ECG SIGNAL PROCESSING TECHNIQUES BY USING ASP.NET APPLICATION BASED ON GUI IN MATLAB

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by

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We have read the thesis entitled **"ECG Signal Processing Techniques by Using ASP.NET Application Based on GUI with MATLAB"** completed by **HUSSAIN ABED JABER ALZIARJAWEY** under supervision of **Assoc. Prof. Dr. İlyas ÇANKAYA** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

An electrocardiogram (ECG/EKG) is an electrical recording of the heart and is used as an essential diagnostic tool in the investigation of heart disease, so any defect of heart rate or rhythm, or change in the shape of the QRS complex, is very significant to get an evidence for detecting cardiac arrhythmia. The most of earlier methods of ECG signal analysis for detecting PQRST was based on Digital Signal Processing (DSP) technique, for example Wavelet Transform(WF), Fast Fourier Transform(FFT) and Artificial Neural Networks(ANN). The work in this thesis have proposed a simple and dependable method to detect the P, Q, R, S and T values of an ECG signal normal and abnormal cases. This method is based on determination a mathematical relationship between the highest values (peaks and valleys) of the ECG waveform and time.

Second part in the thesis includes using three different digital signals processing techniques for ECG signals are: Digital Filters (FIR and IIR), Wavelet signal processing (Filters Banks technique) and adaptive Filter Signal Processing.

The work in this thesis is exemplified through designing a graphical user Interface (GUI) in MATLAB for creating a new software package for revealing of PQRST for both normal and abnormal ECG using a simple mathematical algorithm to get PQRST values, draw these values at the same time and share the package results to website using the ASP .NET application.

The proposed software system will be devoted to the purposes of scientific research in the medical and engineering fields together, rather than clinical diagnosis as well as it can be utilized in training for clinicians and engineers working together in the same field which related to heart disease.

MATLAB’DA GRAFİK KULLANICI ARAYÜZÜ BAZLI ASP.NET UYGULAMASI KULLANILARAK EKG SİNYAL İŞLEME TEKNİKLERİ

ÖZET

Elektrokardiyogram (EKG) kalple ilgili elektronik kayıttır ve kalp atış hızı ve ritminin veya QRS kakopleksinin şeklinde meydana gelen değişikliklerin tespit edilmesi için kalp hastalığının araştırılmasında kullanılan gerekli bir teşhis aletidir ve kalpteki ritim bozukluğunu tespit etmekle ilgili kanıtları elde etmek için çok önemlidir. PQRST tespiti için EKG sinyal analizinin en eski metodu Dalgacık Dönüşümü (WF), Hızlı Fourier Dönüşümü (FFT)ve Yapay Sinir Ağları (ANN) gibi Dijital Sinyal İşleme (DSP) teknikleri kullanılmaktadır. Bu tez çalışması EKG sinyallerinin normal ve anormal vakaların P,Q,R,S,T ve T değerlerini korumak için basit ve güvenilebilir bir metot önermektedir. Bu metot, EKG dalga şekli ve zaman arasındaki en yüksek değerler (yüksek ve alçak) arasındaki matematiksel ilişkileri bulmaya dayandırılmaktadır.

Bu tezin ikinci kısmı EKG sinyalleri için üç farklı dijital sinyal işleme tekniğinin kullanılmasını ihtiva etmektedir. Bu sinyaller şunlardır: Dijital Filtreler (FIR ve IRR), Dalgacık sinyal işleme (Filtre Bankası tekniği) ve Uygulanabilir Filtre Sinyal İşlemi.

Bu tez çalışması, PQRST değerlerini elde etmek ve aynı zamanda bu değerleri EKG üzerinde çizmek ve ASP.NET uygulamalarını kullanarak paket sonuçlarını paylaşmak, basit matematiksel algoritmalar kullanarak hem normal EKG hem de anormal EKG için PQRST’yi ortaya koymak ve yeni yazılım paketleri oluşturmak için MATLAB’da Grafik Kullanıcı Arayüzü tasarlayarak örneklendirilmiştir.

Önerilen bu yazılım sistemi, klinik tanılar yerine kullanılmak için bilimsel araştırma amacına hizmet etmesi ve kalp hastalığı ile ilgili aynı alanda çalışan klinisyen ve mühendislerin eğitimi için kullanılacaktır.

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Last but not least, special thanks to my parents who have sacrificed so much to give me a good education. I thank them for all they have done for me.

August, 2015 Hussain A. Jaber Alziarjawey

CONTENTS

ABBREVATIONS

A/D	Analog to Digital
AECG	Ambulatory ECG
AHA	American Heart Association
AIAS	Arrhythmia Intelligent Analysis Software
ALE	Adaptive Line Enhancement
ANC	Adaptive Noise Cancellation
APB	Atrial Premature Beat
API	Application Programming Interface
ASP	Active Server Pages
AV node	Atrioventricular Node
AVF	Augmented Vector Foot
AVL	Augmented Vector Left
AVR	Augmented Vector Right
BSS	Blind Source Separation
CWT	Continuous Wavelet Transform
DAC	Digital Analog Convertor
DOM	Difference Operation Method
DOP	Difference Operation Process
DSP	Digital Signal Processing
DWT	Discrete Wavelet Transform
ECG/EKG	Electrocardiogram
EEG	Electroencephalogram
ELM	Extreme Learning Machine
EMG	Electromyogram
FECG	Fetal Electrocardiograms
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
GUI	Graphical User Interface
HPF	High Pass Filter

I/P	Input
IAC	Improved Adaptive Power Line Interference Canceller
IIR	Infinite Impulse Response
LA	Left Atrium
LDA	Linear Discriminant Analysis
LMS	Least Mean Square
LPF	Low Pass Filter
LV	Left Ventricle
MLP	Multilayered Perceptron
music	Multiple Signal Classifications
PLI	Power Line Interference
PLL	Phase-Locked Loop
PNN	Probabilistic Neural Network
RA	Right Atrium
RV	Right Ventricle
SA node	Sinoatrial Node
SEMG	Signal Distorted Surface Electromyogram
SFG	Signal-Flow Graph
SVM	Support Vector Machine
SVW	Slope Vector Waveform
VE	Ventricular Extra systoles
VLSI	Very Large Scale Integration
VPB	Ventricular Premature Beat
VPC	Ventricular Premature Complexes
WA- PM	Wavelet Analysis and Pattern Matching

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CHAPTER 1

INTRODUCTION

The greatest progress to date in the use of computers for the clinical analysis of physiological data has occurred in the field of cardiology. There are several reasons for this; first of all, electrocardiogram (ECG) potentials are relatively easy to measure; secondly, the ECG is an extremely useful indicator for both screening and diagnosis. In addition, certain abnormalities of the ECG are quite well defined and can be readily identified. The ECG signal provides the following information of a human heart [1]:

- Impulse origin and propagation
- Drug effects on the heart
- Heart position and its relative chamber size
- Changes in electrolyte concentrations
- Extent and location of myocardial ischemia
- Heart rhythm and conduction disturbances

This chapter will be organized as follows: A brief overview of advantage of ECG test, objective of the thesis and organization of the thesis.

1.1. Objective of the Thesis

The proposed software system tool can be utilized in training for clinicians and engineers working together in the same field which related of heart disease. Therefore the main objective of this thesis is designing a new software package using MATLAB Graphical User Interface (GUI) and shares the package results to website by using ASP .NET, this package provides the following main features are as follows:

1. Introduces three DSP techniques for removing noise in the ECG signal which includes: digital filters, FIR and IIR, wavelet processing (Filters Banks technique) and adaptive filter signal processing. Detecting R peaks and measuring the heart rate in normal ECG signal and the abnormalities ECG signal.

2. Detecting PQRST values in normal ECG signal and the abnormalities ECG signal.

3. To classify the signals to detect Arrhythmia problems based on the signals that had been analyzed which includes Supraventricular Arrhythmia, Apnea, Normal Sinus Rhythm, Ventricular Tachyarrhythmia and Intracardiac Atrial Fibrillation.

4. To know the shape of the normal ECG signal and the abnormalities ECG signal through analyzing these signals and extract the features of all types of ECG signals.

5. To build a project package (windows standalone application) is a self-extracting executable file. Other people who do not have MATLAB can use this package directly; it is a .zip file (setup file) or executable file.

6. To create .NET applications for publishing and share them as an ASP.NET application site by using visual studio. NET.

1.2. Organization of the Thesis

The work in this thesis has been organized to be in six chapters, and summarized as follows: Chapter 1 of this thesis titled “introduction” presents a brief overview of advantage of the ECG test, the objective of the thesis and organization of the thesis.

In Chapter 2 that titled “Background on ECG Signal” presents a literature review of theories on ECG techniques of some methods done by others in the relevant research areas. Explains the basic concept of the medical background on ECG, introducing different types of arrhythmias in ECG signal, anatomy and function of the heart, electrical activity of heart cells, modes of lead placement and ECG waves and interval. This chapter also explains the types of noises in ECG signal.

In Chapter 3 that titled “ECG Signal Processing Techniques” discusses three different techniques of biomedical digital signal processing such as Digital Filters, Wavelet signal processing with filter banks and Adaptive signal processing. They have been applied to ECG signal in this thesis in details with providing a review of the background theory of these techniques.

In Chapter 4 that titled “Designing a GUI in MATLAB with .Net Application” explains the how a Graphical User Interface works, creating and displaying a Graphical User Interface and this chapter also explains MATLAB builder NE for Microsoft .NET framework as well as presents .NET application deployment process and finally explain how can deploy .NET components over the web site.

In Chapter 5 that titled “ECG Signal Simulation Based On The MATLAB GUI with .Net Application” presents the results that have been obtained in this thesis which is exemplified by proposing new software packages using a MATLAB GUI and share the package results to website by using ASP NET.

In Chapter 6 that titled “Conclusion and Future works” give a summary of the conclusions and some recommendations are suggested for possible further developments.

CHAPTER 2

BACKGROUND ON ECG SIGNAL

In recent years, many studies and mathematical analyzes have been developed for the exertion of analyzing the ECG signal, detecting arrhythmias, developing heart beat classification system; 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) [2 - 7]. All of these methods above have been dealing with the PQRS complex detection for ECG signals. A brief review of some recent and significant researches is presented for example;

Pande et al. (1985) have improved short-time Fourier Transform technique and algorithm which presented for detection of the QRS-complex [8]. Further, recognition of an isoelectric region on the ECG is needed for fixing a baseline for amplitude measurements of various component waves. An approach and its implementation of microprocessor was suggested for identification of the baseline.

Douglas et al. (1990) have described an approach to cardiac arrhythmia analysis using Hidden Markov models [9]. This technique classified by detecting and analyzing QRS complex and determining the R-R intervals to determine the ventricular arrhythmia. The Hidden Markov modeling approach combines structural and statistical knowledge of the ECG signal in a single parametric model. The Hidden Markov modeling addresses the problem of detecting low amplitude P waves in typical ambulatory ECG recordings.

Xu et al. (2004) have described a Slope Vector Waveform (SVW) method that has proposed an algorithm to detect ECG QRS complex and evaluate RR interval [10]. 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. Yu et al. (2007) have presented a Discrete Wavelet Transform (DWT) method that states to extract the relevant information from the ECG input data in order to perform the classification task [11]. 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 called 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.

Ahmad et al. (2008) have presented an ECG beat classification scheme based on multiple signal classification (MUSIC) algorithm, morphological descriptors, and neural networks for discriminating nine ECG beat types [12]. That are normal, fusion of ventricular and normal, fusion of paced and normal, left bundle branch block, right bundle branch block, premature ventricular concentration, atrial premature contraction, paced beat, and ventricular flutter. MUSIC algorithm is used to calculate pseudo spectrum of ECG signals. The low-frequency samples are picked to have the most valuable heartbeat information. These samples along with two morphological descriptors which deliver the characteristics and features of all parts of the heart and form an input feature vector. Which is used for the initial training of a classifier neural network. The neural network is designed to have nine sample outputs which constitute the nine beat types. Two neural network schemes, namely multilayered perceptron (MLP) neural network and a probabilistic neural network (PNN), are employed. The experimental results achieved a promising accuracy of 99.03% for classifying the beat types using MLP neural network.

Chouhan et al. 2008 have presented an algorithm for detection of QRS complexities using Adaptive Quantized Threshold [13]. The recognition of QRS complexes forms the origin for more or less all automated ECG analysis algorithms. The presented algorithm utilizes a modified definition of slope of ECG signal, as the feature for detection of QRS. A succession of transformations of the filtered and baseline drift corrected ECG signal is used for mining of a new modified slope-feature. Yeh et al. (2008) have presented a Difference Operation Method (DOM) that have 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 [14]. 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. Franklin et al (2013) have described a method by using Artificial Neural Networks (ANN) for detecting PQRST through use of the derivative where search for the minimum and maximum of the derivative of a wave [15]. 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. In this thesis 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.

2.1. Medical Background on ECG Signal

An arrhythmia is a disturbance of the normal rhythm of the heart. Arrhythmias are very common and affect over 700.000 people in the worlds today. Arrhythmias may occur naturally, or be due to heart disease or other causes, such as a reaction to a medicine. An arrhythmia may occur continuously or just occasionally. The heart rate can become abnormally rapid, slow and/or irregular. The causes of this irregularity are from different parts of the heart. Arrhythmias are identified by its origin in the heart and the rhythm of the heartbeat. Bradycardia is heart rhythm which is slower than 60 beats-per-minute and tachycardia is heart rhythm that is faster than 160 beats-per-minute. All arrhythmias can generally be identified from the ECG signal by two categories of features; morphological and statistical. Morphological features are ECG wave structures that can be visually identified and these features are used in short term monitoring applications. [16, 17] Statistical features are detected by mathematical methods, e.g., expectation vectors, covariance matrix and so on. There are a number of different types of arrhythmia; Table 2.1 shows many types of abnormal ECG.

Table 2.1 A brief guide for the most of abnormalities ECG signal with graphs

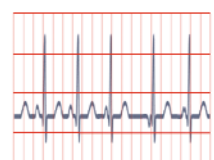
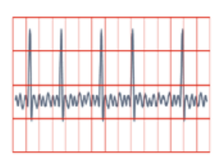
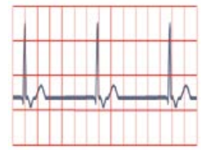
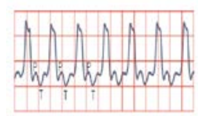
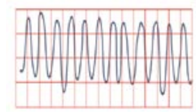
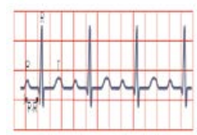
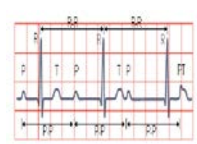
Name of Abnormality	Rate	Rhythm	Waves Characteristics	Graph
Normal sinus rhythm	Normal (60-100 bpm)	Regular	P Wave- Normal (positive & precedes each QRS), PR Interval Normal (0.12-0.20 sec), QRS Normal (0.06-0.10 sec).	
Sinus bradycardia	Slow (< 60 bpm)	Regular	P Wave -Normal, PR Interval Normal (0.12-0.20 sec), QRS Normal (0.06-0.10 sec).	
Sinus tachycardia	Fast (> 100 bpm)	Regular	P Wave -Normal, may merge with T wave at very fast rates, PR Interval Normal (0.12-0.20 sec), QRS Normal (0.06-0.10 sec). QT interval shortens with increasing heart rate	
Wandering pacemaker	Normal (60-100bpm)	May be irregular	P Wave -Changing shape and size from beat to beat (at least three different forms), PR Interval-Variable, QRS Normal (0.06-0.10 sec), T wave normal. If heart rate exceeds 100 bpm, then rhythm may be multifocal atrial tachycardia (MAP).	
Atrial flutter	Fast (250-350 bpm) for Atrial, but ventricular rate is often slower	Regular or irregular	P Wave- Not observable, but saw-toothed flutter waves are present, PR Interval- Not measureable ,QRS- Normal (0.06-0.10 sec)	
Atrial fibrillation	Very fast (> 350 bpm) for Atrial, but ventricular rate may be slow, normal or fast	Irregular	P Wave- Absent - erratic waves are present, PR Interval- Absent,QRS- Normal but may be widened if there are conduction delays.	

Table 2.1 Cont.

Name of Abnormality	Rate	Rhythm	Waves Characteristics	Graph
Junctional rhythm	Slow (40-60 bpm)	Regular	P Wave- Present before, during (hidden) or after QRS, if visible it is inverted, PR Interval- Not measurable, QRS Normal (0.06-0.10 sec).	
Ventricular tachycardia	Fast(100-250 bpm)	Regular	P Wave- Absent, PR Interval- Not measurable, QRS Wide (>0.10 sec), bizarre appearance.	
Ventricular fibrillation	Unmeasurable	Highly irregular	P Wave- Absent, PR Interval- Not measurable, QRS None, ECG tracings is a wavy line.	
First-degree heart block	The underlying rate	Regular	P Wave- Normal, PR Interval- Prolonged (>0.20 sec), QRS Normal (0.06-0.10 sec), a first degree AV block occurs when electrical impulses moving through the Atrioventricular (AV) node are delayed (but not blocked). First degree indicates slowed conduction without missed beats.	
Second-degree heart block	Characterized by Atrial rate usually faster than ventricular rate (usually slow)	Regular (atrial) and irregular (ventricular)	P Wave- Normal form, but more P waves than QRS complexes, PR Interval- Normal or prolonged, QRS Normal or wide, sometimes does not follow P-Wave.	
Third-degree heart block	Constant (20-55 bpm)	Regular, but atrial and ventricular rhythms are indepent	P Wave- Normal shape and size, may appear within QRS complexes, PP Interval- Normal and constant, QRS Normal.	

2.1.1 Anatomy of the Heart

The human heart is at the center of the cardiovascular system, which is responsible for oxygenating blood and delivering it to different parts of the human body. The heart is a hollow muscle that is about the size of a fist. In one minute, it pumps about five liters (roughly five quarts) of blood through the body, it is made up of four chambers as shown in Figure 2 .1 Right Atrium (RA), Left Atrium (LA), Right Ventricle (RV), Left Ventricle (LV). The morphology and heart rate reflects the cardiac health of human heart beat [18]. It is a noninvasive technique that means this signal is measured on the surface of human body which is used in identification of the heart diseases [19, 20]. Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of cardiac arrhythmia which could be detected by analysis of the recorded ECG waveform. The amplitude and duration of the PQRS-T wave contains useful information about the nature of disease afflicting the heart. The electrical wave is due to depolarization and repolarization of $Na+$ and K ions in the blood [19]. ECG is considered to be one of the most powerful diagnostic tools in medicine that is routinely used for the assessment of the functionality of the heart. An ECG is the conventional method for noninvasive interpretation of the electrical activity of the heart in real-time. The electrical cardiac signals are recorded by an external device by attaching electrodes to the outer surface of the skin of the patient’s thorax. These currents stimulate the cardiac muscle and cause the contractions and relaxations of the heart. The electrical signals travel through the electrodes to the ECG device which records them as characteristic waves. Different waves reflect the activity of different areas of the heart which generate the respective flowing electrical currents. Figure 2.2 shows a schematic representation of a normal ECG and its various waves. A main study of this thesis is to detect abnormal signals generated by the human heart; hence, a substantial understanding of the source of this signal is essential.

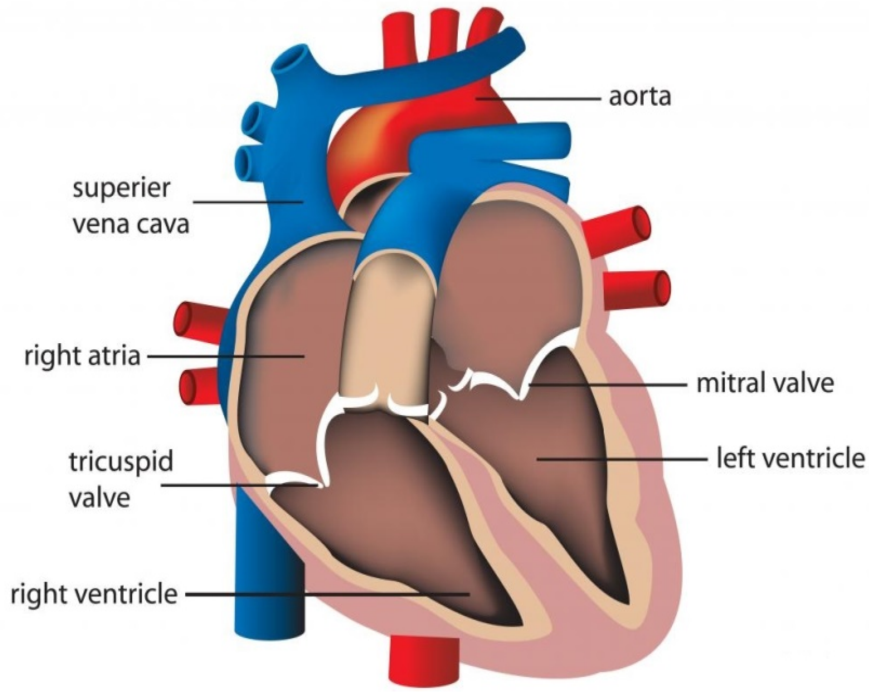


Figure 2.1 Structure of heart chamber

2.1.2 Electrical Activity of Heart Cells

The mechanical mechanism of the heart is founded on and tightly related to electrical activity of heart cells. The electrical activity of one cell or part of one cell can interact with its surroundings. In the resting state of the cell, the difference in potential between inside the cell and the outside, called the resting membrane potential, is in range of – 60 mV to – 90 mV (inside cell has lower potential than the outside) [21].

