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ECG - Cardiac Investigation Using Signal Processing Techniques

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ABSTRACT: Cardiac diseases are frequent reason for death which kills millions of people worldwide each year. However, they can be effectively prevented by early diagnosis. ECG signal is the most important and powerful reference tool used for the diagnosis and treatment of heart diseases. ECG represents the electrical activity of the heart and contains vital information about its rhythmic characteristics. The accurate ECG interpretation is necessary in order to evaluate the valuable information inside the ECG signal. The conventional techniques of visual analysis to inspect the ECG signalsby doctors or physicians are not effective and time consuming. The software developed for image capturing from ECG machine performs analysis on the captured ECG graph in display before sending through the internet network.Test images show that this software able to extract information from ECG accurately. The analysis of normality or abnormality of the signal so as to start the early treatment for the problems and many lives could be saved. Converting ECG records into computer based digitised signal reduces the physical storage space and the retrieval of the requisite information can be made quicker and accurate.

KEYWORDS: ECG, peak detection, QRSdetection, RR intervals, signal transmission, Correlation, Dilation, Image Binarization, Morphological Filtration.

I. INTRODUCTION

Electrocardiography (ECG or EKG) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle depolarizing during each heart beat.

During each heartbeat, a healthy heart will have an orderly progression of depolarization that starts with pacemaker cells in thesinoatrial node, spreads out through the atrium, passes through the atrioventricular node and then spreads throughout theventricles. This orderly pattern of depolarization gives rise to the characteristic ECG tracing. To the trained clinician, an ECG conveys a large amount of information about the structure of the heart and the function of its electrical conduction system.

The medical state of the heart is determined by the shape of the Electrocardiogram, which contains important pointers to different types of diseases afflicting the heart. However, the electrocardiogram signals are irregular in nature and occur randomly at different time intervals during a day.

The electrocardiogram (ECG) is a graphical representation of the electrical activity of the heart and is obtained by connecting specially designed electrodes to thesurface of the body [1]. It has been in use as a diagnostic toolfor over a century and is extremely helpful in identifyingcardiac disorders non-invasively. The detection of cardiacdiseases using ECG has benefited from the advent of thecomputer and algorithms for machine identification of thesecardiac disorders.

This is also the first individual to standardize theelectrode locations for collecting ECG signals as right arm(RA), left arm (LA) and left leg (LL), and these locations areknown after him as the standard leads of Einthoven or limbleads, as shown in Figure 1. The limb leads consist of sixunipolar chest leads, starting from lead V1 until V6 in anelectrocardiogram, as shown in Figure 1 below.

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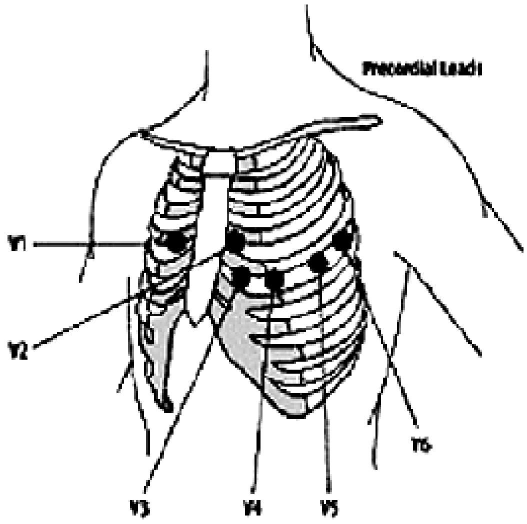

Fig.1.1 The placement of the exploratory electrode

The cardiac disease classification algorithms beginwith the separation or delineation of the individual ECG signalcomponents. The ECG signal comprises of the QRS complex,P and T waves as shown in Figure 3. Occasionally a U-wavemay also be present which lies after the T-wave. The QRScomplex is the most distinguishable component in the ECGbecause of its spiked nature and high amplitude as it indicatesdepolarization of the ventricles of the heart which have greatermuscle mass and therefore process more electrical activity [3].Detection of the QRS complex is one of vital importance inresponse to the subsequent processing of the ECG signal suchas calculation of the RR interval, definition of search windowsfor detection of the P and T waves and etc. In terms of diseaseclassification, the QRS complex is of pathological importanceand its detection serves as an entry point for almost allautomated ECG analysis algorithms.

