes number of disjoint processing modules which are data acquisition, Pre-processing beat detection, feature extraction, and classification. In the feature extraction module the Wavelet Transform is designed to address the problem of non-stationary ECG signals. It was derived from a single generating function termed the mother wavelet by dilation and translation processes. By using this technique in feature extraction can get to big advantage is that it has a varying window size, narrow at higher frequencies and broad at lower frequencies, which leads to an optimal time-frequency resolution in all frequency ranges. [13] Difference Operation Method (DOM) is used for detecting the QRS complex of an electrocardiogram signal, this technique includes two processes, one is the difference operation process (DOP) and the other is the waves' detection process. The outline of this technique includes two steps. The first step is finding the point R by applying the difference equation operation to the ECG signal. The second step looks for the points Q and S according to the point R to find the QRS complex [14]. Another different system to determine the features of ECG signal by using neural networks, presented an integral system where this system consists of cepstrum coefficient method for feature extraction from long-term ECG signals and artificial neural network (ANN) models for the classification. From these methods we can recognize features cache inside an ECG signal and then classify the signal in addition to diagnose the abnormalities [15]. While a new technique by using neural networks and wavelet transformation to classify ECG image by extracting their feature. Features are extracted from wavelet decomposition of the ECG images intensity, and then further processed by using artificial neural networks. The features are: mean, median, maximum, minimum, range, standard deviation, variance, and mean absolute deviation [16]. Another method by using Artificial Neural Networks for detecting PQRST through use of the derivative where search for the minimum and maximum of the derivative of a wave .The highest peak (R wave) should be the zero crossing between the maximum and minimum of the derivative. Similarly, the Q point should be at the zero crossing before the maximum and the S point should be at the zero crossing after the minimum. The P and T waves are done similarly by looking for local maximums in the original waveform and then using the derivative to identify peak and end points [17] .While proposed work in this paper has presented a simple and dependable method to detect the P, Q, R, S and T values of an electrocardiogram (ECG) signal. This method is based on finding a mathematical relationship between the highest values (peaks and valleys) of the ECG waveform and time. In this proposed method is based on designing a graphical user Interface (GUI) by using MATLAB to detect PQRST by using simple mathematical algorithm to get PQRST values and draw these values on ECG wave at the same time.

III. ECG Description

An electrocardiogram is a measurement of the electrical activity of the heart muscle which can be obtained from the surface of the skin and from different angles Fig. 1. When the heart muscle contracted and pumping the blood for all parts of body, action potentials will be released through the mechanical process within the heart muscle which leads to electrical activity [18].

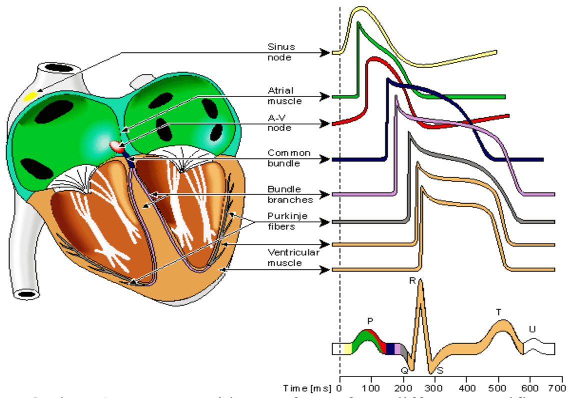

Fig. 1. the heart's anatomy with waveforms from different specific part of the heart [19].

A. ECG Waveform

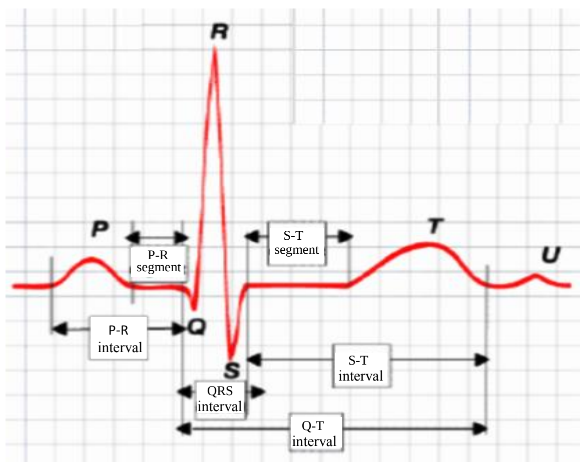

Fig. 2. Typical ECG waveforms [18].