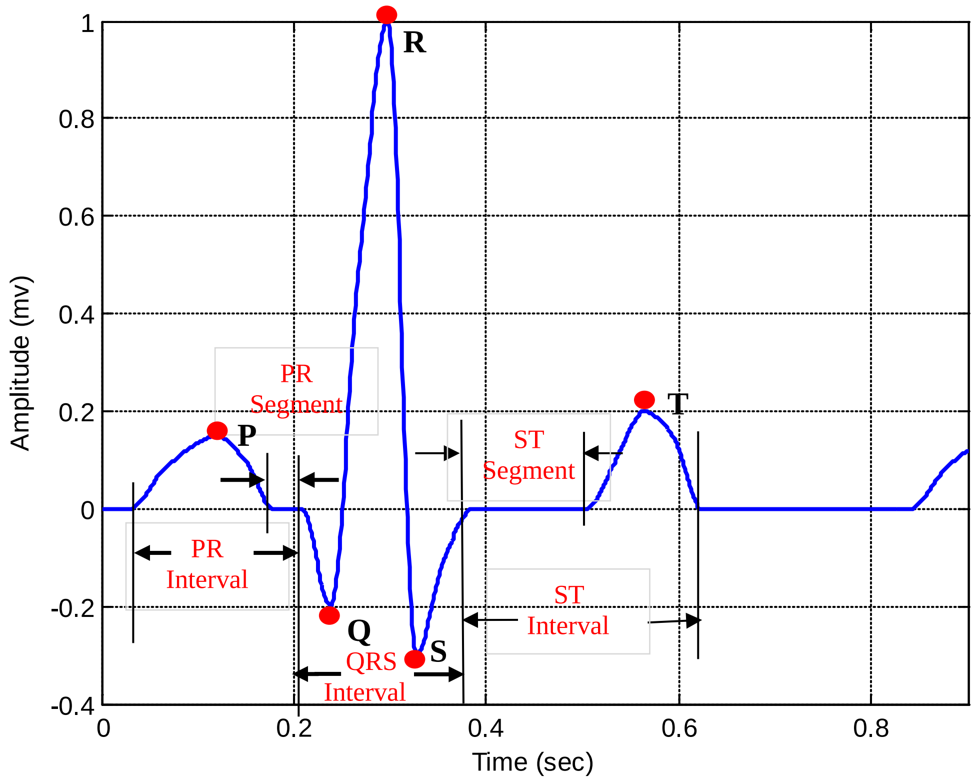


Figure 2.2 Normal ECG with the waves that is consisted noted

The electrical potential remains relatively unchanged without any external stimulus. An electrical stimulus from an external source or from neighboring cells or parts of cells with potential higher than a threshold level increases the cell membrane permeability to sodium ions and causes a rapid sequence of changes in the membrane potential called an action potential. The underlying electrophysiology in an action potential is as follows [22].

❖ Initially, the electrical stimulus causes a rapid change in permeability of the membrane to sodium; sodium ions flow into the cell abruptly increasing the membrane potential to 20 mV. This phenomenon is called depolarization and is shown as phase 0 in Figure 2.3

❖ Eventually the membrane potential will decrease and return to resting state called repolarization. This process happens slower than depolarization, and it can be divided into three phases.

a) Phase 1 is a slightly decrease in potential due to the opening of potassium channels

b) In phase 2, the membrane potential remains almost constant in the plateau phase, due to balance of sodium and potassium ions

c) Finally, in phase 3, the membrane potential decreases continuously to level of membrane resting potential [21]

An action potential in one part of a cell stimulates an action potential in another cell or part of the same cell dependent on its electrical influence or ability to meet the threshold. This mechanism is used to conduct electrical activity through all the muscle cells of the heart.

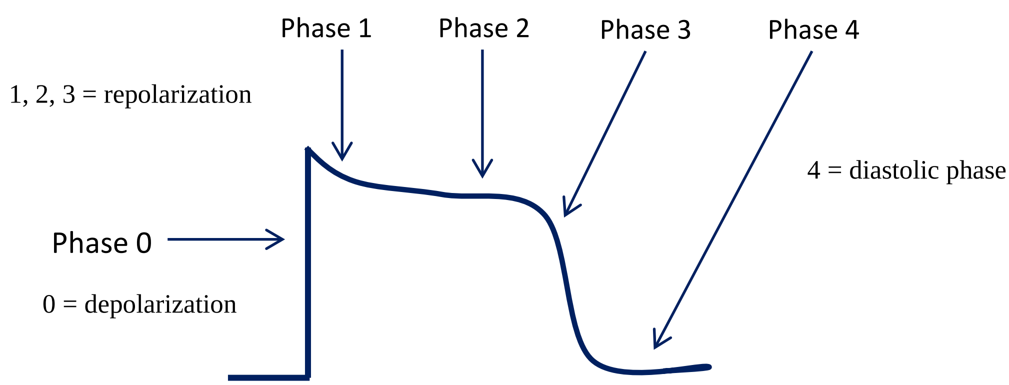


Figure 2.3 Schematic of action potential in ventricle cell

2.1.3 ECG Waveform

The output of ECG is a graph of two-dimensional plot, the *x*-axis represents time in seconds and the *y*-axis represents signal voltage in milli-volts. Conventional ECG machines prints its output on grid graph papers, each square grid is $1mm^2$. Each second is represented by 25mm on the *x*-axis, and one millivolt is represented by 1cm on the graph. A typical normal ECG beat, known as Normal Sinus Rhythm (NSR), can be represented by the PQRST waves. Each wave is generated by a physiological event of the heart.

A normal ECG consists of a P wave, a QRS complex, and a T wave. The P wave is caused by electric currents produced by the depolarization of the atria before their contraction, while the QRS complex is caused by electric currents produced by the depolarization of the ventricles prior to their contraction, during the extending of the depolarization in the ventricular myocardium. The QRS complex usually consists of three different waves, the Q, R, and S waves. Note that both the P wave, and the waves that form the QRS complex, are depolarization waves. The T wave is caused by the electric currents produced during recovery of the ventricles from the state of depolarization. This process is takes place in the ventricular myocardium 0.25sec to 0.35sec after the depolarization. The T wave is characterized as the wave of repolarization. The Figure 2.2 shows a representation of an ECG with the waves and complexes annotated. ECG signal intervals and segments can be indicators of different heart disorders. The P-R interval is used to estimate the functionality of the AV node, this interval measures the time taken for an electrical impulse to travel from the sinus node to the AV node. P-R intervals greater than 0.2sec are generally considered to be symptoms of 1st degree heart blocks, whereas P-R intervals duration less than 0.12sec could be diagnosed as tachyarrhythmia. The R-R interval is the time between two consecutive R-waves; it can be used to estimate a person heart rate by a beats-per-minute (BPM) calculation.

The normal heart rate is range between 50-100 BPM, a heart rate count exceeding this range will indicate tachycardia or bradycardia. Another common interval measure is the Q-T interval, it indicates the period of time the ventricular depolarizes and repolarizes. The Q-T interval is highly variable, depending on gender, age, heart rate and the influence of drugs. Hence, the Bazett's formula can be used to calculate the QT interval taking into account of the variations, (it is given:$\mathrm{QT_c} = \frac{\mathrm{QT}}{\sqrt{\mathrm{RR}}}$) RR is the R-R interval and $\mathrm{QT_c}$ is the QT interval corrected. A prolonged QT interval greater than 0.45sec is a sign of ventricular tachyarrhythmia which is a risk factor of sudden death occurrence.

A QRS complex is the most easily identified wave deflection of an ECG wave; it corresponds to the event of the ventricles depolarization. A normal QRS complex will have a duration range between 0.06sec to 0.10sec and a R-wave amplitude measuring at 0.7mV. The morphology of the QRS complex is often used to diagnose various different heart diseases. The P-R segment and S-T segment are both isoelectric, this means that no electrical activity can be recorded by the surface electrodes over this period; hence, there is no wave deflection visible on the ECG wave.

The S-T segment represents depolarization of the ventricles, this segment can indicate that there is insufficient blood supply to the heart, also known as ischemia, when it is elevated or depressed from the isoelectric line. This shift is caused by the changes in electrical current flow properties of the dead conductive cells, due to ischemia from coronary blockage. Elevation of the S-T segment implies that myocardial infarction is taking place. Depression of the S-T segment indicates coronary ischemia, which can be caused by coronary blockage or overdose of substance, e.g. digoxin or potassium.

The P-R segment corresponds to the electrical impulse triggered by the AV node, traveling through conductive cells in the heart towards the ventricles, this segment does not signify any clinical diagnosis of heart disorder but it helps us understand how the heart conduction system works. Table 2.2 shows amplitude and duration of waves, intervals and segments [14, 23] of ECG signal.

2.1.4 ECG Leads System

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 leads 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, it allows seeing the heart from various different angles. The different leads can be compared to radiographs taken from different angles [24– 26]. 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. 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. 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 Figure 2.4.

Table 2.2 Amplitude and duration of waves, intervals and segments of ECG signal [14, 23]

Sl. no.	Features	Amplitude (mV)	Duration (ms)
1	P wave	0.1-0.2	60-80
2	PR-segment	-	50-120
3	PR- interval	-	120-200
4	QRS complex	1	80-120
5	ST-segment	-	100-120
6	T –wave	0.1-0.3	120-160
7	ST-interval	-	320
8	RR-interval	-	(0.4-1.2)s

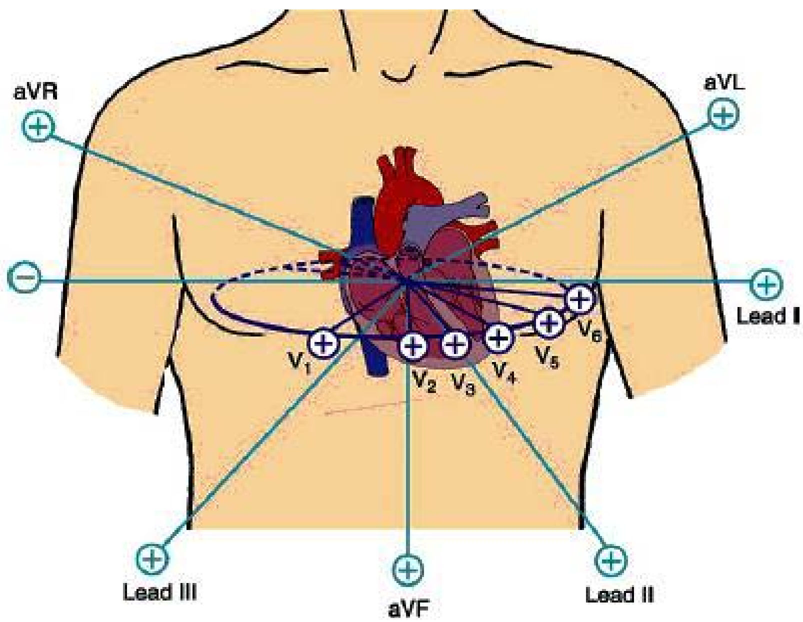


Figure 2.4 A vector view of the standard 12 Leads ECG [27]

2.2. Noise in the ECG Signal

Generally the recorded ECG signal is often contaminated by different types of noises and artifacts that can be within the frequency band of ECG signal, which may change the characteristics of ECG signal. Hence, it is difficult to extract useful information of the signal. The primary sources of noise in ECG signals are:

- Power line interferences
- Low frequency Noise

- Muscle contraction (EMG noise)

These artifacts strongly affects the ST segment, degrades the signal quality, frequency resolution, produces large amplitude signals in ECG that can resemble PQRST waveforms and masks tiny features that are important for clinical monitoring and diagnosis. Cancelation of these artifacts in ECG signals is an important task for better diagnosis.

2.2.1 Power Line Interferences

Power line interferences consist of depending on the power supply 60 Hz/50 Hz, pickup and harmonics because of improper grounding [28]. It is indicated as an impulse or spike at 60 Hz/50 Hz harmonics, and will appear as additional spikes at integral multiples of the fundamental frequency as shown in Figure 2.5. Its frequency content is 60 Hz/50 Hz and its harmonics, amplitude is up to 50 percent of peak-to-peak ECG signal amplitude [26]. A 60 Hz notch filter can be used to remove the power line interferences [14]. Besides providing power to the electrocardiograph itself, power lines are connected to other pieces of equipment and appliances in the typical hospital floor, and ceiling running past the room to other points in the building. This power line can affect the recording of the ECG and introduces interference at the line frequency in the recorded trace [29]. Also it occurs through two mechanisms: capacitive and inductive coupling. Capacitive coupling refers to the transfer of energy between two circuits by means of a coupling capacitance present between the two circuits. The value of the coupling capacitance decreases with increasing separation of the circuits. Inductive coupling on the other hand is caused by mutual inductance between two conductors. When current flows through wires it produces a magnetic flux which can induce a current in adjacent circuits. Typically, capacitive coupling is responsible for high frequency noise while inductive coupling introduces low frequency noise. For this reason inductive coupling is the dominant mechanism of power line interference in ECG. To limit the amount of power line interference, electrodes should be applied properly, that there are no loose wires, and all components have adequate shielding [30].

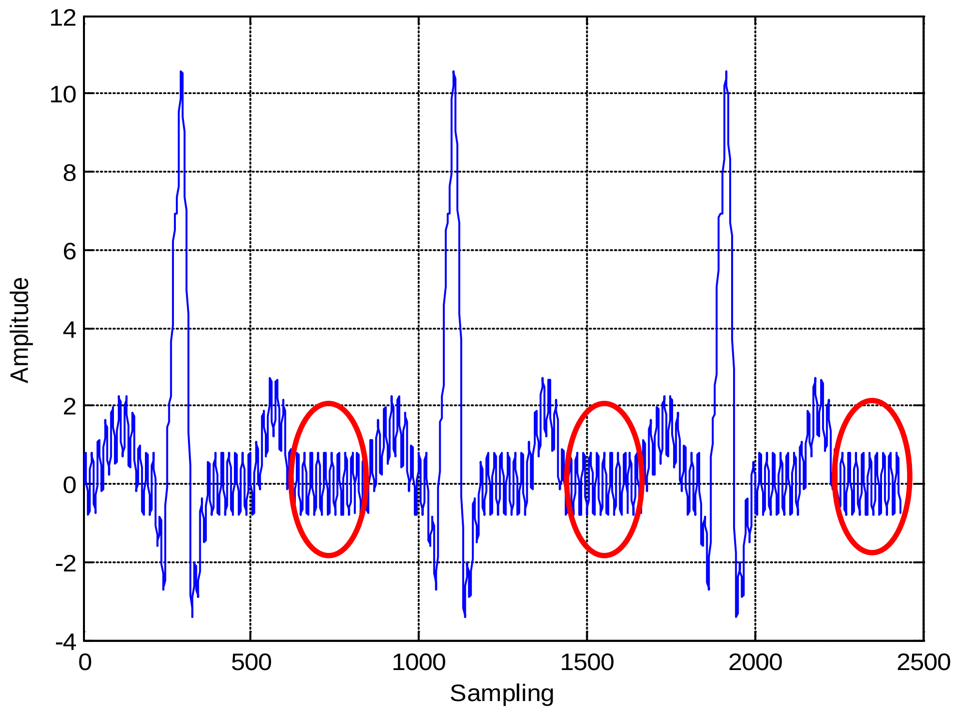


Figure 2.5 Power line interference (50 Hz) in ECG signal

2.2.2 Low Frequency Noise

This noise is a result of changes of impedance between the electrode and a body of the patient. The impedance changes as a result of changes of distances between the source of signal (heart) and the electrode caused by the movement of the patient including breathing and changes of contact between the body and the electrode which to a significant extent is caused by the movement of the body of the patient, as shown in Figure 2.6. The low frequency noise is located in the frequency below 1Hz. However, in some types of examinations, say exercise examination of ECG, this range of frequencies is far higher and can reach the frequency of several Hz [31]. In exercise test of ECG, the amplitude of low frequency noise becomes higher which calls for the use of more effective means of noise suppression.

Figure 2.6 Low frequency noises present in ECG signal [29]

2.2.3 Muscle Contraction (EMG noise)

The noise of this nature is caused by the contraction of skeletal muscles which appear because of the movement of the patient (related with the movement or inappropriate ambient temperature in which the ECG examination is being carried out). Muscle signals, as shown in Figure 2.7, are always associated with ECG signals. The highest level of noise is present in stress tests. In these conditions, the noise is caused by intensive muscle contractions during running on a treadmill or the load of the patient caused by cycle ergometer. The movement of the patient is present during a long-term recording of ECG signals under normal conditions which is present in Holter testing. In this case, the level of muscle noise depends quite significantly on a level of activity (movement) of the patient, which could vary within the testing.

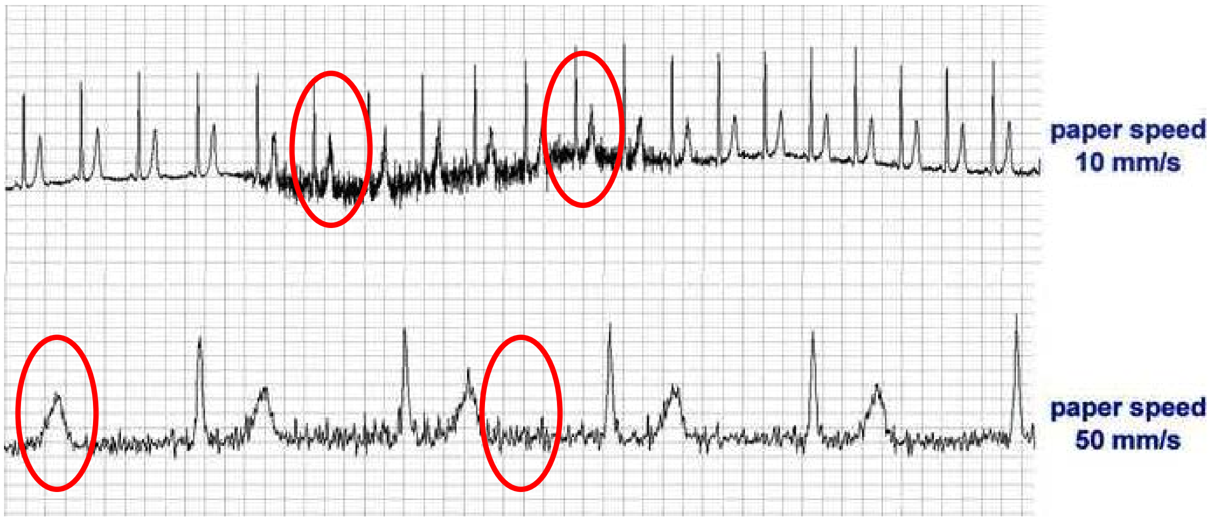


Figure 2.7 Example of muscle noise of ECG signals

CHAPTER 3

ECG SIGNAL PROCESSING TECHNIQUES

ECG Signal Processing has become an essential and effective pedagogical approach to solve a problem of detecting selected arrhythmia conditions from a patient's ECG signals. Several advanced signal processing techniques have been applied for cardiac arrhythmia detection using Wavelets, Fourier Transforms, Artificial Neural Networks, Independent Component Analysis, etc. Introducing a simple algorithm for arrhythmia detection can be very useful for better conceptual understanding of signal processing. In this thesis, simple methods have been discussed and used to clean ECG signal corrupted by noise and to extract required parameters for detecting arrhythmia condition. These simple procedures involve using Digital filter techniques, wavelet techniques and Adaptive filter techniques. There are various artifacts which get added in these signals and change the original signal; therefore there is a need of removal of these artifacts from the original signal.

3.1 Digital Filters

The function of a digital filter is the same as its analog counterpart, but its implementation is very different. Analog filters are implemented using either active or passive electronic circuits, and they operate on continuous waveforms. On the other hand, Digital filters are implemented using either a digital logic circuit or a computer program and they operate on a sequence of numbers that are obtained by sampling the continuous waveform. There are several advantages of digital filters over analog filters. A digital filter is highly immune to noise because of the way it is implemented (software/digital circuits). Accuracy is dependent only on round-off error, which is directly determined by the number of bits that the designer chooses for representing the variables in the filter.

Digital filtering has specific characteristics that you need to pay special attention. The analog input signal must satisfy certain requirements. Furthermore, on converting an output digital signal into analog form, it is necessary to perform additional signal processing in order to obtain the appropriate result. Figure 3.1 shows the block diagram of digital filtering process.

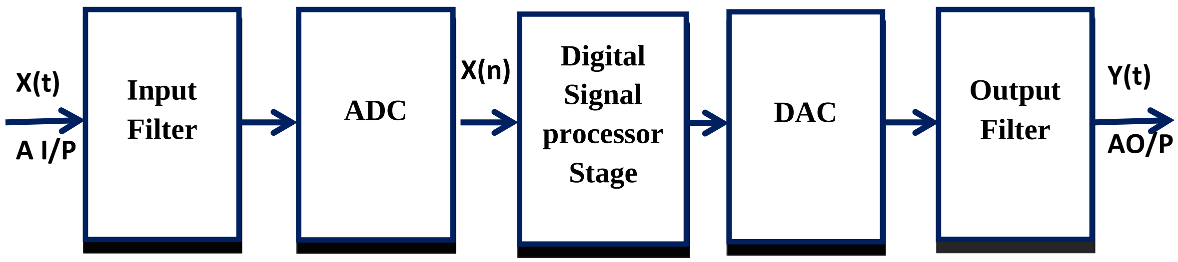


Figure 3.1 A simplified block diagram of a real-time digital filter with analogue input and output signal

The bandlimited analogue signal is sampled periodically and converted into a series of digital samples, *x(n), n = 0, 1, ...* The digital processor implements the filtering operation, mapping the input sequence, *x(n),* into the output sequence, *y(n),* in accordance with a computational algorithm for the filter [32]. The DAC converts the digitally filtered output into analogue values which are then analogue filtered to smooth and remove unwanted high frequency components. The process of converting an analog signal into digital form is performed by sampling with a finite sampling frequency *fs.* If an input signal contains frequency components higher than half the sampling frequency (*fs*/2), it will cause distortion to the original spectrum. This is the reason why it is first necessary to perform filtering of an input signal using a low-pass filter that eliminates high-frequency components from input frequency spectrum. This filter is called anti-aliasing filter as it prevents aliasing. After the process of filtering and sampling, a digital signal is ready for further processing which, in this case, is filtering using the appropriate digital filter. The output signal is also a digital signal which, in some cases, needs to be converted back into analog form. After digital-to analog conversion, signal contains some frequency components higher than *fs*/2 that must be eliminated. Again, it is necessary to use a low pass filter with the sampling frequency *fs*/2. Digital filter attenuation is usually expressed in terms of the logarithmic decibel scale (dB) [33]. The attenuation measured in decibels can be found using the following equation (3.1):

$$a = 20 * \log\left(H(f)\right) \tag{3.1}$$

Cut-off frequencies are used for filter specification, the cut-off frequency of the passband is a frequency at which the transition of the passband to the transition region occurs. The cut-off frequency of the stopband is a frequency at which the transition of the transition region to the stopband occurs. These two frequencies are equivalent only for the ideal filter which is not possible to realize in practice.