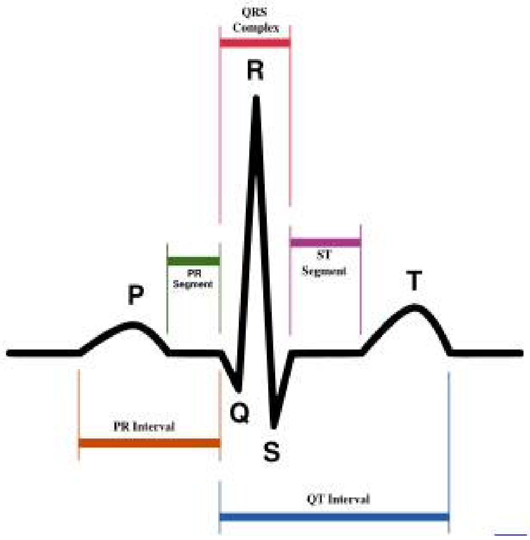

Fig.1.2 single cycle of ECG signal

The models for proposed for heart beat classification ischallenged by the variability of the ECG waveforms fromone patient to another even within the same person.However, different types of arrhythmias have certaincharacteristics which are common among all the patients.Thus, there arises the need for continuous monitoring ofthe ECG signals, which by nature are complex to comprehendand hence there is a possibility of the analyst missing vitalinformation which can be crucial in determining the natureof the disease. Thus computer based automated analysis

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isrecommended for early and accurate diagnosis. So to achievethis objective many works have been done in this field based on image processing. The objective of this work is to identify the normal beatsfrom ECG beats so that other beats can be detected asabnormal beats by use of soft computing technique.

The detection of RR interval serves as the coreof project in order to calculate the heart rate of patient.According to previous researches in literature, there are anumber of algorithms have been developed to determine heartrate and kind of diseases based on detected electrocardiogram.For example, Prashanth Swamy et al. had proposed animproved method for digital time series signal generation fromscanned ECG records [5]. Their proposed technique is anotherapproach to compute the RR internal for heart rate calculationfrom the obtained time series to facilitate the evaluation of themethodology.

The biomedical signal in the present work is the filtering technique suggested is Butterworth filter or simply FIR Type-1 filter. This ECG gets corrupted due to different kinds of the artifacts. The different types of artifacts are Power line interference, motion artifacts, base line drift and instrumental noise. Due to these types of the artifacts ECG gets corrupted and correct information not transfers to the cardiac specialist. The care must be taken to nullify the artifacts to avoid wrong diagnosis. Certain type of the noise may be filter directly by time domain filters using signal processing techniques or digital filters. The advantage of the time domain filtering is that the spectral characterization of the filter may not be required (at least in the direct manner). Different researchers are working on noise reduction in the ECG signal. Wu Y, Yang Y in his article given new method for the ECG noise reduction by using 50 persons ECG based on Levkov method. The Wang H, Dong X has suggested filter method with in filtered QRS wave can be exactly regarded as the mark identifying other physiological Signal. The method for the removal of the power line interference suggested by ferd Jallah M, Barr RE based on iterative division or multiplication of a set of frequencies centred at 60 Hz[17]. The Choy TT, Lenng PM has suggested in his literature the real time microprocessor based notch filter for ECG[9]. The Mc manus CD, Neubert KD has compared the digital filtering methods[6]. The technique for suppressing transient states of ECG the IIR notch filter is investigated by Pie SC and T Seng CC [18]. The work on the ECG beat detection using filter bank is carried out by the Tompkins W J and Luos [1]. Other method like Signal averaging for line interface reduction is also suggested by the scientists [11].

The unique of proposed project in this paper is serving ECGimage as the input of developed algorithm by implementing alow cost digital webcam camera to capture the ECG signal indisplayed at ECG machine screen. Some simple and reliableimage processing techniques was also proposed beforeanalysis of heart rate calculation. Measurement result will beshown in self-generated report and sending through theinternet network.

II. ANALYSIS OF ECG

A previous research was investigated by a research groupfrom Ragnar Granit Institute, Tampere University ofTechnology, Finland which using mobile phone to implementthe ECG information transmission. They introduce an ECGmeasurement, analysis and transmission system through amobile phone as a base station. The system is based on asmall-sized mobile ECG recording device which sendsmeasurement data wirelessly to the mobile phone. In themobile phone, the received data is analysed and in cases ofany abnormalities are found among parts of the measurementdata; it will be send to a server for the use of medical personnel simultaneously.