The ECG is the chart of the heart which prints out on paper and record all the electrical activity of the human heart. The normal ECG wave is composed of a series of positive and negative waveforms as following P wave, QRS complex, and T wave. The relationship between P wave and QRS complexes helps distinguish various cardiac irregularities. These waves are shown as in Fig. 2; where the P wave represents the First upward deflection and atrial depolarization. While QRS complex is composed of three waves Q, R and S and represents ventricular depolarization, T wave represents the Repolarization of ventricles and concurrent with end of ventricular systole. [18].

The above Fig. 2 represents a typical ECG waves where the horizontal axis of a wave represents a measure of time while the vertical of a wave which includes height and depth represent a measure of voltage. Where, the first time interval in the horizontal axis is P-R interval which represents the period from the onset of the P–wave to the beginning of the QRS complex. This interval represents the time between the beginning of atrial depolarization and the beginning of ventricular depolarization. The S–T segment following the QRS and describes the part between the end of the S wave (the J point) and the beginning of the T wave and it represents the interval between ventricular muscle depolarization and repolarization. The Q–T interval is a time period between the beginnings of the Q wave to the end of the T wave in the heart's electrical cycle. The QT interval representing the total duration of electrical activity depolarization and repolarization of the ventricles. Table I represents the normal amplitudes range of the ECG waveform [18].

TABLE I: THE NORMAL AMPLITUDES RANGE OF THE ECG WAVEFORM [18]

Wave	Amplitude Range		
	Lead I Potential(mv)	**Lead II Potential(mv)**	**Lead III Potential(mv)**
P	0.015 to 0.12	0.00 to 0.19	–0.073 to 0.13
Q	0.00 to 0.16	0.00 to 0.18	0.00 to 0.28
R	0.02 to 0.13	0.18 to 1.68	0.03 to 1.31
S	0.00 to 0.36	0.00 to 0.49	0.00 to 0.55
T	0.06 to 0.42	0.06 to 0.55	0.06 to 0.3
	Lead aVR Potential(mv)	**Lead aVL Potential(mv)**	**Lead aVF Potential(mv)**
P	–0.179 to 0.01	–0.085 to 0.140	–0.06 to 0.16
Q	0.00 to0.90	0.00 to 0.22	0.00 to 0.19
R	0.00 to 0.33	0.00 to 0.75	0.02 to 0.15
S	0.00 to 0.15	0.00 to 0.90	0.00 to 0.71
T	–0.00 to 0.00	–0.16 to 0.27	0.04 to 0.46
	Lead V1 Potential(mv)	**Lead V2 Potential(mv)**	**Lead V3 Potential(mv)**
P	-0.08 to 0.18	0.15 to 0.16	0.00 to 0.18
Q	–	–	0.00 to 0.05
R	0.00 to o.49	0.04 to 1.52	0.06 to 2.24
S	0.08 to 2.13	0.19 to 2.74	0.09 to 2.22
T	0.03 to 1.22	–0.14 to 1.44	0.00 to 1.60
	Lead V4 Potential(mv)	**Lead V5 Potential(mv)**	**Lead V6 Potential(mv)**
P	0.01 to 0.23	0.00 to 0.24	0.00 to 0.19
Q	0.00 to 0.16	0.00 to 0.21	0.00 to 0.27
R	0.18 to 3.20	0.42 to 2.42	0.25 to 2.60
S	0.02 to 2.09	0.00 to 0.97	0.00 to 0.84
T	0.05 to1.31	0.00 to 0.96	0.00 to 0.67

B. ECG Leads [20]-[22]

Any muscle contraction causes an electrical change – depolarization, these changes can be detected by pairs of electrodes placed on the surface of the body by using ECG leads, these Lead indicates to an imaginary line between two ECG electrodes and these leads consist of 12-leads, each one of these leads represent electrical activity from a different angle on the heart muscle. This leads to the 12 different electrical pictures which refer to different shapes and amplitudes depending on the position of electrodes on the surface of the body as a result allows seeing the heart from various different angles. The 12 standard ECG leads are divided in two groups, the first group called limb leads and consist of three bipolar limb leads (I, II, and III), I: is a lead obtained between a negative electrode and a positive electrode where the negative electrode placed on the right arm while the positive electrode placed on the left arm. While II: is a lead obtained between a negative electrode and a positive electrode where the negative electrode placed on the right arm while the positive electrode placed on the left foot. And III: is a lead obtained between a negative electrode and a positive electrode where the negative electrode placed on the left arm while the positive electrode placed on the left foot. and the unipolar limb leads (AVR, AVL, and AVF), and the second group called chest leads, also called precordial or V leads,(V1,V2,V3,V4,V5 and V6) .The description of the 12 ECG leads and the mapping of electrodes positions are shown in the following Fig. 3.