Digital filters can be classified in several different groups, depending on what criteria are used for classification. The two major types of digital filters which are finite impulse response (FIR) and infinite impulse response (IIR). Both types have some advantages and disadvantages that should be carefully considered when designing a filter. Besides, it is necessary to take into account all fundamental characteristics of a signal to be filtered as these are very important when deciding which filter to use. In most cases, it is only one characteristic that really matters and it is whether it is necessary that filter has linear phase characteristic or not [34]. It is necessary that a filter has linear phase characteristic to prevent loosing important information. When a signal to be filtered is analyzed in this way, it is easy to decide which type of digital filter is best to use. Accordingly, if the phase characteristic is of the essence, FIR filters should be used as they have linear phase characteristic. Such filters are of higher order and more complex, therefore. Otherwise, when it is only frequency response that matters, it is preferable to use IIR digital filters which have far lower order, i.e. are less complex, and thus much easier to realize. Either type of filter, in its basic form, can be represented by its impulse response sequence, h (k) (k = 0, 1, ...). The input and output signals to the filter are related by the convolution sum, which is given in equations (3.2) for the IIR and in (3.3) for the FIR filter

$$y(n) = \sum_{k=0}^{\infty} h(k)x(n-k) \tag{3.2}$$

$$y(n) = \sum_{k=0}^{N-1} h(k)x(n-k) \tag{3.3}$$

It is evident from these equations that, for IIR filters, the impulse response is of infinite duration whereas for FIR it is of finite duration, since *h (k)* for the FIR has only N values. In practice, it is not feasible to compute the output of the IIR filter using equation (3.2) because the length of its impulse response is too long (infinite in theory). Instead, the IIR filtering equation is expressed in a recursive form:

$$y(n) = \sum_{k=0}^{\infty} h(k)x(n-k) = \sum_{k=0}^{N} a_k x(n-k) - \sum_{k=1}^{M} b_k y(n-k) \qquad (3.4)$$

Where the a_k and b_k are the coefficients of the filter and M , N are finite. The values of $h(k)$, for FIR, or a_k and b_k, for IIR, are often very important objectives of most filter design problems. In Equation (3.4), the current output sample, $y(n)$, is a function of past outputs as well as present and past input samples, that is the IIR is a feedback system of some sort. This should be compared with the FIR equation in which the current output sample, $y(n)$ is a function only of past and present values of the input. Note, however, that when the b_k are set to zero, the equation (3.4) reduces to the FIR equation (3.3).

3.1.1 Finite Impulse Response (FIR) Filter

A finite impulse response (FIR) filter has a unit impulse response that has a limited number of terms, Figure 3.2 as opposed to an infinite impulse response (IIR) filter which produces an infinite number of output terms when a unit impulse is applied to its input. FIR filters are generally realized nonrecursively, which means that there is no feedback involved in computation of the output data. The output of the filter depends only on the present and past inputs. This quality has several important implications for digital filter design and applications. FIR filters typically used for real-time ECG processing.

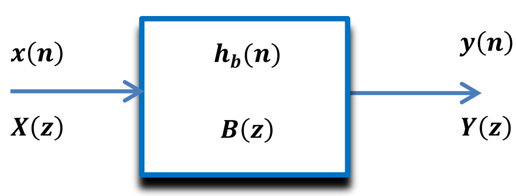


Figure 3.2 Block diagrams of FIR filters

FIR filters can be designed using different methods, but most of them are based on ideal filter approximation. The objective is not to achieve ideal characteristics, as it is impossible anyway, but to achieve sufficiently good characteristics of a filter. The transfer function of FIR filter approaches the ideal as the filter order increases, thus increasing the complexity and amount of time needed for processing input samples of a signal being filtered.

The basic characteristics of (FIR) filters are:

- **Finite impulse response,** finite impulse response implies that the effect of transients or initial conditions on the filter output will eventually die away. Figure 3.3 shows a signal-flow graph (SFG) of a FIR filter realized nonrecursively.

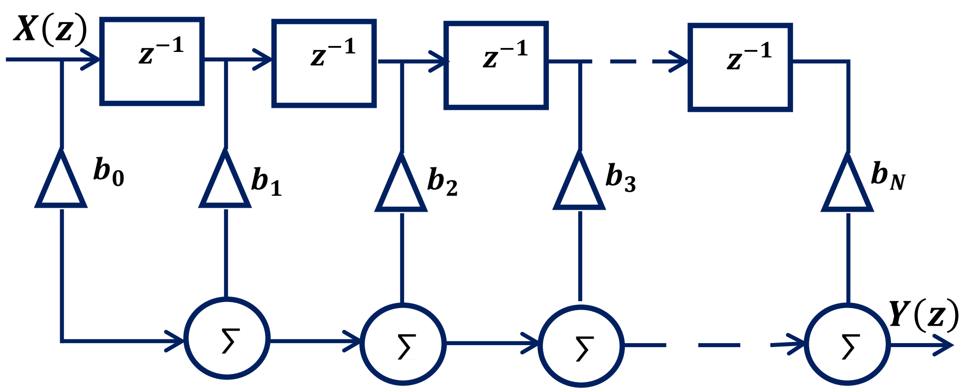


Figure 3.3 The output of a FIR filter of order N is the weighted sum of the values in the storage registers of the delay line

The filter is merely a set of “tap weights” of the delay stages. The unit impulse response is equal to the tap weights, so the filter has a difference equation given by equation (3.5), and a transfer function equation given by equation (3.6).

$$y(nT) = \sum_{k=0}^{N} b_k x(nT - kT) \tag{3.5}$$

$$H(z) = b_0 + b_1 z^{-1} + b_2 z^{-2} + \cdots + b_N z^{-N} \tag{3.6}$$

- **Linear phase,** in many biomedical signal processing applications, it is important to preserve certain characteristics of a signal throughout the filtering operation, such as the height and duration of the QRS pulse. A filter with linear phase has a pure time delay as its phase response, so phase distortion is minimized. A filter has linear phase if its frequency response $H(e^{j\theta})$can be expressed as

$$H(e^{j\theta}) = H_1(\theta)\mathrm{e}^{-\mathrm{j}(\alpha\theta+\beta)} \tag{3.7}$$

where $H_1(\theta)$ is a real and even function, since the phase of $H(e^{j\theta})$ is

$$\angle H(e^{j\theta}) = f(x) = \begin{cases} -\propto \theta - \beta, & H_1(\theta) > 0 \\ -\alpha\theta - \beta - \pi, & H_1(\theta) < 0 \end{cases} \tag{3.8}$$

FIR filters can easily be designed to have a linear phase characteristic. Linear phase can be obtained in four ways, as combinations of even or odd symmetry (defined as follows) with even or odd length.

$$\begin{cases} h(N-1-K) = h(\theta K), even\ symmetr & for\ 0 \leq K \leq N \\ h(N-1-K) = -h(\theta K), odd\ symm & for\ 0 \leq K \leq N \end{cases} \tag{3. 9}$$

- **Stability,** since a nonrecursive filter does not use feedback, it has no poles except those that are located at z = 0. Thus there is no possibility for a pole to exist outside the unit circle. This means that it is inherently stable [35]. As long as the input to the filter is bounded, the output of the filter will also be bounded. This contributes to ease of design, and makes FIR filters especially useful for adaptive filtering where filter coefficients change as a function of the input data.

There are many areas where FIR filters have been employed, including multirate processing noise reduction [36, 37], matched filtering, and image processing [38]. In multirate processing, for example, FIR filters have been successfully used for efficient digital anti-aliasing and anti-imaging filtering for multirate systems such as high quality data acquisition and the compact disc player. Figure 3.4 shows the application and construction of FIR bandpass filter to an ECG signal using convolution and FFT to evaluate the filter's frequency response. Firstly and in order to show the range of the filter's operation with respect to the frequency spectrum of the ECG data, a spectrum analysis is implemented on both the ECG data and the filter by using the FFT to analyze the data without windowing or averaging as shown in Figure 3.5.

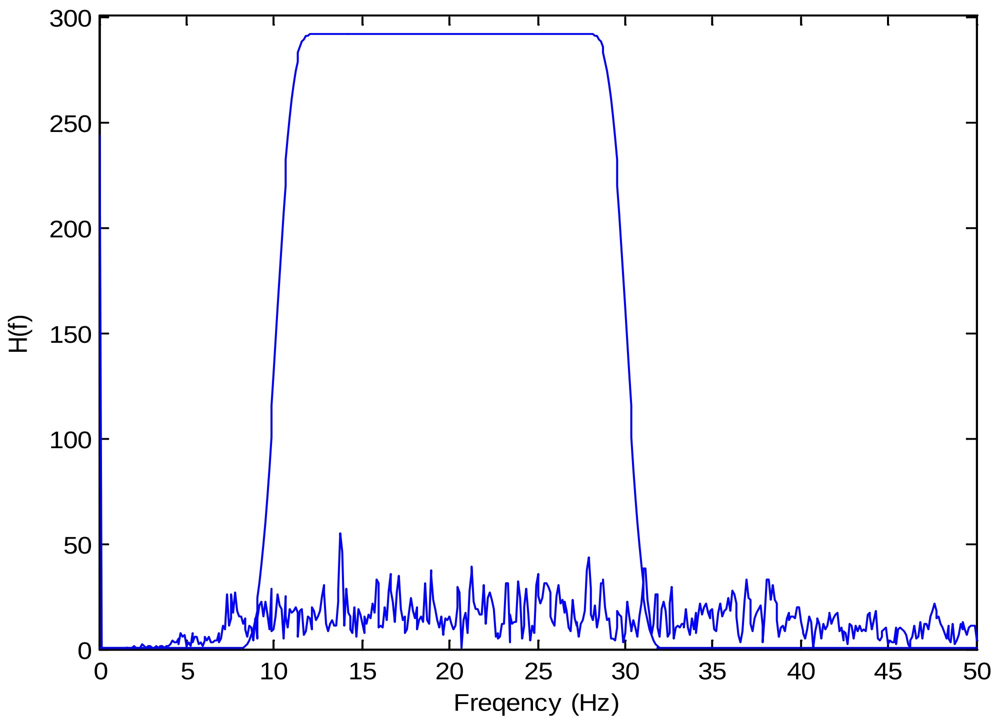


Figure 3.4 Frequency response of the FIR bandpass filter

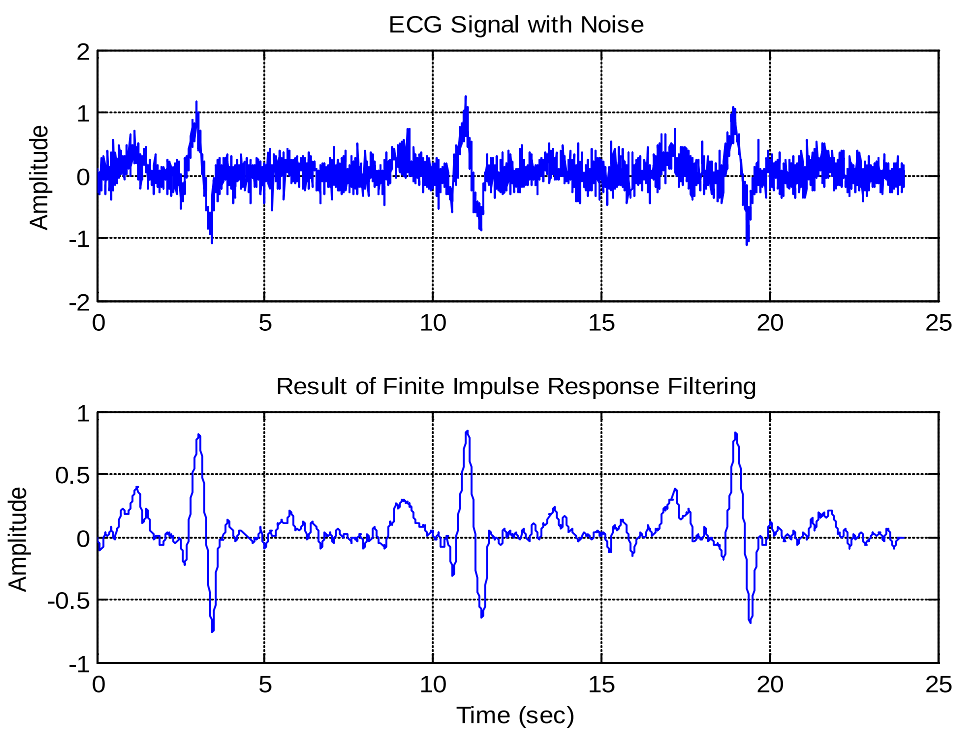


Figure 3.5 The frequency spectrum of ECG signal using the FFT

3.1.2 Infinite Impulse Response (IIR) Filters

The primary advantage of IIR filters as shown in Figure 3.6 over FIR filters is that they can usually meet a specific frequency criterion, such as a cutoff sharpness or slope, with a much lower filter order (i.e., a lower number of filter coefficients).

The transfer function of IIR filters includes both numerator and denominator terms equation (3.10) unlike FIR filters which have only a numerator. The equation for the IIR filter is the same as that for any general linear process shown in equation (3.11).

$$H(z) = \frac{\sum_{i=0}^{n} a_i z^{-1}}{1-\sum_{i=1}^{n} b_i z^{-1}} = \frac{a_0 + a_1 z^{-1} + a_2\, z^{-2} + \cdots + a_N z^{-N}}{1 - b_1 z^{-1} - b_2\, z^{-2} - \cdots - b_N z^{-N}} = \frac{Y(z)}{X(z)} \qquad (3.10)$$

Rearranging the terms gives:

$$Y(z) = b_1 Y(z) z^{-1} + \cdots + b_N Y(z) z^{-n} + a_0\, X(z) + a_1\, X(z) z^{-1} + \cdots a_n X(z) z^{-N} \qquad (3.11)$$

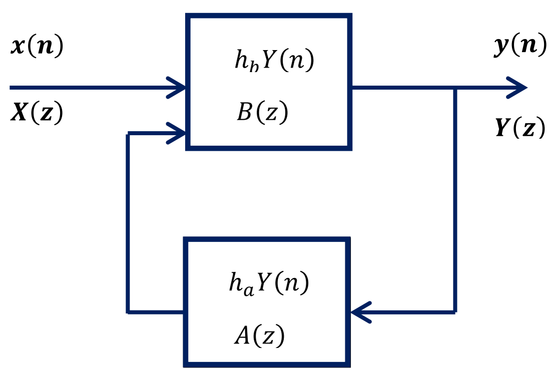


Figure 3.6 Block diagrams of IIR filters

The Y(z) terms on the right side of this equation are delayed feedback terms. Figure 3.7 shows these feedback terms as recursive loops; hence, these types of filters are also called recursive filters. The Figure 3.8 shows Applying IIR filters on the ECG signal with noise.

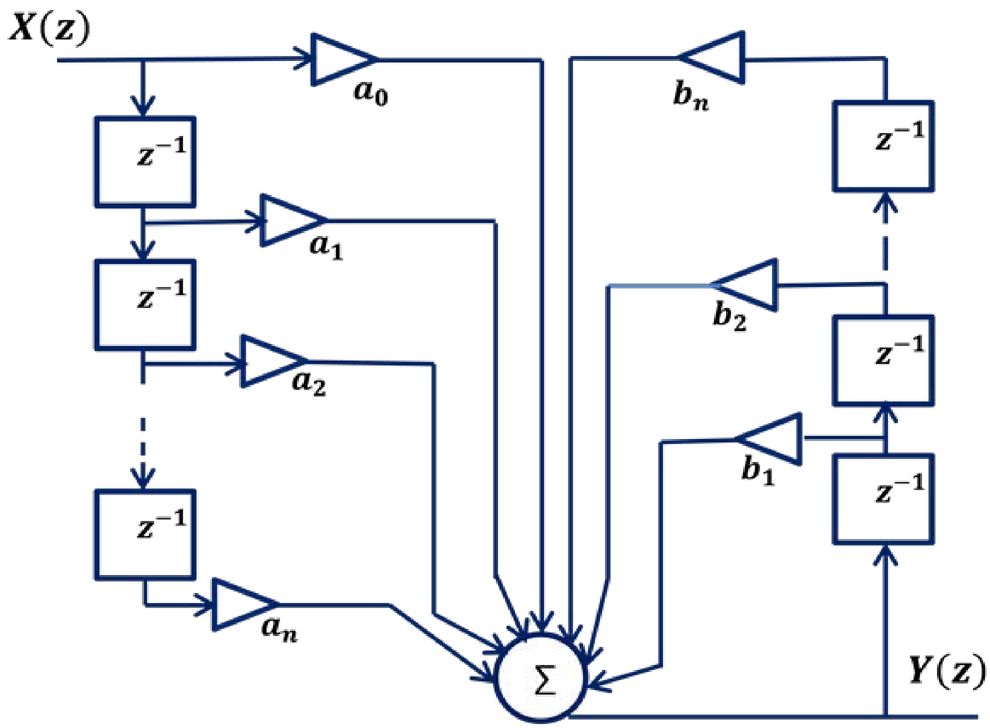


Figure 3.7 The output of an IIR filter is delayed and fed back

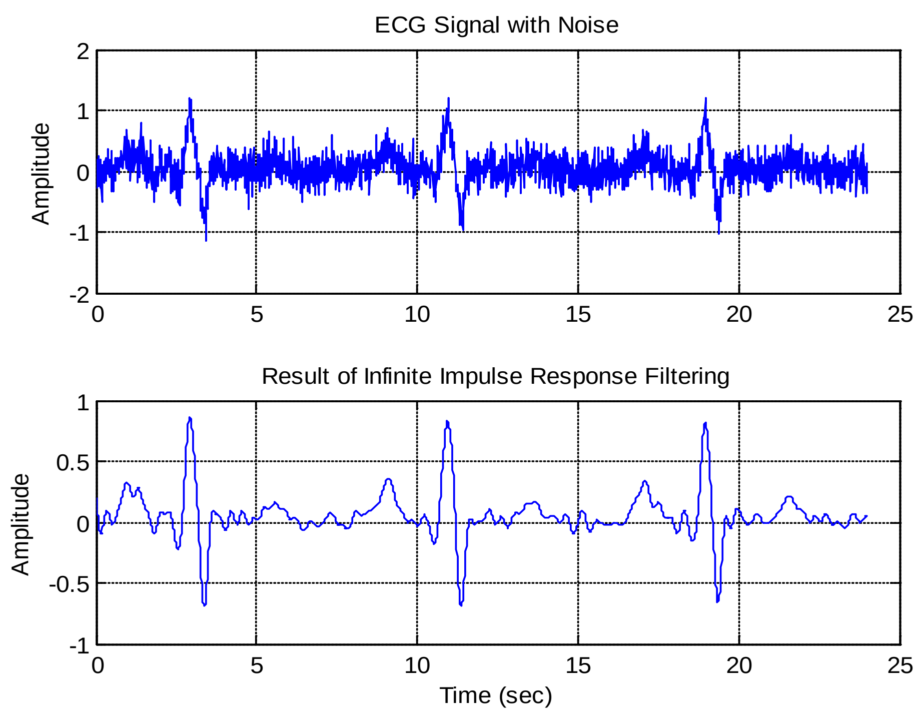


Figure 3.8 Applying IIR filters on the ECG signal with noise

The non-recursive (FIR) and recursive (IIR) filters have different characteristics for numbers of applications. The non-recursive filters are chosen due to its best performance of numerical operations, differentiation and integration. The Table 3.1 below shows the comparison between FIR and IIR filters.

Table 3.1 Comparison between FIR and IIR filters

FIR Filters	IIR Filters
non recursive filter	Recursive filter
No feedback	feedback is involved
Always Stable	May Be Unstable
Linear Phase Response	Non-Linear Phase Response
FIR has no limited cycles.	has limited cycles
Less Efficient	More Efficient
No Analog Equivalent	Analog Equivalent
FIR is dependent upon i/p only.	IIR filters are dependent on both i/p and o/p.
FIR filters are used for tapping of a higher-order.	IIR filters are better for tapping of lower-orders, since IIR filters may become unstable with tapping higher-orders.
FIR only consists of zeros.	IIR filters consist of zeros and poles, and require less memory than FIR filters.
FIR filters have only numerators	IIR filters have both numerators and denominators.
Where the system response is zero, we use FIR filters.	Where the system response is infinite, we use IIR filters,

3.2 Wavelet Analysis

Wavelet transform used as another method to describe the properties or processing biomedical images and a nonstationary biosignal waveform that change over time [39-42]. The wavelet transform is divided into segments of scale rather than sections of time, and it is applied on a set of orthogonal basis functions obtained by contractions, dilations and shifts of a prototype wavelet. The main difference between wavelet transforms and Fourier transform-based methods is that the Fourier transform-based methods use windows of constant width while the wavelet uses windows that are frequency dependent.

The continuous wavelet transform (CWT) can be represented mathematically in the following equation (3.12).

$$W(a, b) = \int x(t)\, \psi^{*}_{a,b}(t)\, dt \tag{3.12}$$

Where the x(t) is given signal, a is the scale factor, b is time and * is the complex conjugate. Probing function ψ is called "wavelet" because it can be any of a number of different functions so it always takes on an oscillatory form. Also a prototype wavelet function $\psi(t)$ is termed a mother wavelet when b = 0 and a = 1, then the wavelet is in its natural form, that is, $\psi_{1,0}(t) \equiv \psi(t)$.