The prototype of the system was made with a portable ECGmonitor and Nokia 6681 mobile phone. The results show thatmodern smart phones might capable for this kind of tasks.Thus, with very good networking and data processingcapabilities, they might be a potential part of the futurewireless health care systems. When requested, the applicationalso displays the ECG signal and heart rate on the phonescreen. The view the received ECG signals on the phonescreen along with the measured heart rate. In addition, an informative Short Message Service(SMS) - message is delivered to the mobile phone of a selectedperson if so chosen. However, due to the limits ofelectronics support and processing unit within the mobilephone, the overall performance is hardly operated in an idealcondition. The display screen of mobile phone is smaller than any conventional ECG machine display and some importantmorphology of the ECG signal might not able to be observed.Delayed in data transmission might also disrupted the dataanalysis and measurement in consequences. To avoid these,the proposed project in this paper are implementing the imagesbased techniques and digitization ECG signal through digitalcamera for input capturing, information extraction and analysisusing MATLAB tools as well as data sending system based oninternet network.

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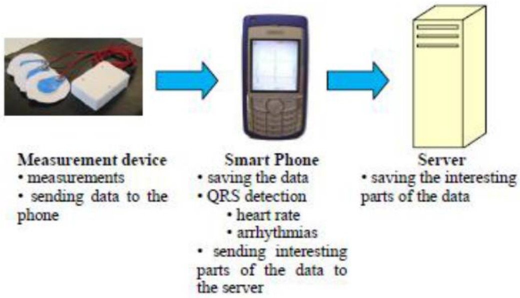

Fig.1.3 The different parts of the system

In addition to automated analysis, the proposed applicationoffers a possibility for a patient to send an alarm if he feelsanxiety, faintness or other distress. The result of sending analarm is the same as exceeding the heart rate limits. That is, apredefined amount of measurement data around this event issent through the internet network.

III. ALGORITHMS

The algorithm is start with ECG image capturing by using areal time operating digital webcam camera and saved in thecomputer. The format of captured image above can be JPG,TIFF, BMP and etc. Besides, the algorithms can also integratewith off time input signal either in video based file or prior saved image in the computer as well. Then the algorithms arefollows by a series of image processing techniques thatperform image conversion, image filtering, imageenhancement, and image cropping. The processed ECG imagewill be analysed for the detection of distance between R peakto peak, in order to calculate the heart rate. Lastly, a sendingreport will be self-generated which includes all the information regarding patient's data and heart rate measurement result.

A. Capturing Panel

The developed capturing panel providesthree distinct ways to feed image as the input for the followingimage processing panel. Firstly, the user can activate the realtime operating webcam in order to get the snapshot of ECGsignal from ECG machine. Meanwhile, the algorithm alsoallows the user to implement the off time input such asrecorded ECG video based file or prior saved image incomputer. After the selection of input methods, it is followedby some reliable image processing techniques for theelimination of undesired noise.

B. Image Processing Panel

The first step in this panel is to eliminate the hue andsaturation information while retaining the luminance of theimage. This can be done by converting the true colour imageRGB format to the grayscale intensity image format. Thisconversion is essentially required due to the subsequent imagefiltering that can only able to be performed on grayscaleimage. Image filtering will make the ECG signal line sharperthan the noise behind the image background. Or in the otherwords, the implemented Laplacian image filtering making thepixel values of the ECG signals less than the noise in imagebackground. As consequence of this, less information will belose during the binary image conversion later. The followingmathematical equations is the Laplacian filter for the imagefiltering, where the parameter alpha controls the shape of the Laplacian and it must be in the range of 0.0 to 1.0.

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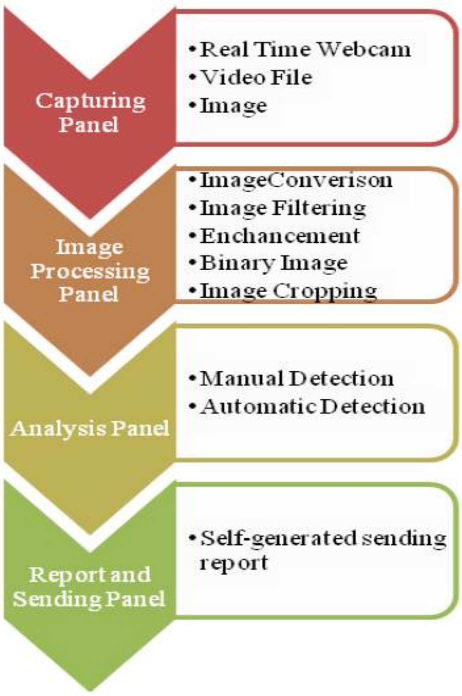