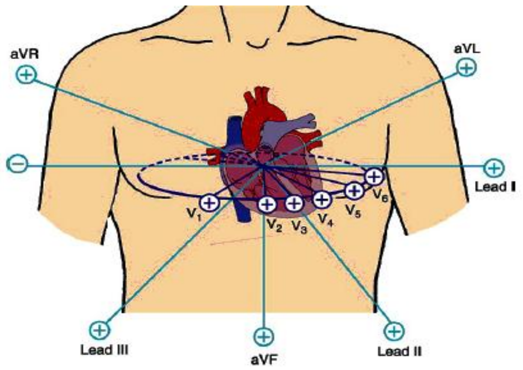

Fig. 3. A vector view of the standard 12 Lead ECG [23].

C. Heart Rate

Heart rate is the speed of the heartbeat measured by the number of heartbeats per unit of time usually expressed as beats per minute (bpm).The normal heart rate for normal person is in the range of 60 to 100 beats per minute, but this may change with age and sex, when a heart rate less than 60 bpm is called Bradycardia while when a heart rate more than 100 bpm is called Tachycardia [24], [25]. There are many methods to calculate heart rate depends on an ECG wave by using the R-R interval and as following. The first one depends on count the number of R waves in a 6 second rhythm strip, then multiply by 10. Secondly, count the number of small boxes (RR interval in millimeters) for a typical R-R interval. Divide this number into 1500 to calculate heart rate. Thirdly, count the number of large boxes (between successive R waves) for a typical R-R interval. Divide this number into 300 to determine heart rate [22].

IV. RESULT AND RELATED WORK

The result of this work is a Matlab program which analyzes of ECG recordings to get P, Q, R, S, and T as well as detect heart rate. The graphical user interface is very easy to use and enables to get P, Q, R, S and T values from analysis of ECG signal. It is necessary for anyone who works on this program should select the numbers of samples for one cardiac cycle in an ECG signal of the P-QRS-T waves are equal to 400 samples. The software tool provides the following main features for ECG processing and analysis:

- Loading ECG recordings from any source of data as text or binary files and excel files.
- Plotting the loaded ECG recordings of every lead.
- PQRST detections as individual values and also appears on the graph.
- Export graph as (fig, png and bmp types).
- Save data as (txt, mat and xlsx types).
- Print out of any lead of ECG graphs.
- Detecting R peaks and measuring the heart rate, the diagram (Fig. 4) introduces the steps of heart rate detection.

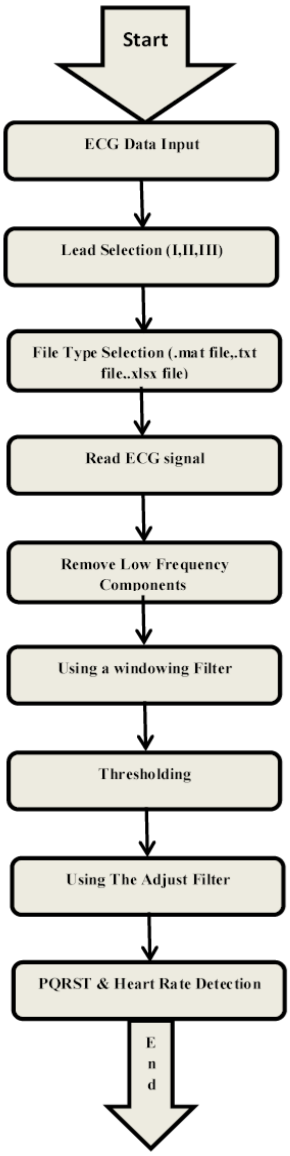

Fig. 4. Steps of PQRST & heart rate detection.

The above chart (Fig. 4) describe stages of detecting heart rate and P-QRS-T waves, firstly read ECG data after selecting which lead you select and type of data from any type of file and then removing low frequency components after that using windowing filter and later thresholding and then adjust filter (again windowing filter) and detect R-peaks to detect heart rate and P-QRS-T waves after a simple mathematical calculations by matlab equations to calculate P, Q, R, S and T.

Fig. 5- Fig. 12 show the results of graphical user interface (GUI).

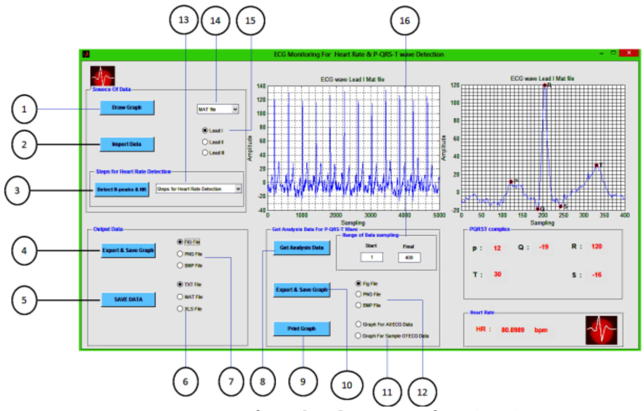

Fig. 5. Design of graphical user interface (GUI).