The orthogonal basis functions denoted by $\psi^*_{a,b}(t)$ are obtained by scaling and shifting $\psi(t)$by scale factor *a* and time *b* respectively in the following equation (3.13).

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\,\psi\left(\frac{t-b}{a}\right) \tag{3. 13}$$

By adjusting the scale factor, the window duration can be arbitrarily changed for different frequencies, i.e. if *a* is greater than one then the wavelet function ψ is stretched along the time axis whereas when it is less than one (but still positive) it contacts the function. Negative values of a simply flip the probing function ψ on the time axis. Because of the redundancy in the transform by using CWT coefficients then it is rarely performed recovery of the original waveform using CWT coefficients, while the more parsimonious DWT when reconstruction of the original waveform is desired. The redundancy in CWT is not a problem in analysis applications but will be costly when the application needs to recover the original signal because for recovery, all of the coefficients (that are generated due to oversampling many more coefficients than are really required to uniquely specify the signal) will be required and the computational effort could be too much. While the DWT may still require redundancy to produce a bilateral transform except if the wavelet is carefully chosen such that it leads to an orthogonal family or basis in order to produce a nonredundant bilateral transform.

For most signal and image processing applications, DWT-based analysis is best described in terms of filter banks. The use of a group of filters to divide up a signal into various spectral components is termed subband coding. The most basic implementation of the DWT uses only two filters as in the filter bank shown in Figure 3.9.The waveform under analysis is divided into two components, $Y_{lp}(n)$ and $Y_{hp}(n)$, by the digital filters $H_0(\omega)$ and $H_1(\omega)$. The spectral characteristics of the two filters must be carefully chosen with $H_0(\omega)$ having a lowpass spectral characteristic and $H_1(\omega)$ a highpass spectral characteristic. The highpass filter is analogous to the application of the wavelet to the original signal, while the lowpass filter is analogous to the application of the scaling or smoothing function.

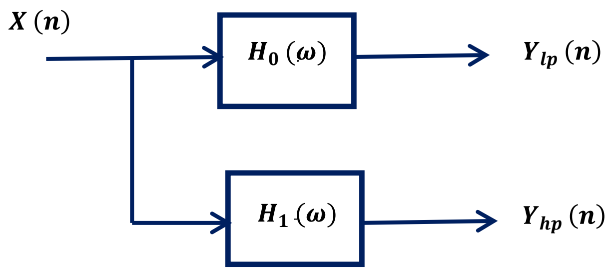


Figure 3.9 Simple filter bank

Signal recovery is illustrated in Figure 3.10 where a second pair of filters, $G_0\ (\omega)$ and $G_1\ (\omega)$, operate on the high and lowpass subband signals and their sum is used to reconstruct a close approximation of the original signal, $X'\ (t)$. The Filter Bank that decomposes the original signal is usually termed the analysis filters while the filter bank that reconstructs the signal is termed the syntheses filters [43]. FIR filters are used throughout because they are inherently stable and easier to implement.

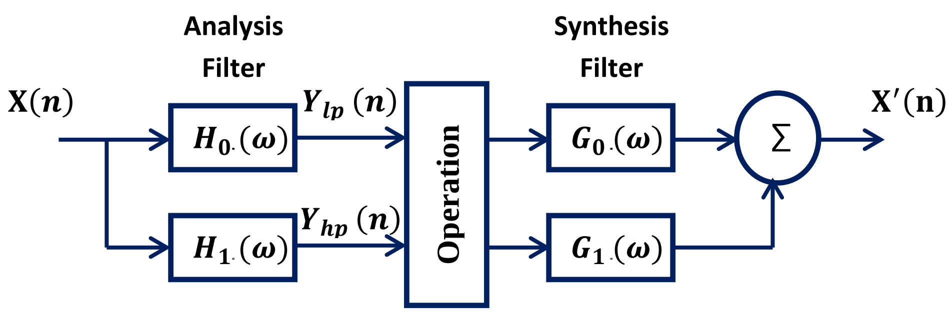


Figure 3.10 A typical wavelet application

The DWT can also be used to construct useful descriptors of a waveform. Since the DWT is a bilateral transform, all of the information in the original waveform must be contained in the subband signals. Figure 3.11 shows the frequency characteristics of the high and lowpass filter while the Figure 3.12 shows the ECG signal generated by the analysis filter bank.

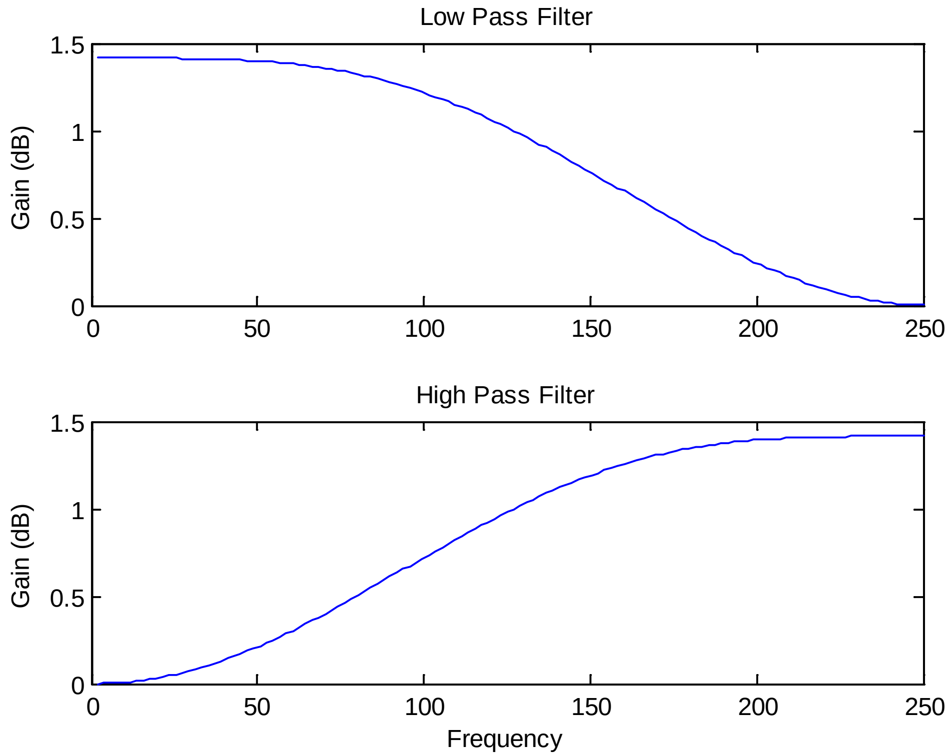


Figure 3.11 Frequency response of low and high pass filter

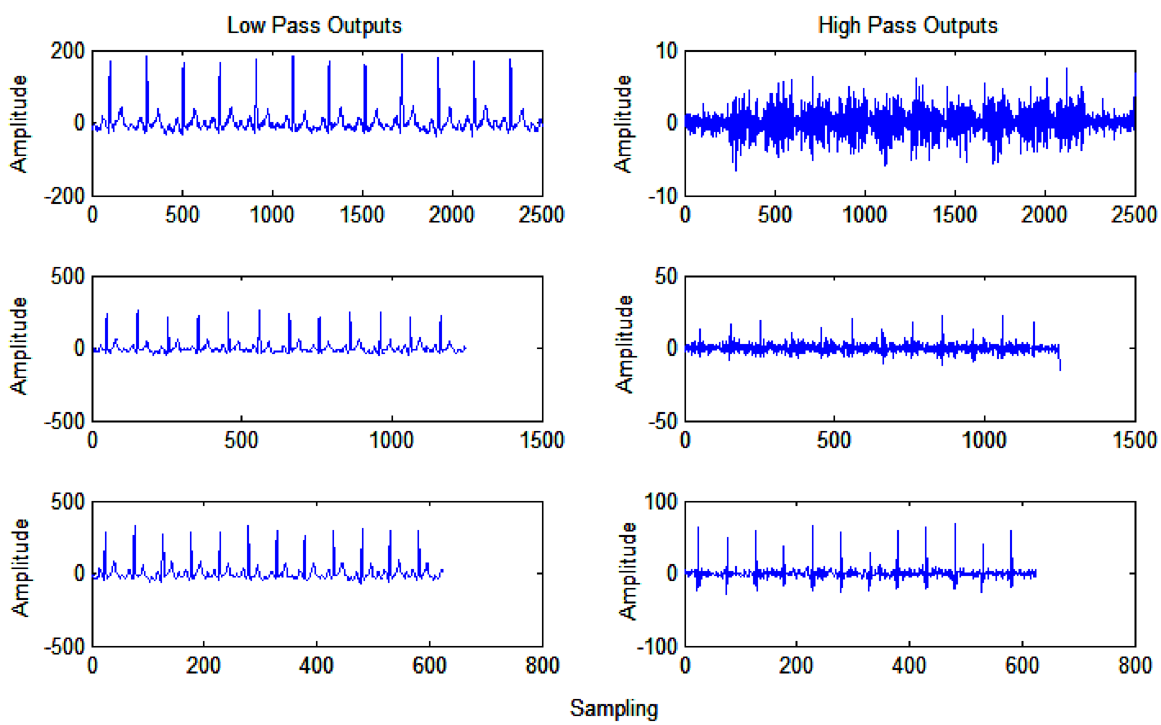


Figure 3.12 ECG signal generated by the analysis filter bank

3.3 Adaptive Signal Processing

An adaptive filter is essentially a digital filter with self-adjusting characteristics. It adapts, automatically, to changes in its input signals. Adaptive filters are the central topic in the sub-area of DSP known as adaptive signal processing. Adaptive techniques have been used in filtering of 60-Hz line frequency noise from ECG signals, extracting fetal ECG signals, and enhancing P waves, as well as for removing other artifacts from the ECG signal [44].

A typical adaptive filter paradigm is shown in Figure 3.13 .The filter coefficients are modified by a feedback process designed to make the filter's output, $\mathrm{y}(n)$, as close to some desired response, $\mathrm{d}(n)$, as possible, by reducing the error, $\mathrm{e}(n)$, to a minimum. As with optimal filtering, the nature of the desired response will depend on the specific problem involved and its formulation may be the most difficult part of the adaptive system specification [35]. The FIR filters with stability criteria make them effective in optimal filtering and adaptive applications [36]. For this reason, the adaptive filter can be performed by a set of FIR filter coefficients.

LMS recursive algorithm is a simpler and more popular approach which is based on gradient optimization when it is adapted for use in an adaptive environment with the same Wiener-Hopf equations [45].

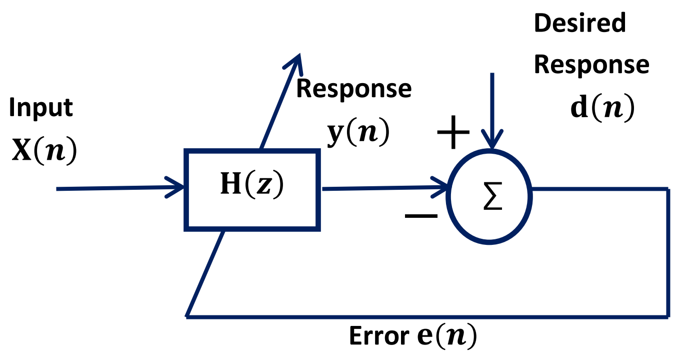


Figure 3.13 Elements of a typical adaptive filter

The LMS algorithm uses a recursive gradient method for detection the filter coefficients that output the minimum sum of squared error [46]. The advantage of the LMS algorithm is simple and easy of mathematical computation, while the drawbacks of this method are the influence of non-stationary interferences on the signal, the influence of signal component on the interference, computer word length requirements, coefficient drift, slow convergence rate and higher steady-state error. Adaptive filter has a number of applications in biomedical signal processing. For example, it can be used to eliminate a narrowband noise 60 Hz line source that distorts a broadband signal, or inversely it can be used to eliminate broadband noise from a narrowband signal and this process is called adaptive line enhancement (ALE) or Adaptive Interference Suppression. In ALE the narrowband component is the signal while in adaptive interference suppression it is the noise. Figure 3.14 introduces an application of adaptive line enhancer that applied to ECG signal where the least square mean (LSM) recursive algorithm used to implement the ALE filter in order to eliminate broadband noise from a narrowband signal.

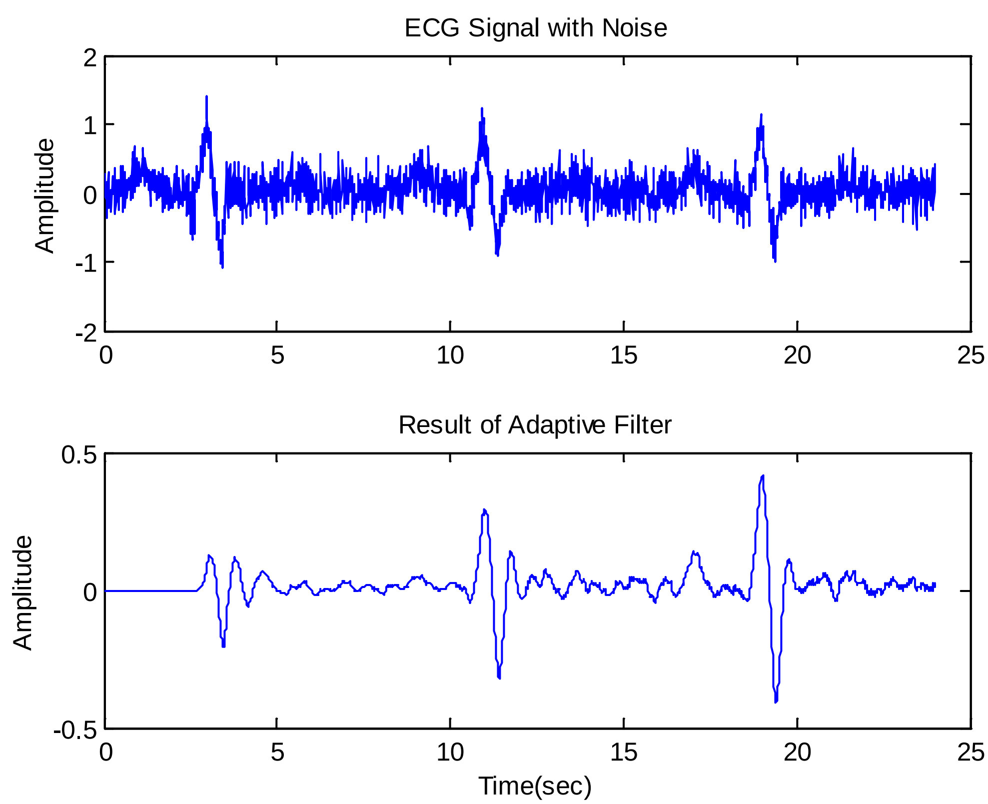


Figure 3.14 ALE application on ECG signal

The Table 3.2 shows the comparison of signal processing techniques that used in this thesis:

Table 3.2 Comparison of signal processing techniques

Methods	Advantages	Limitations
Digital Filters	• Used to reshape the spectrum in order to provide some improvement in SNR • These filters are closely related to spectral analysis • Filters can be divided into two groups according to the way that they achieve the reshape of the spectrum, FIR and IIR filters, and based on their approach • IIR filters are more efficient in terms of computer time and memory than FIR filters; this is the disadvantage of FIR filters	• The user is unable to know which frequency characteristics are the best or any type of filtering will be so effective on splitting up noise from signal • The user will depend on his knowing on signal or source features or by trial and error • Cannot respond to changes that might occur during the path of the signal
Wavelet Analyses	• Describe the properties a nonstationary waveform • It is divided into segments of scale rather than sections of time • It is applied on a set of orthogonal basis functions obtained by contractions, dilations and shifts of a prototype wavelet. • uses windows that are frequency dependent • good technique when it is used especially with signals that have long durations of low frequency components and short durations of high frequency components like EEG signals or signals of differences in interbeat (R-R) intervals	
Adaptive Signal Processing	• Many well documented implementations (LMS, RLS, Kalman filters) • Are optimal in that they minimize the mean squared estimation error • Can be computed in real-time	• They assume your process dynamics are linear • Only provide a point estimate Can only handle processes with additive, unimodal noise

CHAPTER 4

DESIGNING A GUI IN MATLAB

A graphical user interface (GUI) is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so on. The GUI should behave in an understandable and predictable manner, so that a user knows what to expect when anyone performs an action. For example, when a mouse click occurs on a pushbutton, the GUI should initiate the action described on the label of the button. MATLAB Builder NE lets user to create .NET and COM components from MATLAB programs that include MATLAB math and graphics, and GUIs developed with MATLAB. So user can integrate these components into larger .NET and .COM by using Active Server Pages .NET (ASP .NET) and deploy them royalty-free to computers that do not have MATLAB installed. ASP.NET is used to create web pages and web technologies and is an integral part of Microsoft's .NET framework vision. As a member of the .NET framework, ASP.NET is a very valuable tool for programmers and developers as it allows them to build dynamic, rich web sites and web applications using compiled languages like VB and C#. ASP.NET is not limited to script languages, it allows you to make use of .NET languages like C#, J#, VB, etc. It allows developers to build very compelling applications by making use of Visual Studio, the development tool provided by Microsoft. ASP.NET is purely server-side technology. It is built on a common language runtime that can be used on any Windows server to host powerful ASP.NET web sites and technologies. Therefore there are many reasons for using .NET application are as follows [47]:

- Sharing application with others who do not have MATLAB
- Integrating MATLAB algorithms into other applications
- Having many concurrent users work with your MATLAB algorithms
- ASP.NET drastically reduces the amount of code required to build large applications

- The ASP.NET framework is complemented by a rich toolbox and designer in the Visual Studio integrated development environment. Drag-and-drop server controls, and automatic deployment are just a few of the features this powerful tool provides
- Being language-independent, it allows you to choose the language that best applies to your application or partition your application across many languages
- The source code and HTML are together therefore ASP.NET pages are easy to maintain and write. Also the source code is executed on the server. This provides a lot of power and flexibility to the web pages
- All the processes are closely monitored and managed by the ASP.NET runtime, so that if process is dead, a new process can be created in its place, which helps keep your application constantly available to handle requests
- With built-in Windows authentication and per-application configuration, your applications are safe and secured
- The Web server continuously monitors the pages, components and applications running on it. If it notices any memory leaks, infinite loops, other illegal activities, it immediately destroys those activities and restarts itself
- It is purely server-side technology so, ASP.NET code executes on the server before it is sent to the browser
- Provides simplicity as ASP.NET makes it easy to perform common tasks, from simple form submission and client authentication to deployment and site configuration

This chapter introduces the basic knowledge of the MATLAB GUIs and how user can build Graphical User Interfaces (GUIs) in MATLAB. Then discusses how MATLAB .NET applications deploy as WEB site by using ASP.NET with Microsoft Visual Studio.

4.1 Architecture of the MATLAB GUI

A graphical user interface provides the user with a familiar environment in which to work. This environment contains pushbuttons, toggle buttons, lists, menus, text boxes, and so on, all of which are already familiar to the user, so that anyone can concentrate on using the application rather than on the mechanics involved in doing things.

However, GUIs are harder for the programmer because a GUI-based program must be prepared for mouse clicks (or possibly keyboard input) for any GUI element at any time. Such inputs are known as events, and a program that responds to events is said to be event driven. The three principal elements required to create a MATLAB Graphical User Interface are [48]:

a) Components: Each item on a MATLAB GUI is a graphical component. The types of components include graphical controls (pushbuttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function uicontrol, and menus are created by the functions uimenu and uicontextmenu. Axes, which are used to display graphical data, are created by the function axes.

b) Figures: The components of a GUI must be arranged within a figure, which is a window on the computer screen. In the past, figures have been created automatically whenever we have plotted data. However, empty figures can be created with the function figure and can be used to hold any combination of components.

c) Callbacks: Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the MATLAB program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the MATLAB code that implements the function of the button to be executed. The code executed in response to an event is known as a call back. There must be a callback to implement the function of each graphical component on the GUI. The basic GUI elements are summarized in Table 4.1

Table 4.1 Components of basic GUI

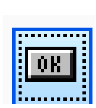
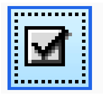
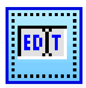
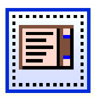
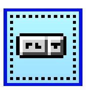
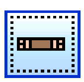
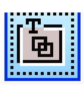
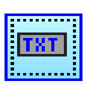
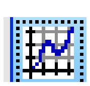
Graphical Controls		
Elements	**Created By**	**Description**
Pushbutton 	Uicontrol	A graphical component that implements a pushbutton. It triggers a callback when clicked with a mouse.

Table 4.1 Cont.

Graphical Controls		
Elements	**Created By**	**Description**
Check box 	Uicontrol	A check box is a type of toggle button that appears as a small square with a check mark in it when it is "on ". Each mouse click on a check box triggers a callback.
Edit box 	Uicontrol	An edit box displays a text string and allows the user to modify the information displayed. A callback is triggered when the user presses the Enter key.
List box 	Uicontrol	A list box is a graphical control that displays a series of text strings. A user can select one of the text strings by single- or double-clicking on it. A callback is triggered when the user selects a string.
Popup menus 	Uicontrol	A popup menu is a graphical control that displays a series of text strings in response to a mouse click. When the popup menu is not clicked on, only the currently selected string is visible.
Slider 	Uicontrol	A slider is a graphical control to adjust a value in a smooth, continuous fashion by dragging the control with a mouse. Each slider change triggers a callback.
Static Elements		
Elements	**Created By**	**Description**
Panel 	Uicontrol	Creates a panel, which is a rectangular box within a figure. Frames arc used to group sets of controls together. Frames never trigger callbacks.
Text field 	Uicontrol	Creates a label, which is a text string located at a point on the figure. Text fields never trigger callbacks.
Menu and Axes		
Elements	**Created By**	**Description**
Menu items	Uimenu.	Creates a menu item. Menu items trigger a callback when a mouse button is released over them.
Axes 	Axes	Creates a new set of axes to display data on. Axes never trigger callbacks

4.1.1 Creating and Displaying a Graphical User Interface

MATLAB GUIs are created using a tool called guide (GUI development environment). This tool allows a user to layout the GUI, selecting and aligning the GUI components to be placed in it. When guide is executed, it creates the Layout Editor [49], as shown in Figure 4.1.