Fig.1.4 Developed algorithm in different panels

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

$$\nabla^2 = \frac{4}{(\alpha+1)}\begin{bmatrix} \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \\ \frac{1-\alpha}{4} & \frac{\alpha}{4} & \frac{1-\alpha}{4} \\ \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \end{bmatrix}$$

Image enhancement is an additional improvement for theimage quality. The pixels values between the ECG signal andthose undesired noise in the background will be compared andone threshold value will be chosen. If the interested line withthe pixels values close to the threshold value, its pixels valuewill be subtracted about 20 to make it dim. Reversely, theundesired noise with the pixels values close to the thresholdvalue, its pixels will be added about 20 to make it light.Therefore, the resulting image will contains distinct ECGsignal in the image.

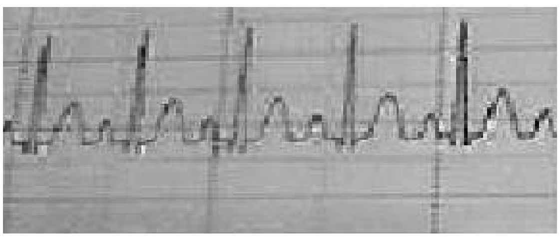

Fig.1.5 Example of image before Image Enhancement

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Furthermore, the resultant image will be converted as thebinary image in which the output replaces all the pixels ininput image with luminance greater than level with the value 1(white) and replaces all other pixels with the value 0 (black).Last but not least, only the interested region of the image willbe cropped and possess through analysis panel.

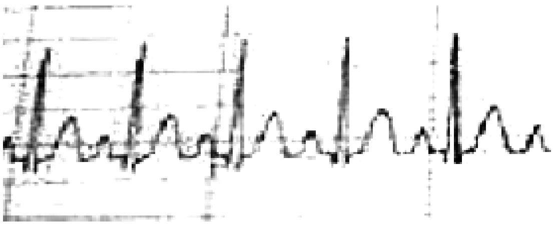

Fig.1.6 ***Example of image after Image Enhancement***

C. *Analysis Panel*

The function of this panel will be the core of the project tocalculate the heart rate of patient simply based on digitizedECG image. The idea behind this panel is to make use thedistance measurement between the R peak to peak selectionsin the ECG signal. Average of multiple distance measurementwill be computed as the final heart rate of the patient.

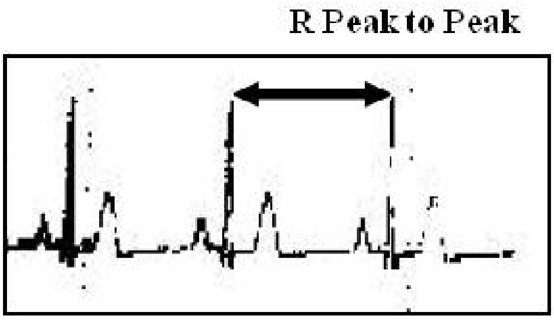

Fig.1.7 Example of RR intervals

For manual calculation, the user will ask to provide the timedivision of ECG machine display. The software allows the userto select the R peak to peak and the distance between theselected two points will be calculated within the time division.The results of the calculation will be the heart rate of thepatient. The Figure 9 shows the distance between R peak topeak selections in an image. However, the automatic panel isable to calculate the distance between R peak to peakautomatically rather than asking user to select it manually. Thealgorithm will scan through the image starting from the leftupper corner to the right lower corner of the image and all theblack pixels will be stored in a new vector M.

The variables of image will equal to zero when it was black inbinary image and stored in new M vector. The RR interval canbe calculated based on M vector above by setting a thresholdvalue to validate the calculated distance.

D. *Report and Sending Panel*

The last stage of the project's activities is self-generatingreport and sending panel. After the image gone through theimage processing panel and analysis panel, a report includingall the patient's information data and heart rate will begenerated and sending through the internet connection. Inaddition, one comment box was set in the report for the usersto add on some important notes for their recipients.