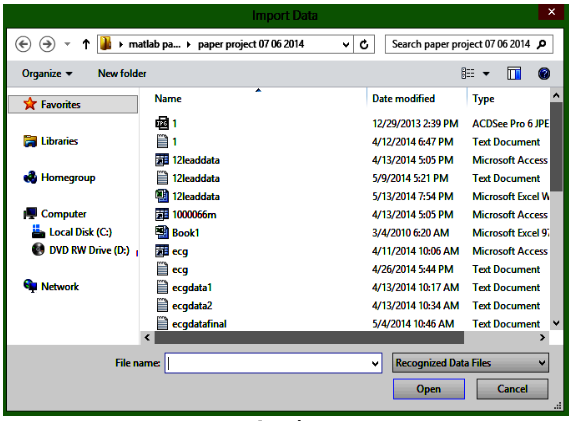

Fig. 6. Import data from any source.

The Fig. 5 represent the main graphical user interface in matlab program and the following points explain everything regard to this program.

1) Draw full sampling of ECG signal and calculate heart rate.
2) Import date from anywhere and from any type of data.
3) When select this button performs steps of heart rate detection by using windowing filter two times.
4) When click this button we can save graph which display on the left side as three types of file (.fig, .png, and .bmp)
5) We can save data as (txt, mat and xlsx types).
6) Types of data that program can save data.
7) Types of image (figure) that program can save figure.
8) Get analysis data button mean get analysis of ECG data to detect PQRST values.
9) We can print out each of figures depend on which one we want.
10) When click this button we can save graph which display on the right side as three type of files (.fig, .png and bmp).
11) Selection about which one we want to print out, all samples or specific samples.
12) Types of image (figure) that program can save figure.
13) POP- UP menu used to select steps of heart detection.
14) Select type of data as (mat, txt and xlsx) to draw ECG

wave.

15) When select data from which data want also these data for any lead of ecg want to draw it.
16) Enter the range of sampling data for analysis data of ecg to get PQRST value.

The Fig. 6 clarifies how user can import data from anywhere and from any type of data.

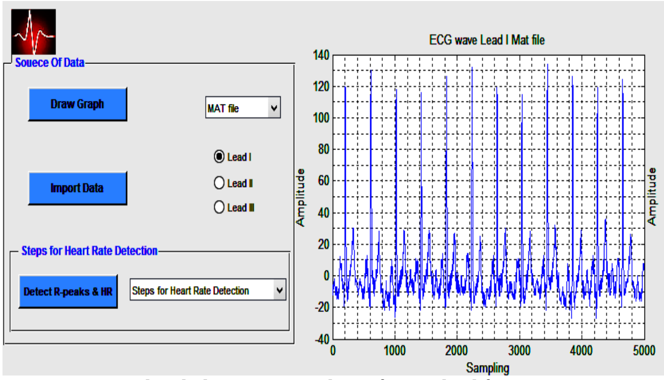

Fig. 7. Load and plot ECG recording of every lead from any source.

The Fig. 7 illustrates how user can load and plot ECG graph after selectof every lead and from any type of data ((txt, mat and xlsx types).

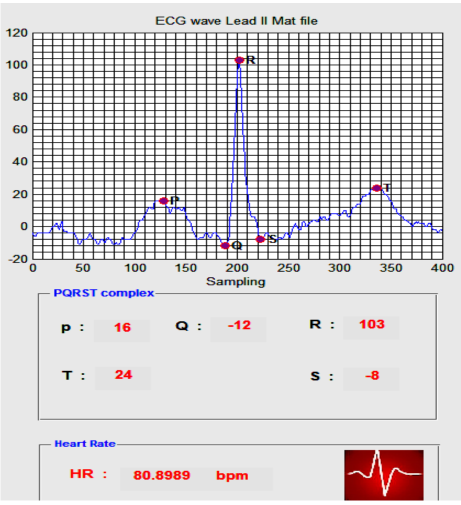

Fig. 8. Detection PQRST values and heart rate.

The Fig. 8 demonstrates how get P, Q, R, S and T values for specific range of data (approximately 400 samples) and detect heart rate.