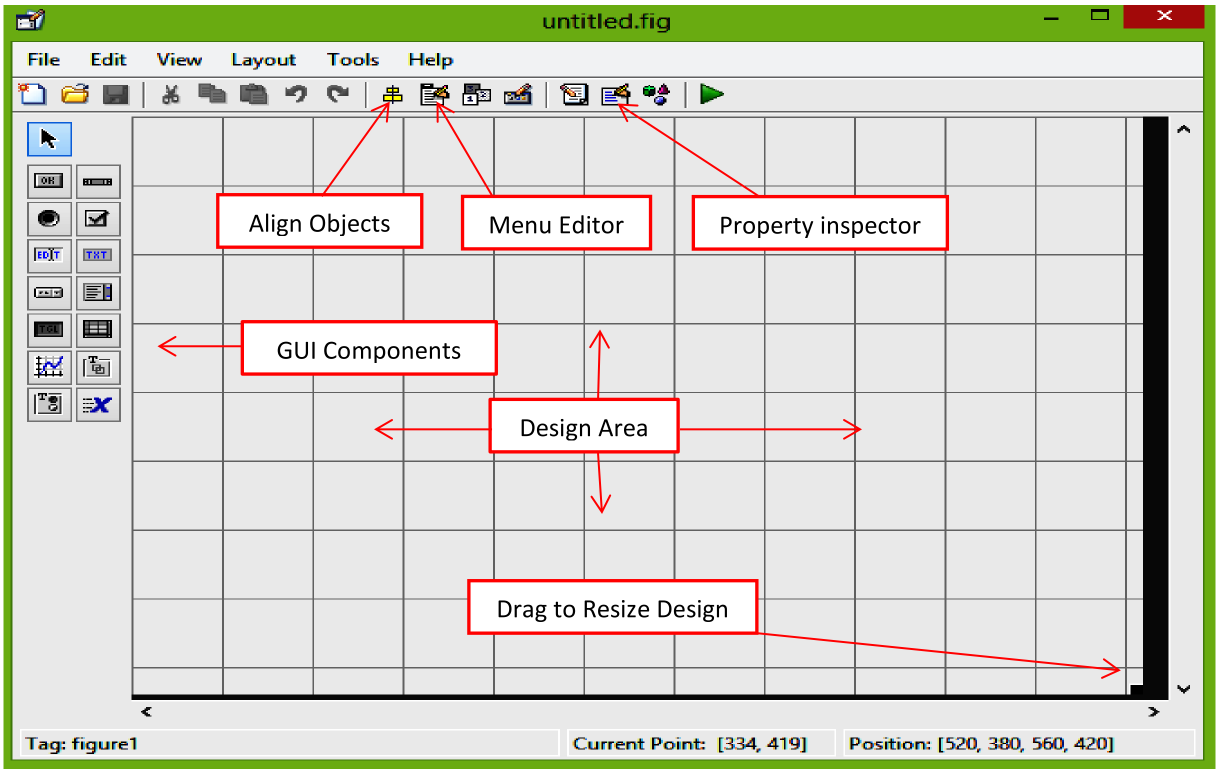


Figure 4.1 The guide tool window in design mode

The large gray area with grid lines is the layout area, where a user can layout the GUI. The layout editor window has components of GUI along the left side of the layout area. A user can create any number of GUI components by first clicking on the desired component, and then dragging its outline in the layout area. The top of the window has a toolbar with a series of useful tools that allow the user to distribute and align GUI components, modify the properties of GUI components, add menus to GUIs, and so on. The basic steps required to create a MATLAB GUI are [50]:

- Decide what elements are required for the GUI and what the function of each element will be. Make a rough layout of the components by hand on a piece of paper.

- Use a MATLAB tool called guide (GUI development environment) to layout the components on a figure. The size of the figure and the alignment and spacing of components on the figure can be adjusted using the tools built into guide.
- Use a MATLAB tool called the Property Inspector (built into guide) to give each component a name (a "tag") and to set the characteristics of each component, such as its color, the text it displays, and so on.
- Save the figure to a file. When the figure is saved, two files will be created on disk with the same name but different extents. The fig file contains the actual GUI that have created, and the M-file contains the code to load the figure and skeleton call backs for each GUI element.
- Write code to implement the behavior associated with each callback function.

As an example of these steps, the Figures 4.2 and 4.3 below illustrates how Creating and Displaying a Graphical User Interface, two files will be created with the same name (filters.fig and filters.m).

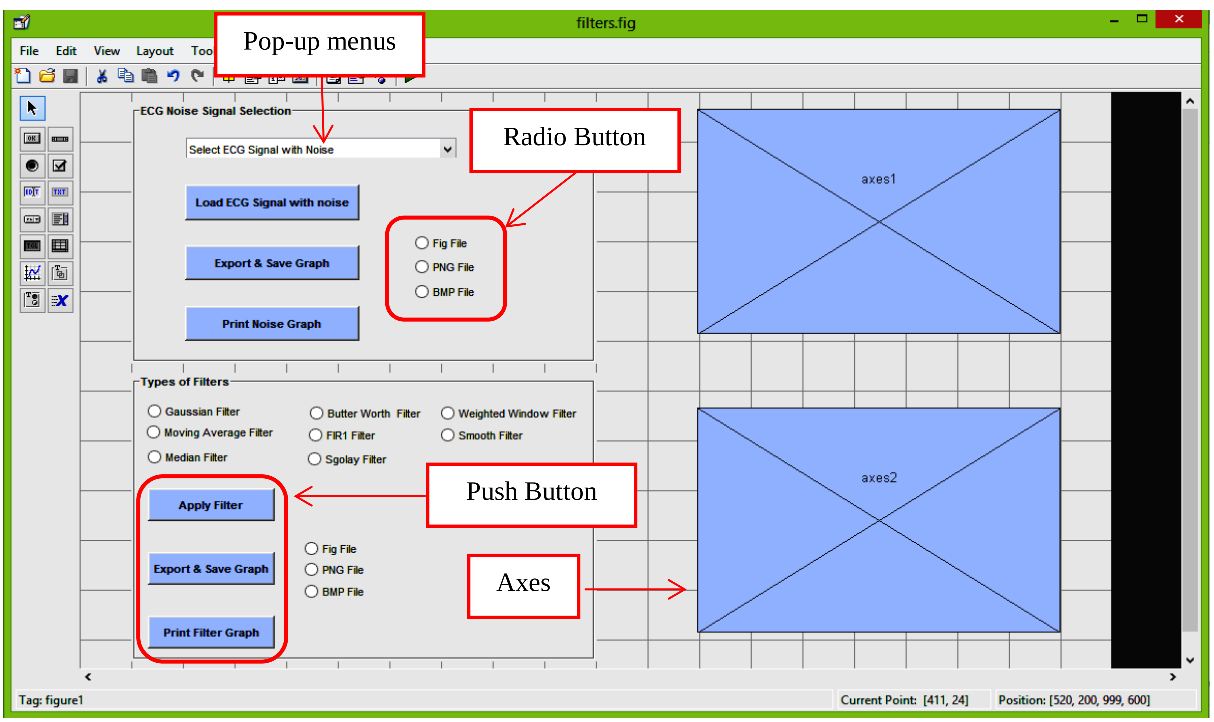


Figure 4.2 Example of GUI layout within the guide window

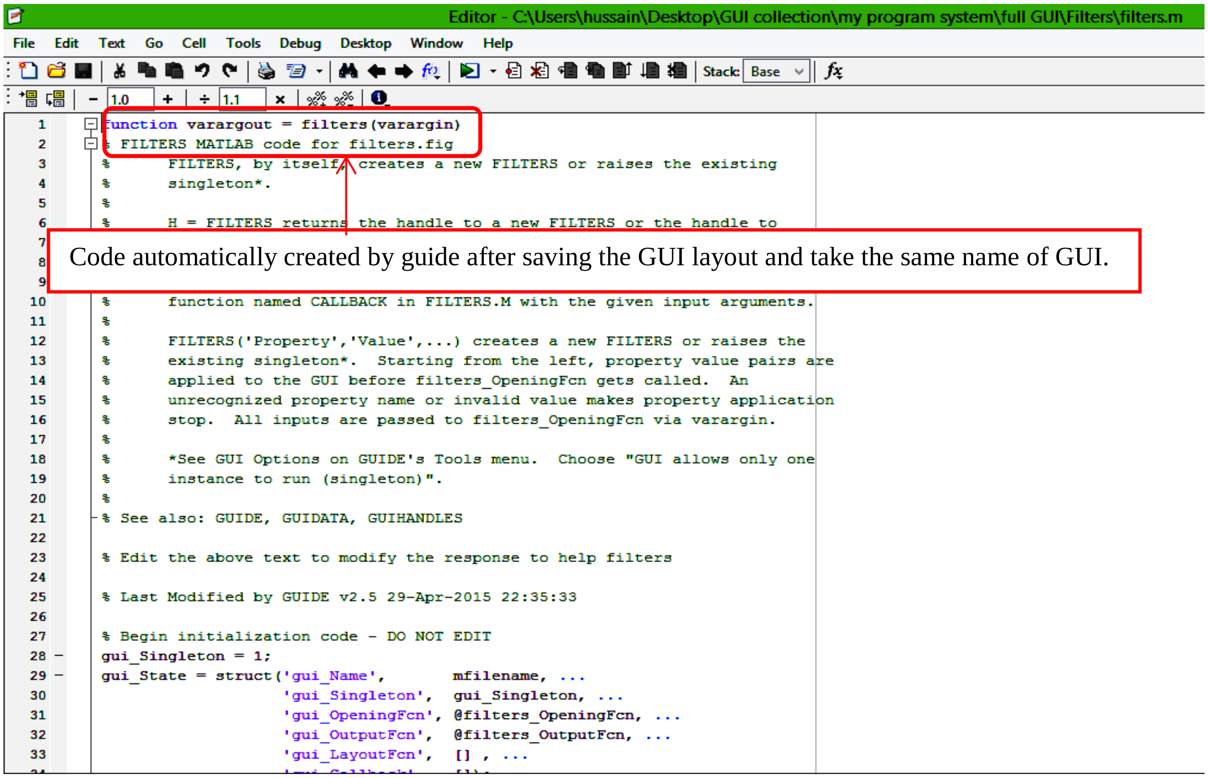


Figure 4.3 The m-file for filters GUI, automatically created by guide

4.1. ECG Signal Simulation Based on the MATLAB GUI

This thesis presents new software packages using a MATLAB GUI and shares the package results to website by using ASP NET, which it is very easy and important at the same time to use for clinicians and engineers in research studies as well as to students who works in the medical section. The results of the system package in MATLAB GUI are composed of four components. Firstly, ECG noises and filtrations. Secondly, ECG analyses for normal signal for detecting heart rate and PQRST values. Thirdly, ECG analysis for the abnormalities for detecting heart rate and PQRST values. Fourthly, DSP techniques of ECG Analysis which includes three techniques Digital filters (FIR and IIR), Wavelet processing (Filters Banks) and Adaptive filter signal Processing. Some of the results are based on our work that have done in previously published paper [51]. The figures of these results have shown in the details in the following five sections.

4.2.1 ECG Noises and Filtrations

In this section of system packages provides the following main features for the first step of processing of ECG by removable some types of important noises in ECG signal as in Figure 4.4.

Figure 4.4 The main first GUI page of the package system

a) Loading ECG signal with noises which consists of three types of noises are as follows :

- ECG Signal with 50 Hz Interference
- ECG Signal with High Frequency Interference
- ECG Signal with mixed Two main Types of above Noises

b) Export and save graphs in anywhere in hard disk or over the network so by default the place of saving is current folder, but the user can select save as to save at anywhere for each type of noise as (.fig, .png and .bmp types) as in Figures 4.5 and 4.6.

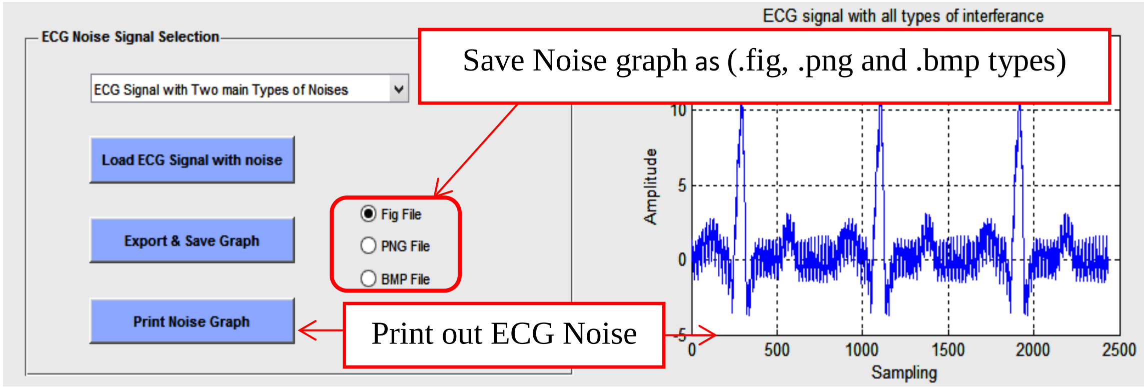


Figure 4.5 Export and print out graph for each type of noise as (.fig, .png and .bmp types)

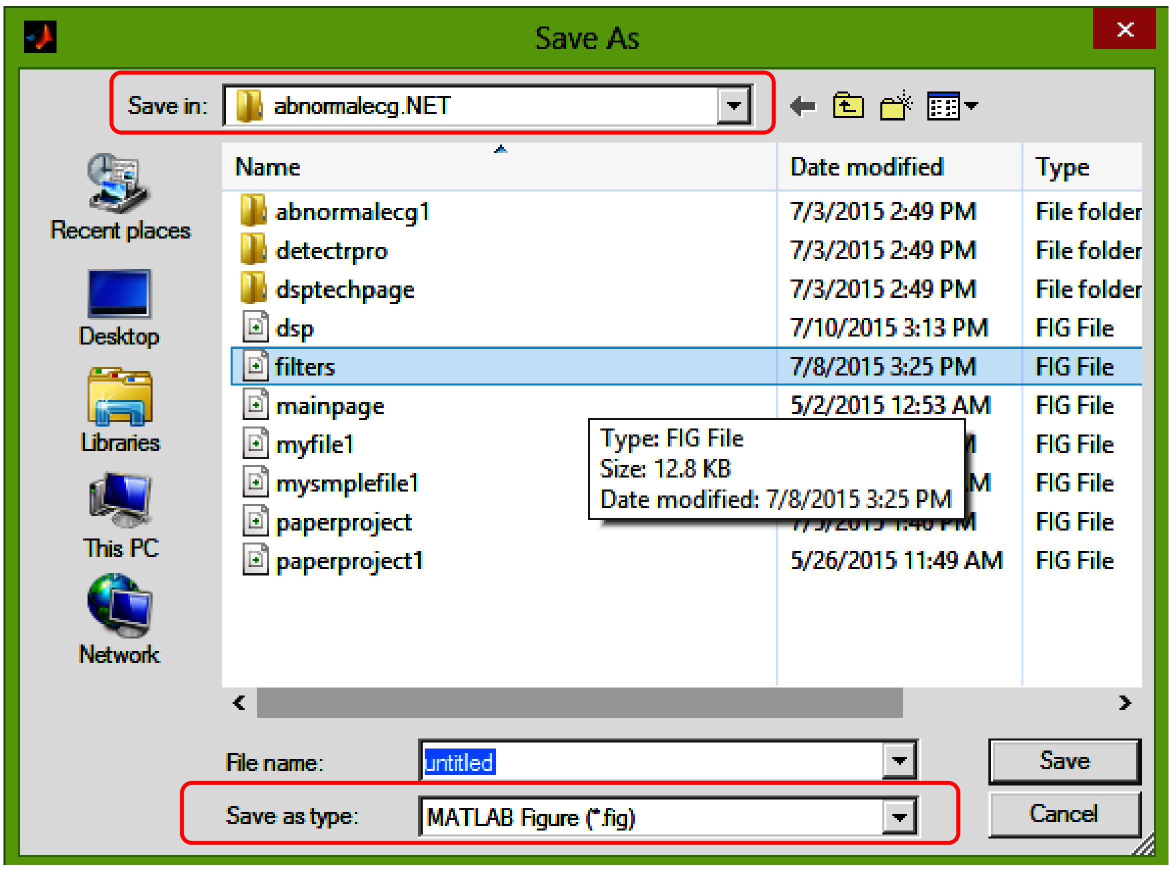


Figure 4.6 The place of saving graphs as (.fig, .png and .bmp types)

c) Applying multi types of filters to remove ECG noises Figure 4.7 are as follows:

- Gaussian Filter
- Moving Average Filter
- Median Filter

- Butter Worth Filter
- FIR1 Filter
- Sgolay Filter
- Weighted Window Filter
- Smooth Filter

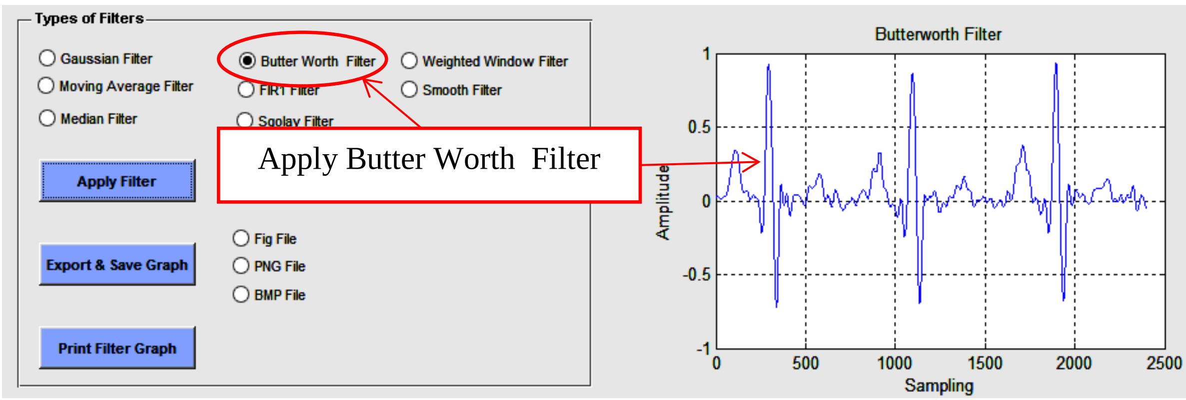


Figure 4.7 Applying multi types of filters to remove ECG noises

d) Export and save graphs in anywhere in hard disk or over the network so by default the place of saving is current folder, but the user can select save as to save at anywhere for each type of filter as (.fig, .png and .bmp types).

4.2.2 Normal ECG Analysis

In this section of system packages provides the following main features for the second step of processing of normal ECG and analysis which analyzes of ECG recordings to get P, Q, R, S, and T as well as detect heart rate as shown in Figure 4.8 are as follows.

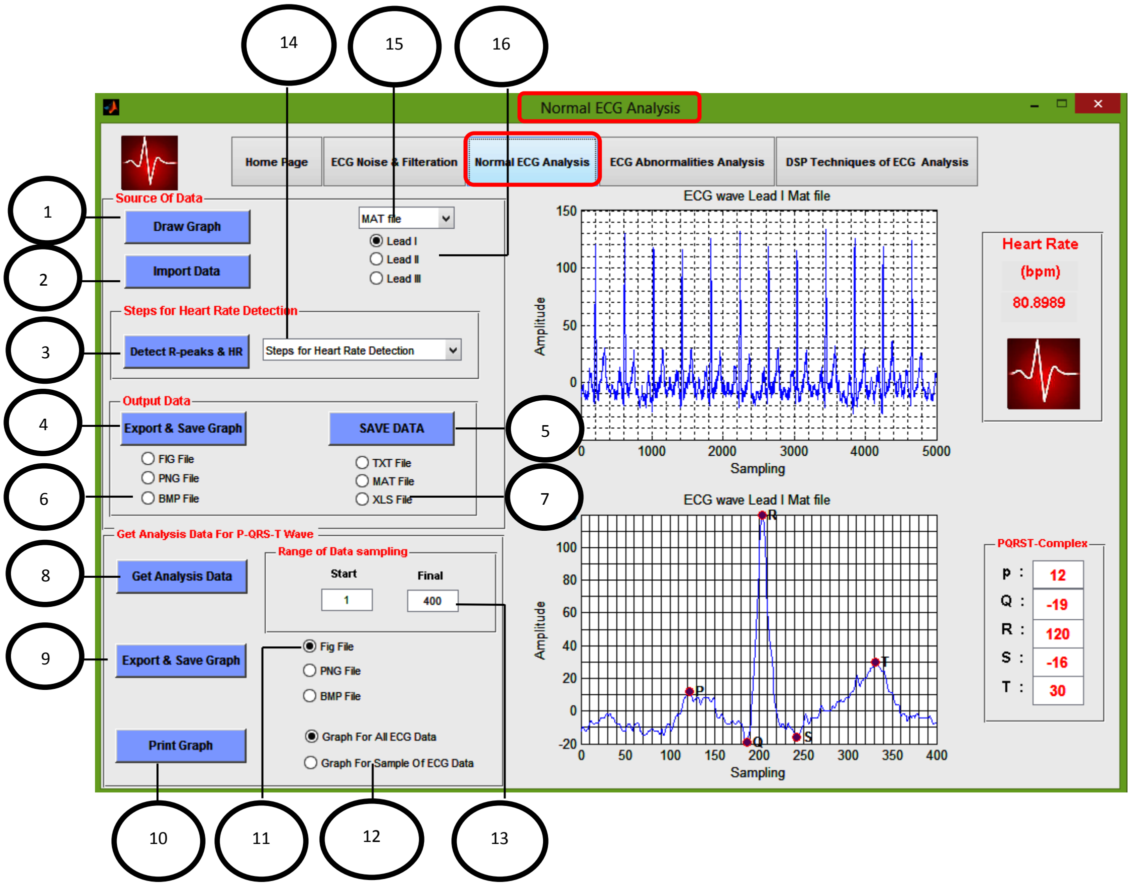


Figure 4.8 The main GUI page for normal ECG analysis

1. Draw full sampling of ECG signal recordings from any source of data as text or binary files and excel files as shown in Figure 4.8.
2. Import date from anywhere in hard disk or over the network and from any type of data.
3. When select detect R-peak and heart rate button performs the steps of heart rate detection by using a windowing filter two times for finding local maxima of R-peak after removing low frequency components then adjusts the filter size.
4. When click export and save button user can save graph which display on the left side as three types of file (.fig,png. And bmp.).
5. User can save data as (txt, mat and xlsx types).
6. Types of image (figure) that program can save figure.
7. Types of data that the program can save data.