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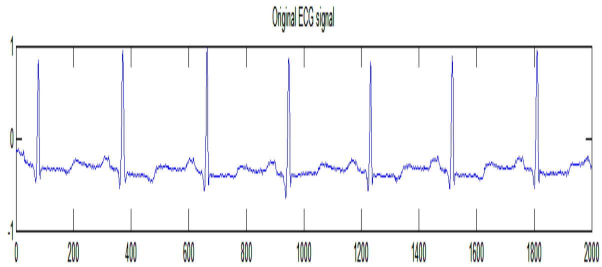

Fig.1.7 Orginal Signal

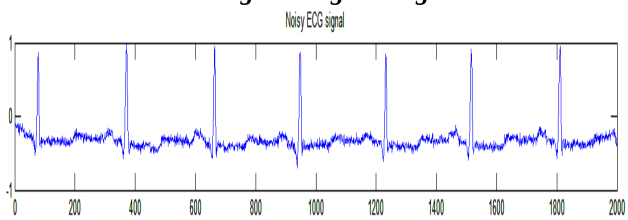

Fig.1.9 Noisy ECG Signal

The implementation of algorithm above will results a report including patient's data and accurate heart rate calculation. In this section, the results of algorithm for each image processing techniques were shown. First of all, the selected ECG image was initially loaded into the software through computerized algorithms. The converted raw ECG image in grayscale is shown in the Figure 10. It is obvious to observe that the ECG signals in the raw image are not clear and mixed with disrupted noises due to the low resolution of the camera. For that reason, image filtering playing a vital role here to extract the interested signal and eliminate the undesired noise simultaneously. Accurate digitization of ECG signal depends heavily on thequality of given image. To ensure the promising quality levelof ECG signal in the relevant image, the developed algorithmwill further enhances the pixels in ECG lines.

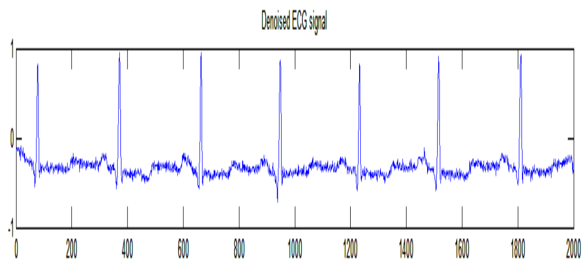

Fig.1.10.Denoising ECG Signal

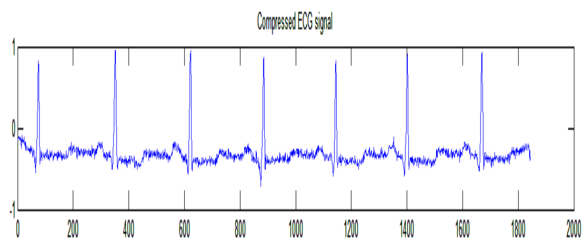

Fig.1.11 Compressed ECG Signal

As far as we concerns is the detection of positive RRintervals, therefore it is necessary to crop the resultant imageabove and avoid the noise from the image. Based on the simulation results, the algorithm can detect theRR intervals automatically by creating a new vector whichcontains the variable of all black pixels in the ECG

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lines.However, one problem can occurs which lead to fault heartrate calculation if undesired noises are located at the positionhigher than the R peak in the image. Therefore, it isrecommended the user to crop the resultant image in which away to avoid the noise upper than R peak in ECG signal.

IV. THE ECG LEADS

Two electrodes placed over different areas of the heart and connected to the galvanometer will pick up the electrical currents resulting from the potential difference between them. For example, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2 mV occur at the same time, then the two electrodes will record the difference between them, Le. a wave of 0.8 mV. The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a "LEAD".

Bipolar Leads*:* In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted. They are sometimes also referred to as Einthoven leads.

In standard lead I, the electrodes are placed on the right and the left arm (RA and LA). In lead II, the electrodes are placed on the right arm and the left leg and in lead III, they are placed on the left arm and the left leg. In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the "right leg". The records are, therefore, made by using three electrodes at a time, the right leg connection being always present.

In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector. The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of die vector. He proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre. The triangle, known as the *"*Einthoven triangle*"*, is shown in the fig 1.3. The sides of the triangle represent the lines along which the three projections of the ECG vector are measured. It was shown the instantaneous voltage measured from any one of the three limb lead positions is approximately equal to the algebraic sum of the other two vector sum of the projections on all three lines is equal to zero.

In all the bipolar lead positions. *QRS* of a normal heart is such that the *R* wave is positive and is greatest in lead II.