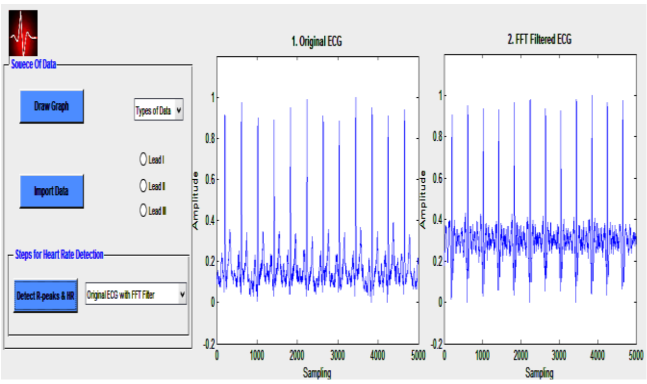

Fig. 9. original ECG with Apply FFT filter.

The Fig. 9 illustrates the first stage of ECG analysis to detect heart rate by applying FFT filter.

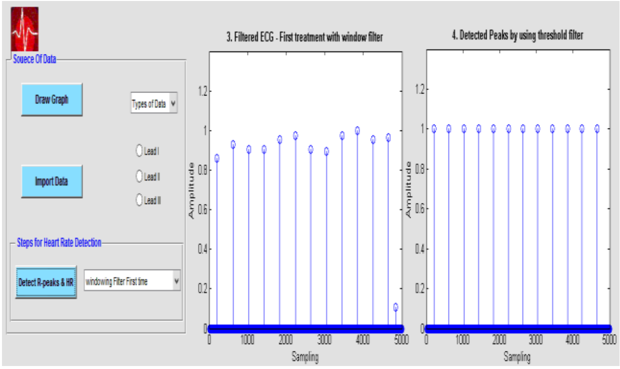

Fig. 10. Windowing filter and detect peaks by using threshold filter.

The Fig. 10 demonstrates the first treatment with windowing filter and detect peaks by using threshold filter.

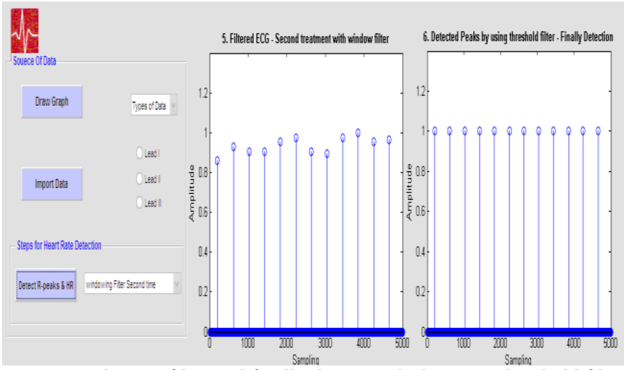

Fig. 11. Windowing filter and finally detect peaks by using threshold filter.

The Fig. 11 clarifies the second treatment with windowing filter and finally detects peaks by using threshold filter.

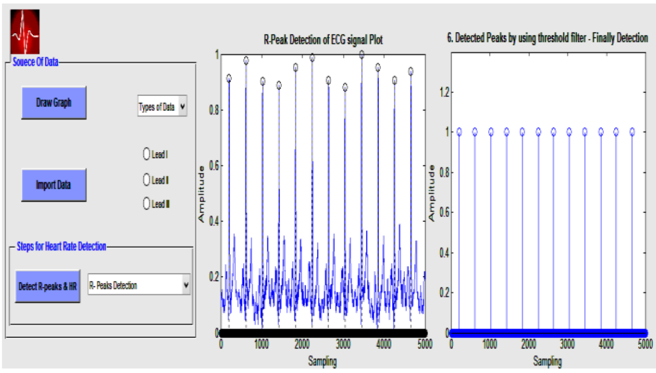

Fig. 12. Plot R- peaks detection of ECG signal.

The Fig. 1 demonstrates R-peaks detection in final stage of ECG analysis.

V. Conclusion And Future Work

This paper has presented a thorough matlab program which it is easy and very useful for clinicians in research studies in addition to students who works in medical section. The most of earlier method of ECG signal analysis for detecting PQRST was based on DSP technique for example (Wavelet Transform and Fast Fourier Transform) and Artificial Neural networks. This paper presents a developed program is a flexible and thorough tool for P, Q, R, S and T analysis from ECGs and detect heart rate. The proposed software tool can be utilized in training for clinicians and engineers working together in the same field which related of heart disease. The graphical user interface is very easy to use and enables to get P, Q, R, S and T values from analysis of ECG signal. For future work I suggest to use microcontroller for real-time ECG signal processing and analyzing, heart rate and QRS complex detection algorithms from ECG signal in real time.

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