8. Get analysis data button mean get analysis of ECG data to detect PQRST values. 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.
9. When click this button we can save graph which display on the bottom side as three types of files (.fig, .png and bmp).
10. The user can print out each of figures depend on which one wants.
11. Types of image (figure) that program can save P-QRS-T waves figure.
12. Selection about which one the user want to print out, all samples or specific samples.
13. Enter the range of sampling data for analysis data of ECG to get PQRST value.
14. POP- UP menu used to select steps for detecting R- peaks and heart rate detection.
15. Select type of data as (mat, txt and xlsx) to draw the ECG signal.
16. When the user selects data from which type of data want also these data for any lead of ECG want to draw it.

The Figure 4.9 describes the P-QRS-T and heart rate detecting flow chart design .The first step of the flowchart have started by selection of ECG lead (I,II,III) as well as type of files (.mat file,.txt file,.xlsx file). After selecting which lead you select and type of data from any type of file the algorithm start to read ECG data and removing low and high frequency components, after that, using a windowing filter and thresholding for finding local maxima .The last step for detecting R – peaks using adjust filter (again windowing filter) to detect heart rate and P-QRS-T waves after a simple mathematical calculation by MATLAB equations to calculate P, Q, R, S and T.

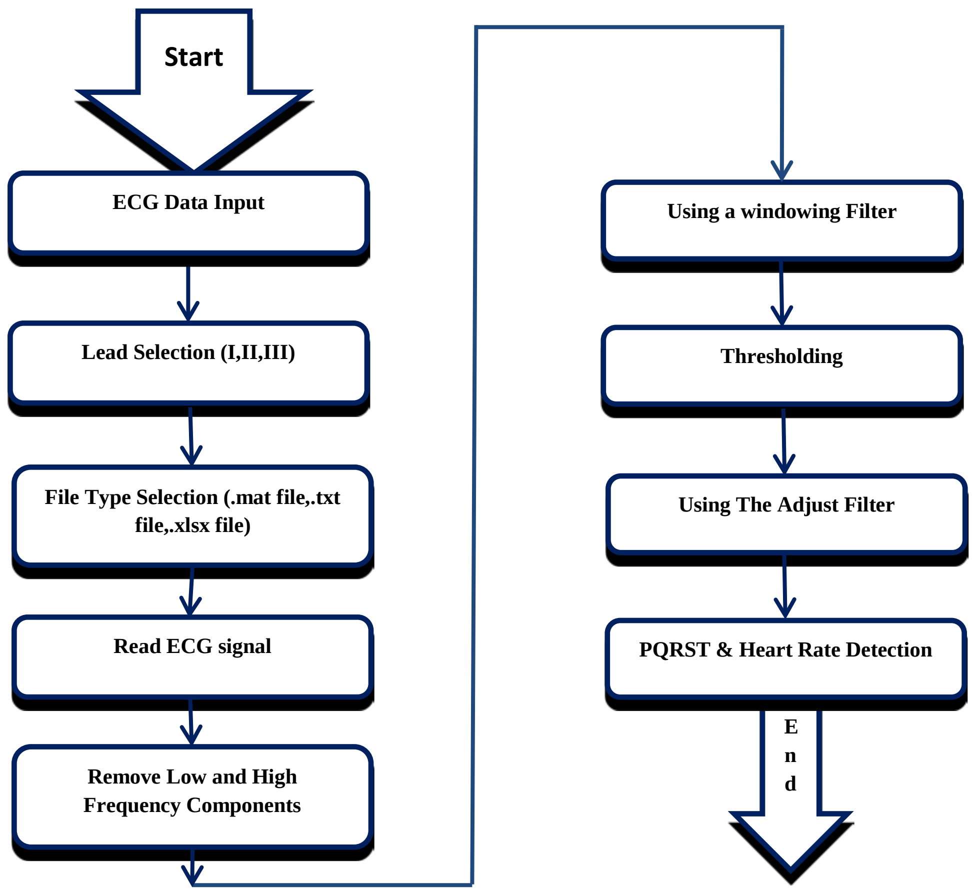


Figure 4.9 Steps of PQRST & heart rate detection

4.2.3 ECG Abnormalities Analysis

In this section of system packages provides the same features as the previous section, but the main different features are the processing for ECG abnormalities Analysis which includes (Supraventricular Arrhythmia, Apnea, Normal Sinus Rhythm, Ventricular Tachyarrhythmia and Intracardiac Atrial Fibrillation) which analyzes of abnormalities ECG recordings for detecting an arrhythmia and calculate P, Q, R, S, and T as well as detect heart rate of ECG abnormalities therefore the Figure 4.10 and Table 4.2 demonstrates all the ECG abnormalities and give a brief summary of the results of analysis of ECG abnormalities are as follows:

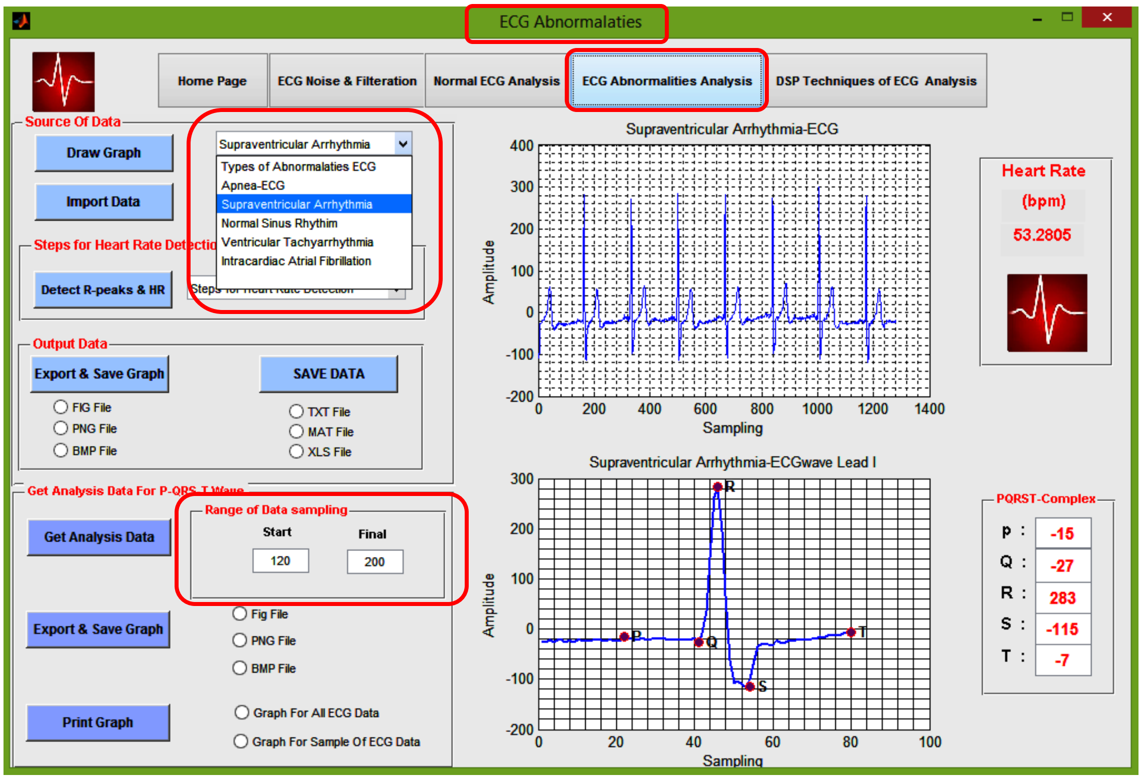


Figure 4.10 The main GUI page for ECG abnormality analysis

The Table 4.2 shows the results of multi cases of ECG abnormalities signals, from these results we found for example; in normal sinus rhythm is the rhythm of a healthy normal heart, where the sinus node triggers the cardiac activation. This is easily diagnosed by noting that the three deflections, P-QRS-T, follow in this order and are differentiable. The heart beat is normal 96 bpm (between 60 and 100). Apnea-ECG in this case is close to be the normal case as regular and normal heart rate is 73 bpm (between 60 and 100) also three deflections, P-QRS-T, follow in this order and are differentiable. Supraventricular arrhythmia is an arrhythmia of an abnormality in the timing or pattern of the heartbeat. Arrhythmias may cause the heart to beat too rapidly, too slowly, or irregularly. They are common and may cause a wide variety of symptoms, such as a racing, skipping or fluttering sensation (called palpitations) in your chest. Ventricular tachyarrhythmia is a rhythm of ventricular origin may also be a consequence of a slower conduction in ischemic ventricular muscle that leads to circular activation (re-entry). The result is activation of the ventricular muscle at a high rate (over 120/min), causing rapid, bizarre, and wide QRS-complexes Intra cardiac. Atrial fibrillation is activation in the atria may also be fully irregular and chaotic, producing irregular fluctuations in the baseline. A consequence is that the ventricular rate is rapid and irregular, though the QRS contour is usually normal. The heart rate is 125 bpm (more than 120 bpm).

Table 4.2 Brief summary of the results of ECG abnormalities signal

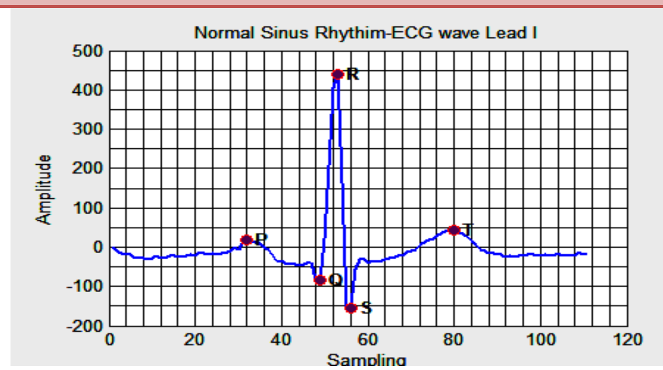
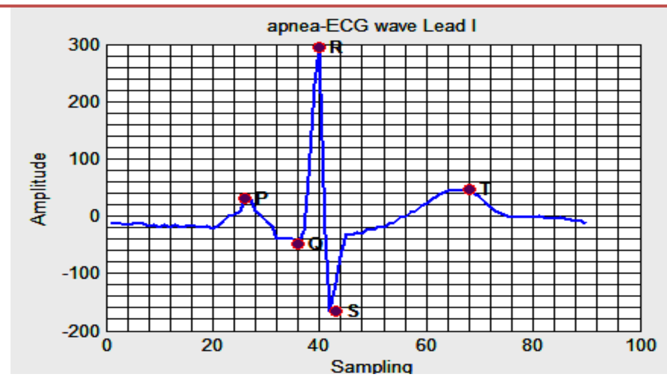
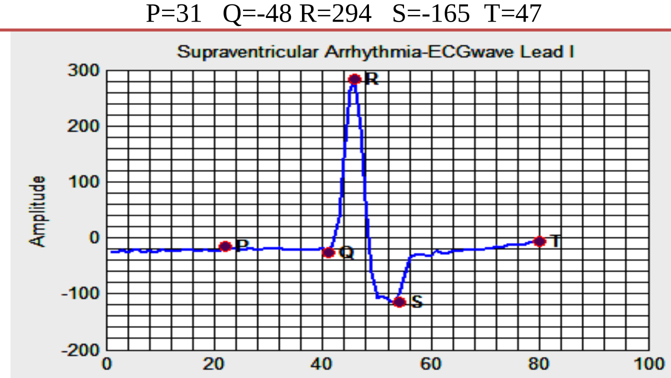
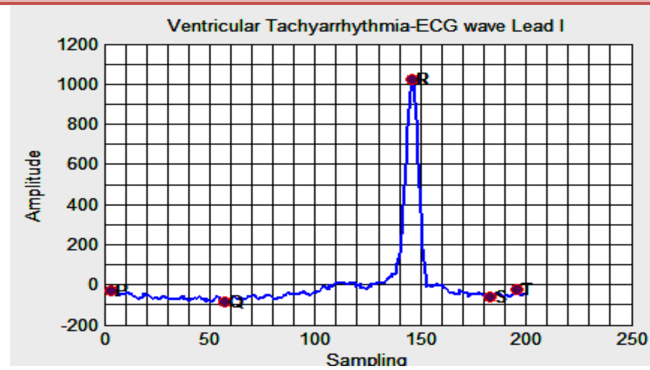
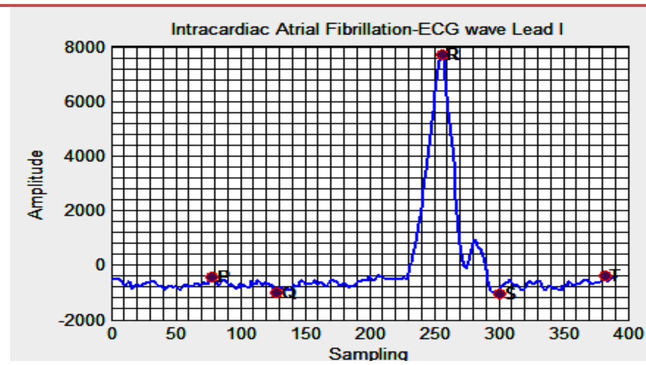
Name of Abnormality	Rate	Rhythm	ECG Graph with Waves Characteristics
Normal sinus rhythm	96 bpm	Regular	 P=19 Q=-83 R=439 S=-155 T=43
Apnea-ECG	73 bpm	Regular	 P=31 Q=-48 R=294 S=-165 T=47
Supraventricular Arrhythmia	53 bpm	Regular	 P=-15 Q=-27 R=283 S=-115 T=-7

Table 4.2 Cont.

Name of Abnormality	Rate	Rhythm	ECG Graph with Waves Characteristics
Ventricular Tachyarrhythmia	125 bpm	May be irregular	 P=-29 Q=-85 R=1026 S=-60 T=-25
Intra cardiac Atrial Fibrillation	125 bpm	Irregular	 P=-432 Q=-984 R=7696 S=-1041 T=-404

4.2.4 DSP Techniques of ECG Analysis

In this section of system packages provides the following main features of using three techniques of Digital signal processing which includes Digital filter technique, wavelet technique and Adaptive filter technique of processing of ECG by removable some types of important noises in ECG signal as shown in Figure 4.11 are as follows.

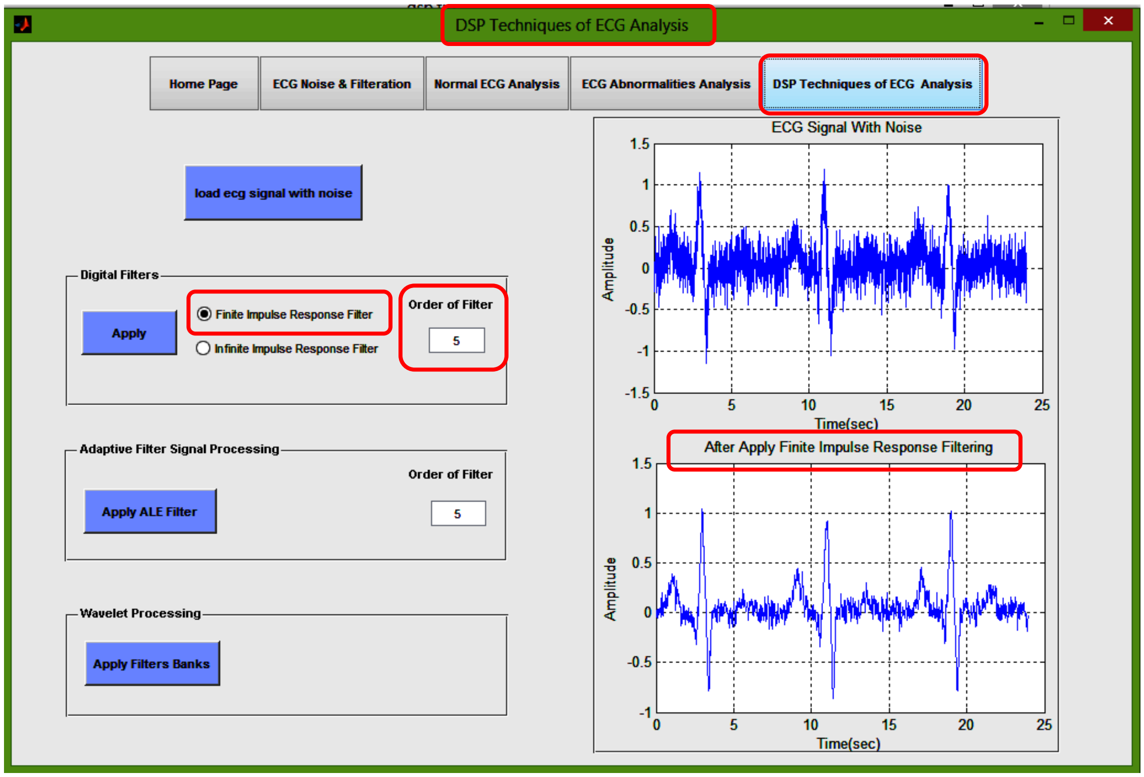


Figure 4.11 The main GUI page for DSP techniques of ECG analysis

a) In Digital filter technique, apply two types of digital filters which are FIR filter and IIR filter as shown in Figure 4.11 with variable order of the filter.

b) In Adaptive filter technique; apply Adaptive Line Enhancement (ALE) Filter with variable order of the filter as shown in Figure 4.12.

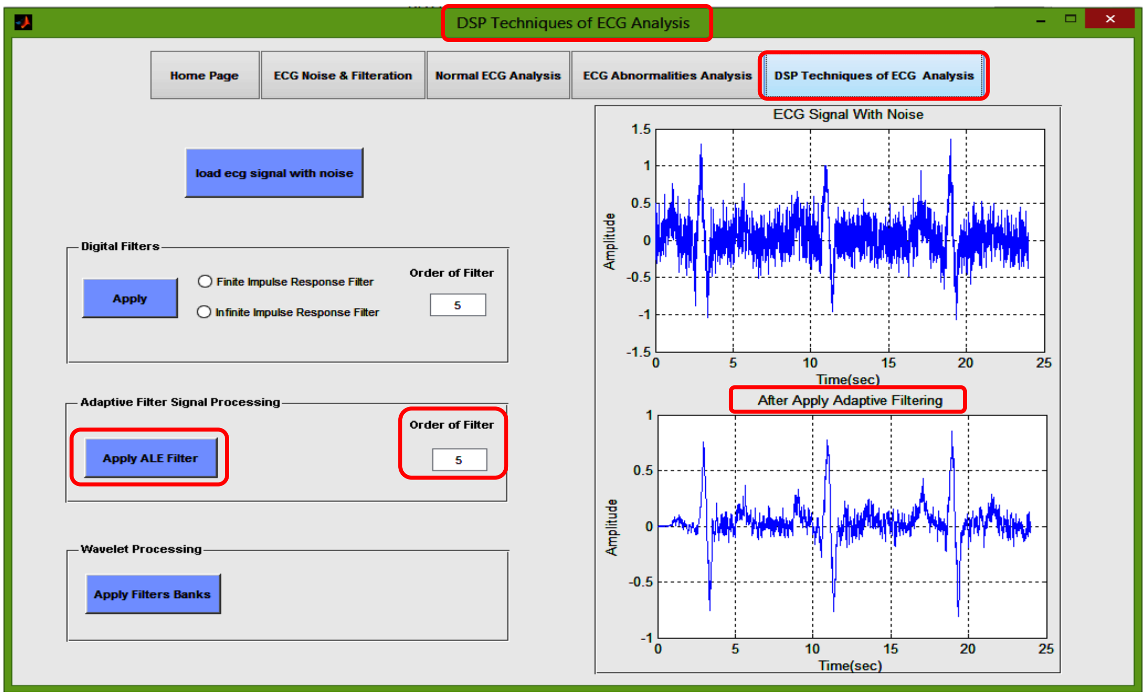


Figure 4.12 An example of using of Adaptive Line Enhancement (ALE) Filter

c) In Wavelet technique, apply Filters Banks Filter by using high and low pass filters as shown in Figure 4.13.