Unipolar Leads (V Leads): The standard leads record the difference in electrical potential between two points on the body produced by the heart's action. Quite often, this voltage will show smaller changes than either of the potentials and so better sensitivity can be obtained if the potential of a single electrode is recorded. Moreover, if the electrode is placed on the chest close to the heart, higher potentials can be detected than normally available at the limbs. This led to the development of unipolar leads introduced by Wilson in 1894. In this arrangement, the electrocardiogram is recorded between a single exploratory electrode and the central terminal, which has a potential corresponding to the centre of the body. In practice, the reference electrode or central terminal is obtained by a combination of several electrodes tied together at one point. Two types ofunipolar leads are employed which are: (i) limb leads, and (ii) pericardial leads.

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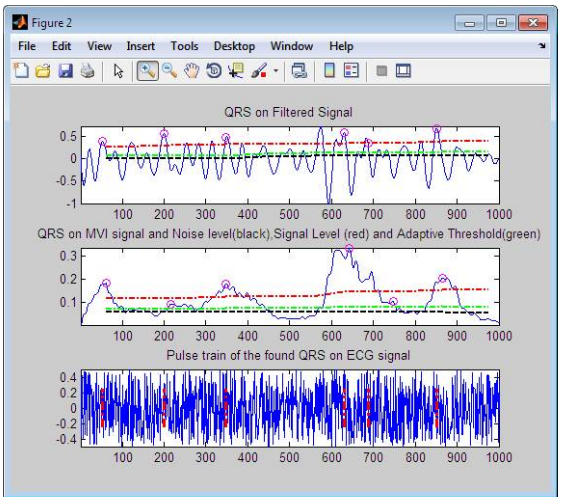

Fig.1.11.QRS Detection using Bipolar limb leads

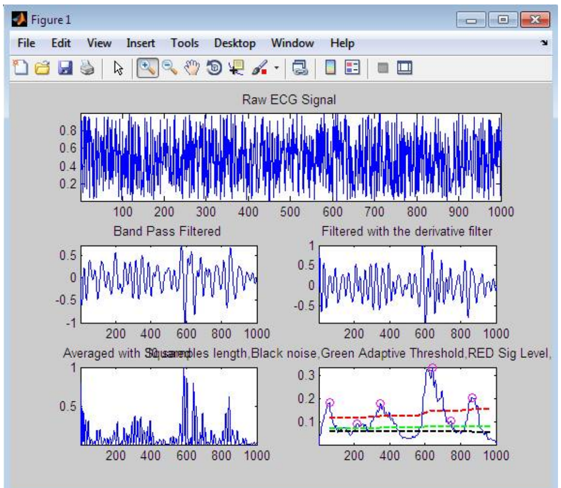

Fig.1.12.Raw ECG signal Filtering using V Leads

V. DISCUSSION

It is not effective and efficient to interpret the ECG signal'sinformation by using the conventional technique of visualanalysis to inspect the ECG signals. This method is essentiallymore complicated and time consuming. Also, only the expertswho are wide experience in this medical field are able tointerpret the ECG displays by using bare eye. Since the humanbeing cannot avoid from technical error, sometimes wronginformation or diagnosis would be occur especially in hospitalwith high patient's load. The needs of making use the digitalcomputer technologies is arise and many artificial intelligentsystems have been developed to make this job easier andeffectively. This includes the focus of digitization of ECGsignal extraction, pattern recognition, automatic ECGevaluation and abnormality heart diseases detection. Patternrecognition approaches are widely used for the detection andanalysis of these waves. For example, direct signal patternanalysis, non-linear signal transformations, principalcomponent analysis, and neural networks (NN) basedtechniques are used for ECG pattern recognition andclassification [10-13]. Also, recently some investigatorsworldwide have applied different forms of wavelet transformto decompose ECG signal for detection of P wave by neuralnetwork [15]. This system always involves the digitalsoftware analysis method to help the doctors or physicians todiagnose heart disease based on recorded ECG signal fromECG machine. The future researches should focus on how toimplement the concept of telemedicine for this digitalintelligent software. So that physiological monitoring process of the patient can be conducted at anywhere and anytime.

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VI. CONCLUSION

As a conclusion here, automation data capturing andsending system based on digitized ECG image have beendeveloped. The present work introduces the digital filtering method to cope with the noise artifacts in the ECG signal. Such automation system especially for medicalpurpose is very important and required in telemedicinepurposes. This is because it enables the patient monitoringprocess with the medical devices without any wireconnections. In this project, the output of the developedprogram will be a self-generated report which includingpatients' information and heart rate. It will then be sendthrough the internet connection to the user's recipients.

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