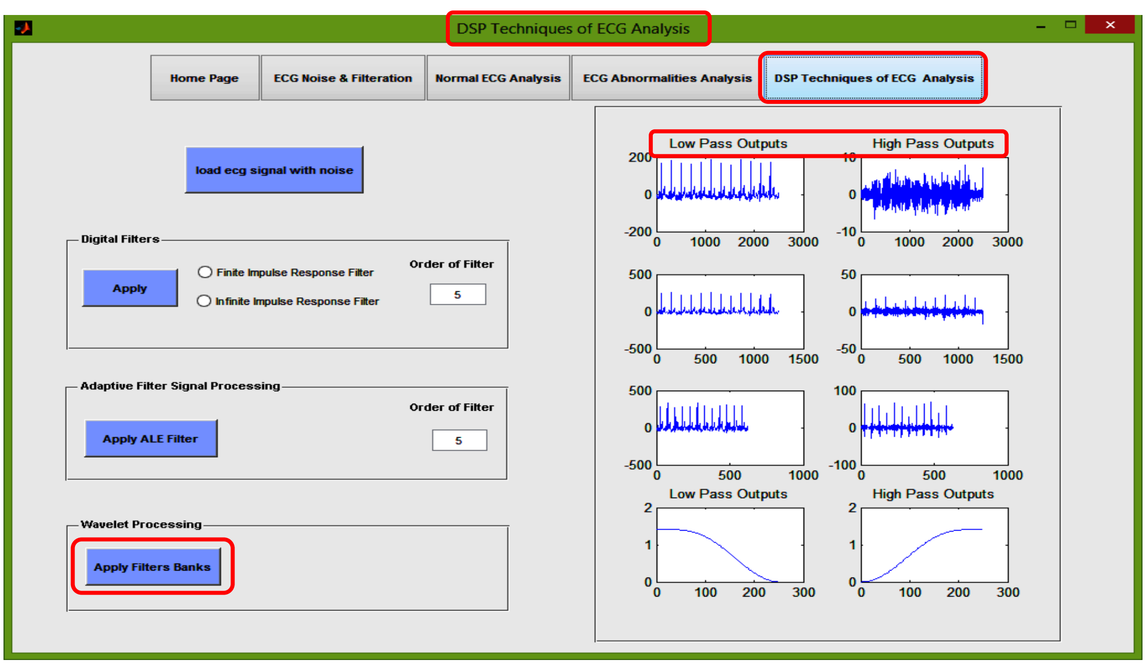


Figure 4.13 Result of Filters Banks Filter by using high and lowpass filters of wavelet technique

CHAPTER 5

ECG SIGNAL PROCESSING USING ASP .NET

This thesis proposes new software packages using MATLAB GUI and shares the package results to website by using ASP .NET. The results of the system packages are composed of five components. Firstly, ECG noises and filtrations. Secondly, ECG analyses for normal signal for detecting heart rate and PQRST values. Thirdly, ECG analysis for the abnormalities for detecting heart rate and PQRST values. Fourthly, DSP techniques of ECG Analysis which includes three techniques Digital filters (FIR and IIR), Wavelet processing (Filters Banks) and Adaptive filter signal Processing. Finally, put all four components above in one graphical user interface (GUI) and create .NET applications as well as publishing and share them as an ASP site by using visual studio .NET.

5.1 .NET Application Deployment Process

When the MATLAB Builder NE product processes your MATLAB code, it creates several overloaded methods that implement the MATLAB functions. Each of these overloaded methods corresponds to a call to the generic MATLAB function with a specific number of input arguments. Creating a .NET component by using the deployment tool GUI to build a .NET class that wraps around the sample MATLAB code are as follows [52]:

a) Writing a code in MATLAB in our example.

b) At the command window type deploytool and press Enter. The deploytool GUI can be opened as shown in figure 5.1.

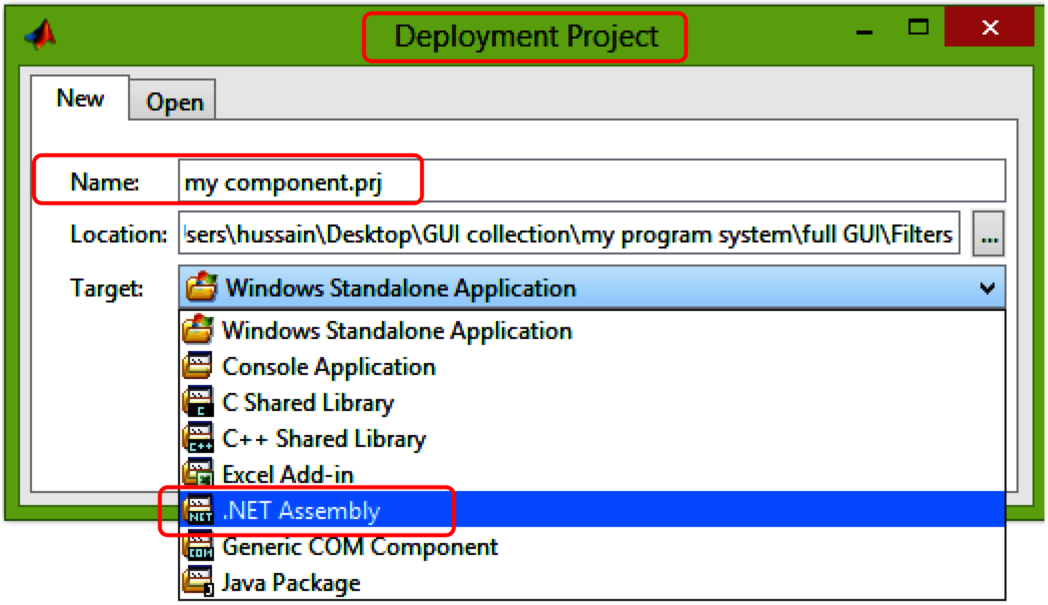


Figure 5.1 Deployment Project dialog

c) Create a deployment project using the Deployment Project dialog steps:

- **i.** Type the name of your project (my component) in the Name field.
- **ii.** Enter the location of the project in the Location field. Alternately, navigate to the location.
- **iii.** Select the target for the deployment project (.NET Assembly) from the Target drop-down menu.
- **iv.** And then click OK

d) On the Build tab Figure 5.2, click Add class. Type the name of the class (mycomponentclass) in the Class Name field, and then add files by clicking Add files.

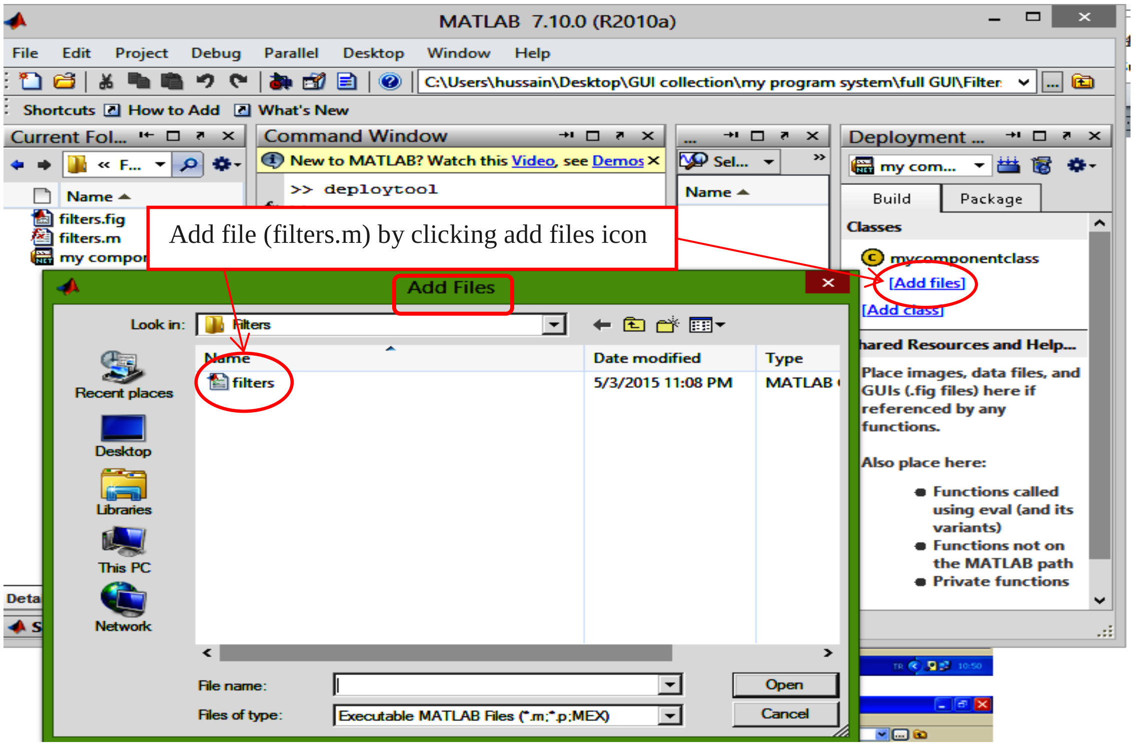


Figure 5.2 Adding files in .NET Project

e) In the last step, click the Build button, Figure 5.3. The builder does two process firstly, generates two C# files, a component data file and a component wrapper. The component data file contains static information for the component. The wrapper contains the implementation code for the .NET component and provides a .NET application programming interface (API) for the MATLAB functions you add to the project at design time. Secondly, the MATLAB Builder NE two compiles the C# code and generates two subfolders under the project folder: project-folder/src and project-folder/distrib files.

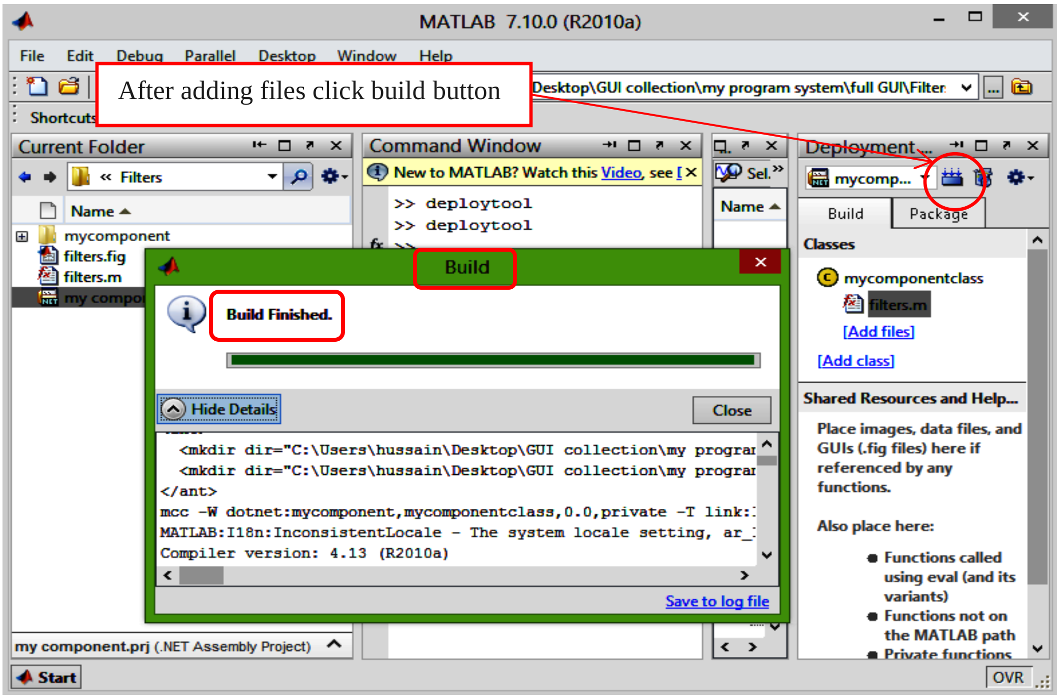


Figure 5.3 Creating a .NET Project

The Figures 5.4 and 5.5 illustrates subfolders which contain the following files.

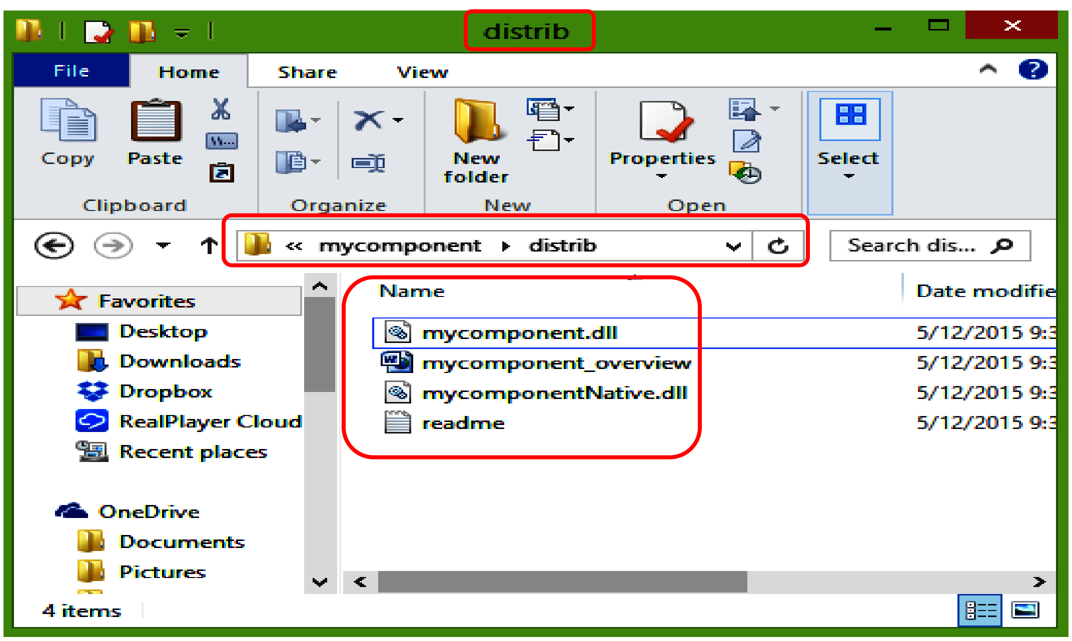


Figure 5.4 Contents of subfolder distrib

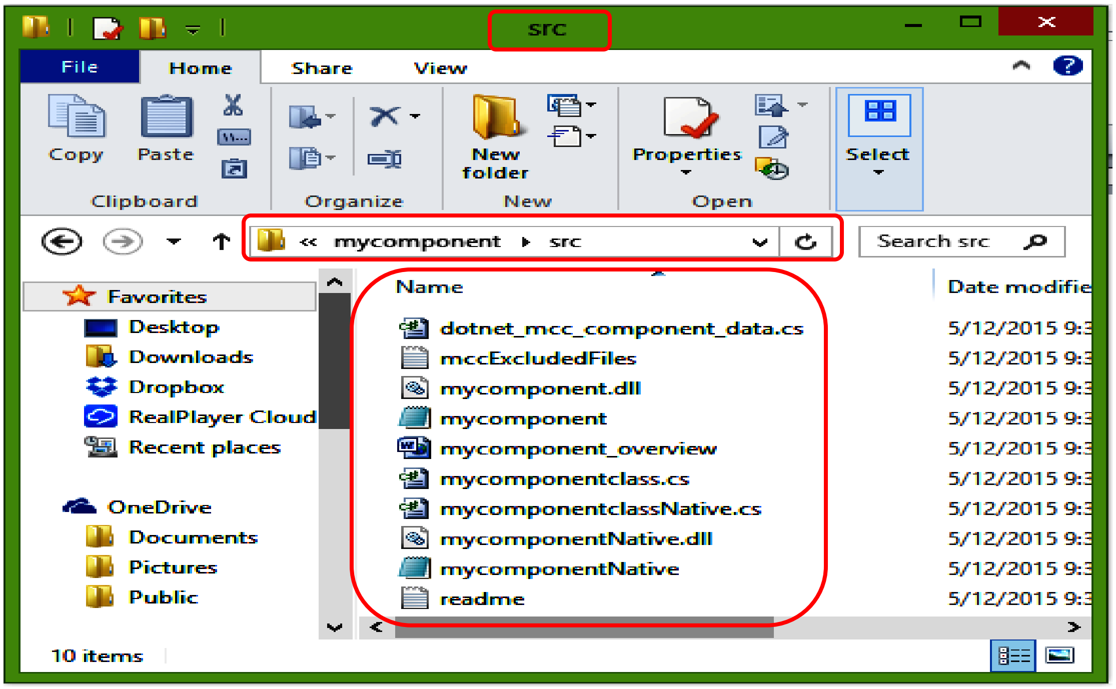


Figure 5.5 Contents of subfolder src

5.2 Deploying .NET Components over the Web Site

Using the WebFigures feature in MATLAB Builder NE you can display MATLAB figures on a Web site for graphical manipulation by end users. This enables them to use their graphical applications from anywhere on the web without the need to download MATLAB or other tools that can consume costly resources. After the compilation of coding files are finished in MATLAB, then can go to the Visual Studio program. It must first create a new ASP.NET website are as follows [53]:

- **a.** Start Microsoft Visual Studio
- **b.** Create an ASP.NET web site Figure 5.6

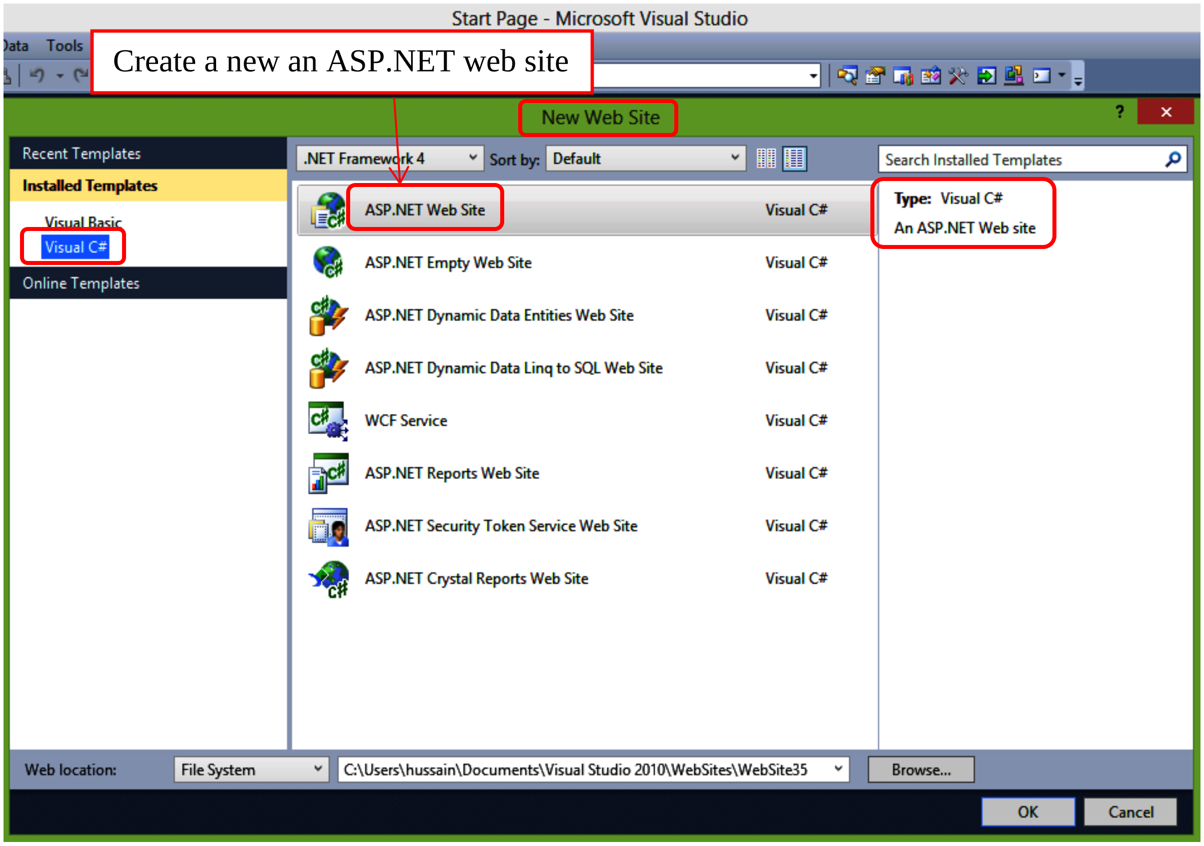


Figure 5.6 Creating an ASP.NET web site

c. Add WebFigure Control to the Microsoft Visual Studio toolbar by dragging the file MATLAB\toolbox\dotnetbuilder\bin\arch\v2.0 WebFiguresService.dll, on to the Microsoft Visual Studio Toolbox toolbar as follows:

i. Expand the **General** section of the **Toolbox** toolbar

ii. Drag the DLL file to the expanded section, as shown in the Figure 5.7

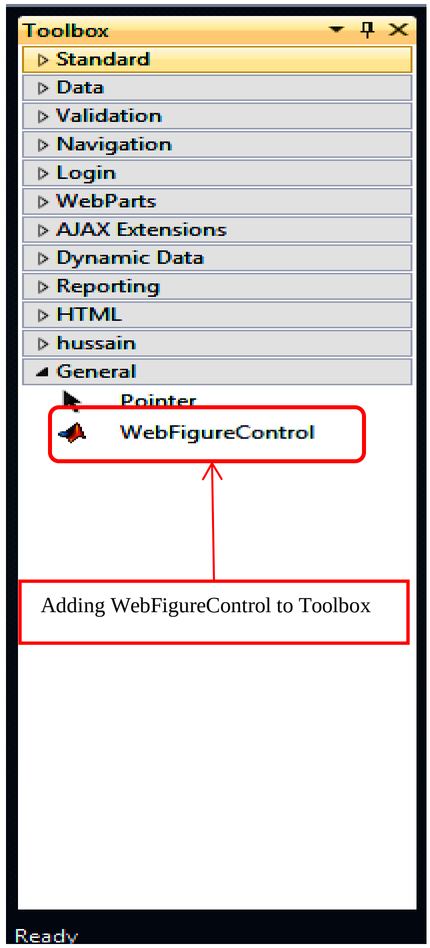


Figure 5.7 WebFigureControl to toolbox

d. Drag the WebFigureControl from the toolbar to your Web page. Then add a reference to MWArray to your project and a reference to the deployed component that created by the MATLAB Builder NE Product (mycomponent project) in the first step Figure 5.8

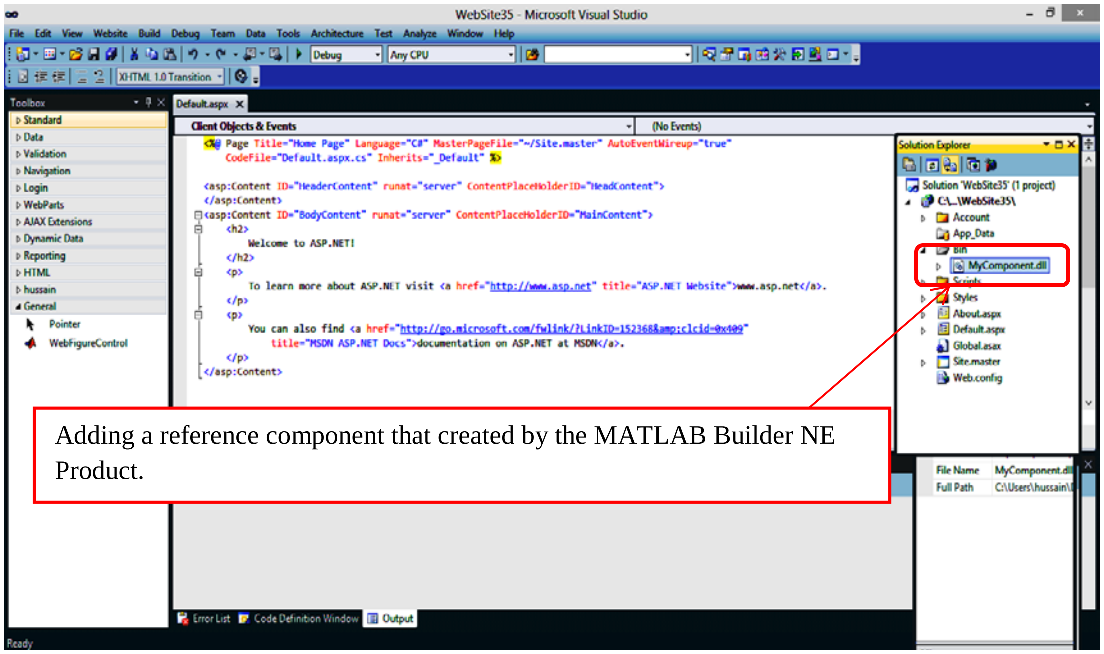


Figure 5.8 Adding a reference to the deployed component that created by the MATLAB Builder NE Product

e. In Microsoft Visual Studio, access the code for the Web page by right-clicking the workspace and selecting View Code. Then Adding code to the Page_Load method ensures it executes every time the Web page loads Figure 5.9

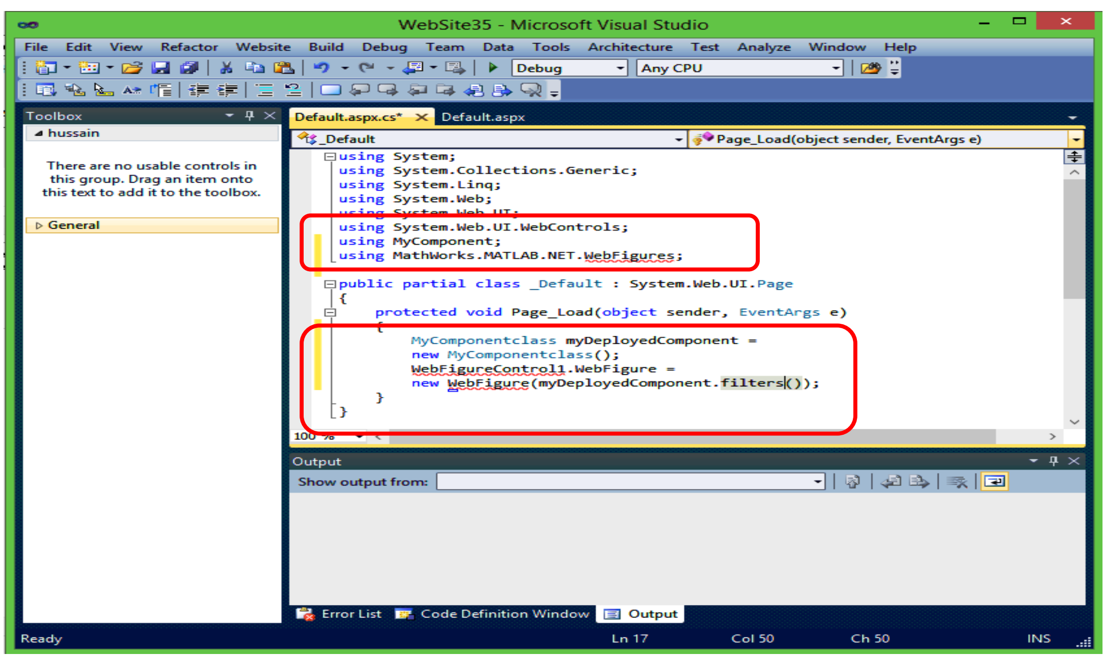


Figure 5.9 Writing code in C#

f. Test the Web page by running it in Microsoft Visual Studio. Select Debug, then starting Debugging. The page must be appearing as shown in the following Figures 5.10 and 5.11 at initialization and running page.

Figure 5.10 Web site page at initialization

Figure 5.11 ASP .NET site page after running

5.3 ASP .NET Web Site Application

In this part after completing the designing software package using MATLAB Graphical User Interface (GUI) we have created an ASP .NET web site by using visual studio .NET, first of all, we must build a simple user registration form that will allow user register to the website in ASP.Net using C#. User will fill up the registration form with details such as username, password, email address, full name and country; these details will be saved in the database table. The registration form will also make sure that duplicate username and email addresses are not saved by verifying whether the username and email address must not exist in the table, so for access to the website in ASP.Net for any user must have registration confirmation in the registration form and then enter at any time by using only user name and password in the login page as shown in Figures 5.12 and 5.13.

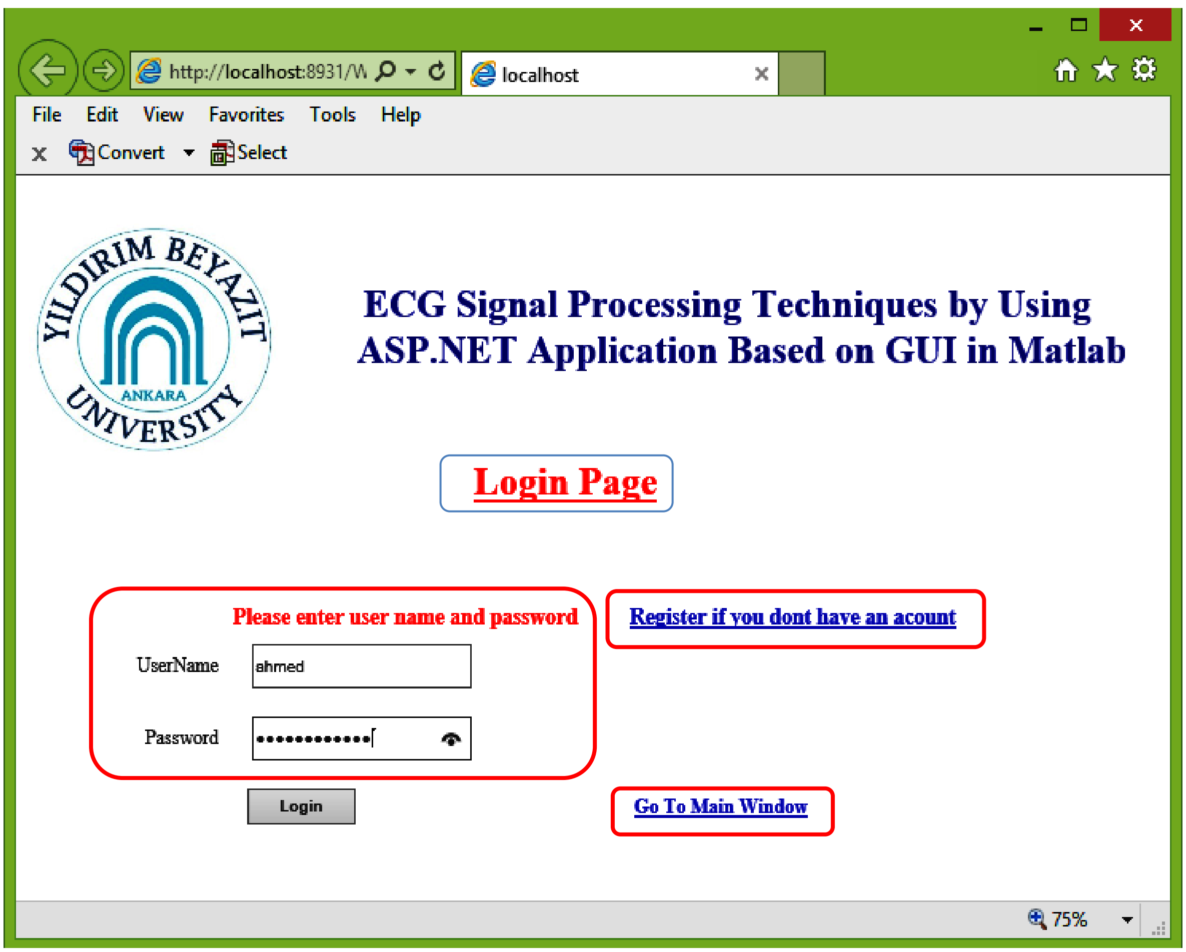


Figure 5.12 ASP .NET web site login page

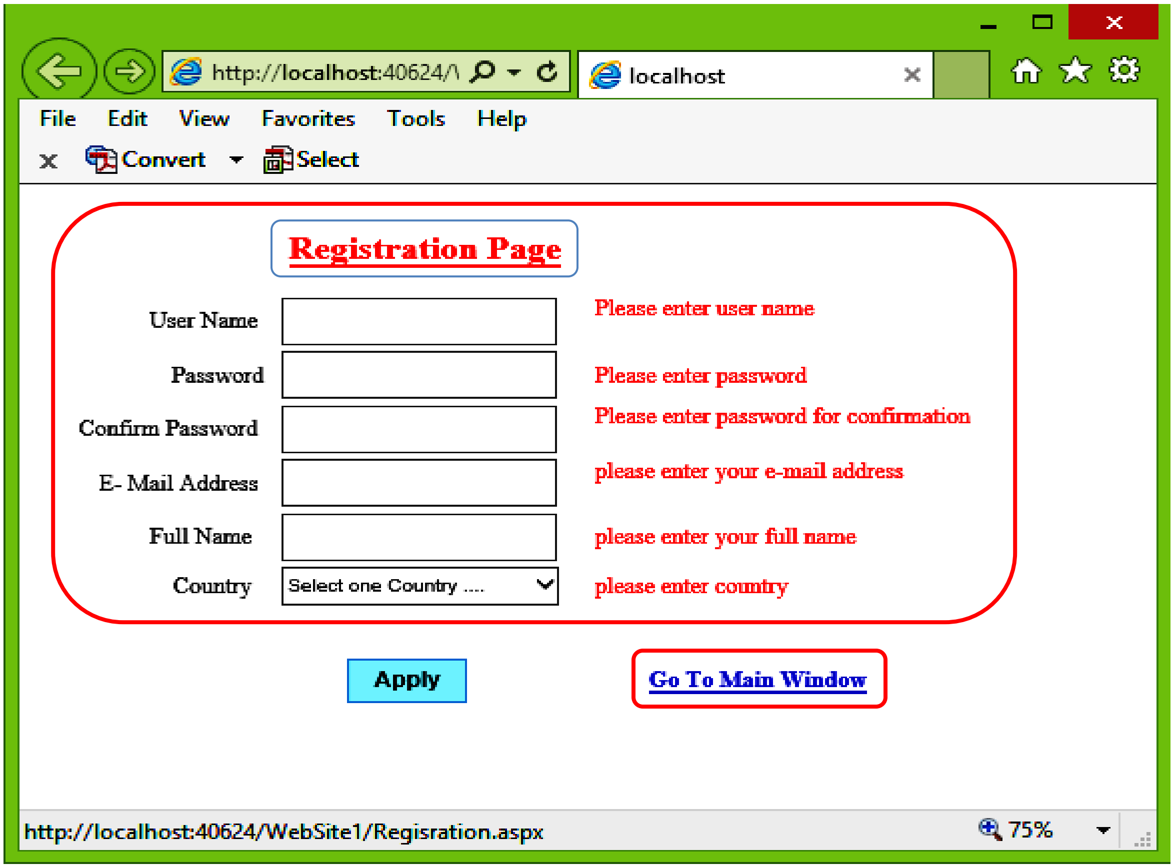


Figure 5.13 ASP .NET web site registration page

The first page will appear for any user who want to access to the website in ASP .Net is a login page so if has registered previously the user can access directly to the web site, but if don't have access previously the user must fill the registration form to able enter to web site in ASP.Net. Our application that has designed in web site in ASP .Net consist of multi pages and the user can navigate from any page to the other just by clicking the name of the page after have made registration confirmation of the registration form. The Figure 5.14 shows the startup (main) page that will appear to user after login correctly to able from choosing any page that the user want to work on it.

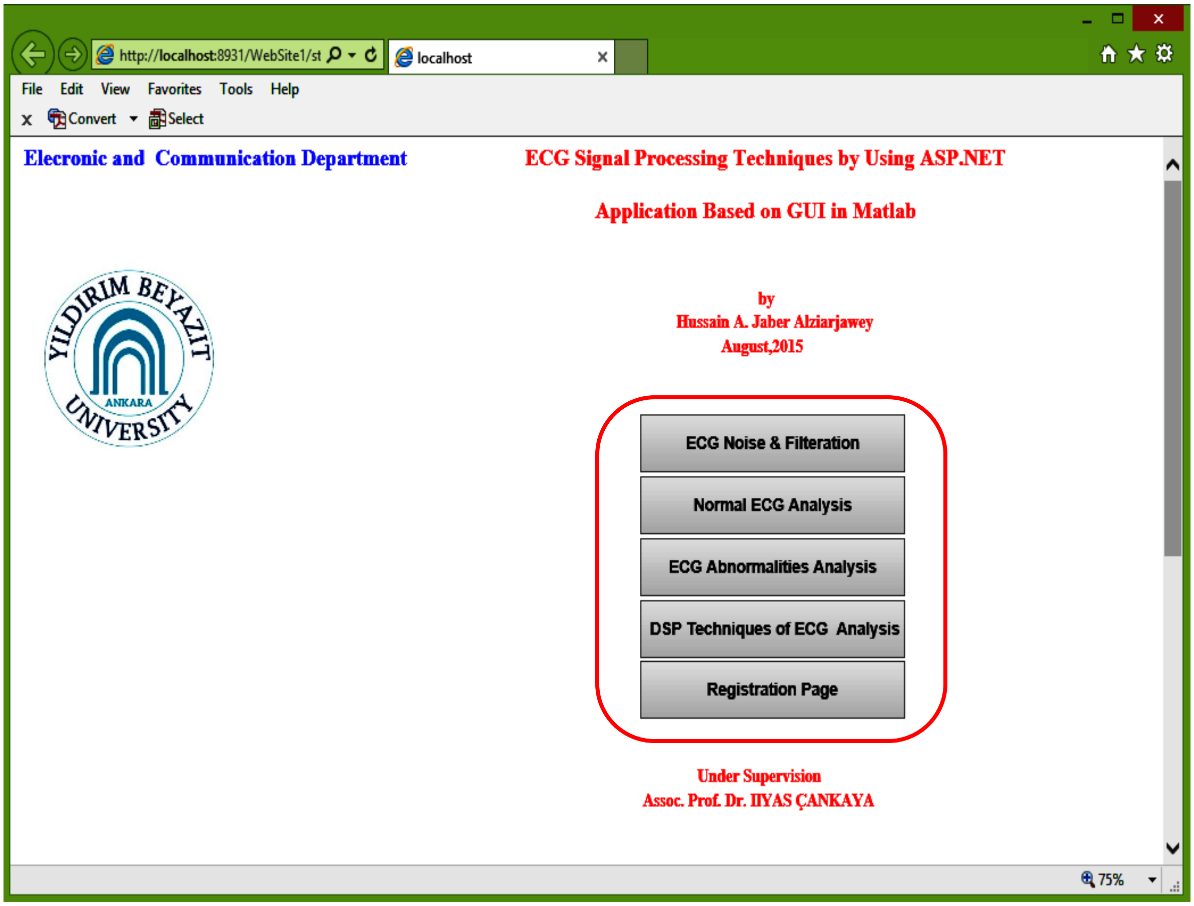


Figure 5.14 ASP .NET web site startup (main) page

Through the startup (main) page the user can navigate to five pages, which are ECG noise and filtration, normal ECG analysis, ECG abnormalities analysis, DSP techniques of ECG analysis and registration page as shown in figures 5.15,5.16,5.17 and 5.18.

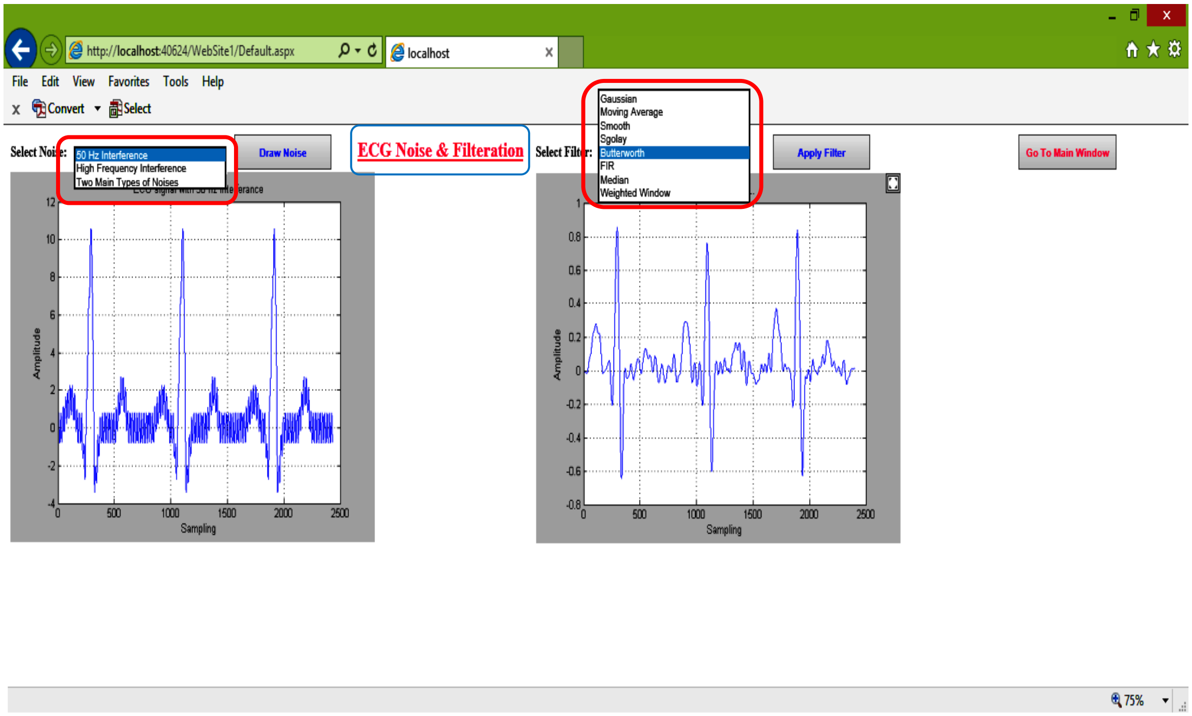


Figure 5.15 ASP .NET web site of ECG noise and filtration page

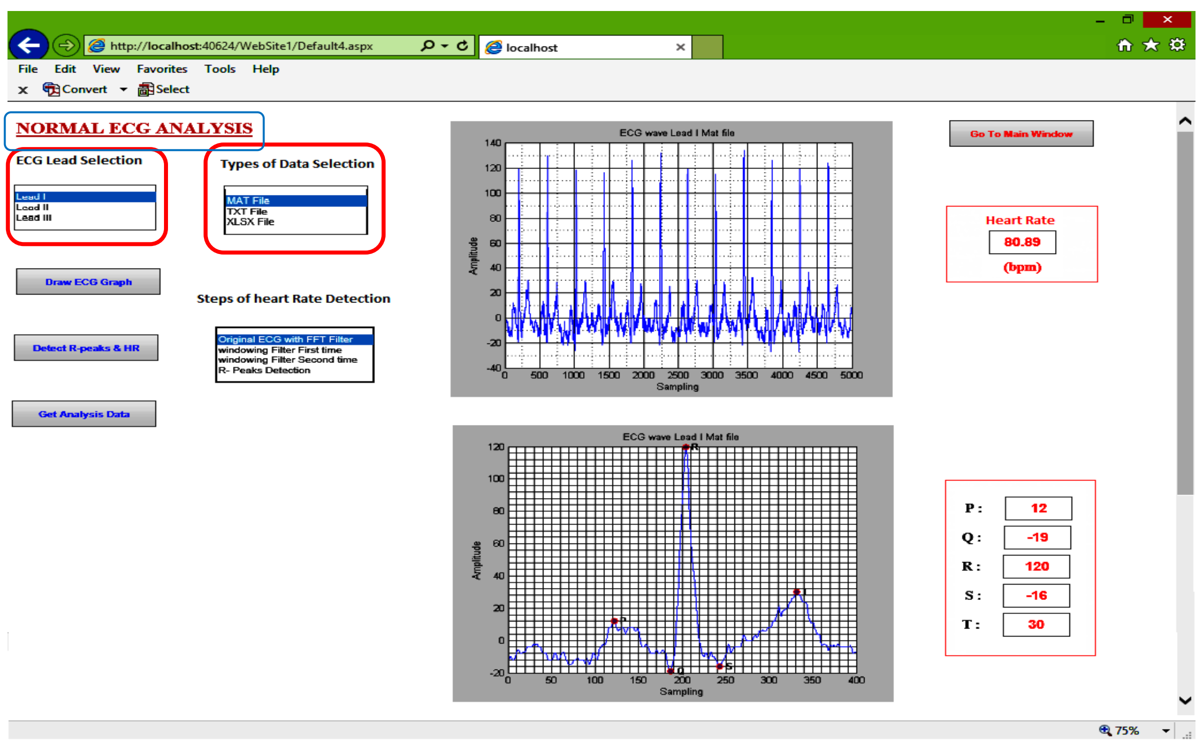


Figure 5.16 ASP .NET web site of normal ECG analysis page

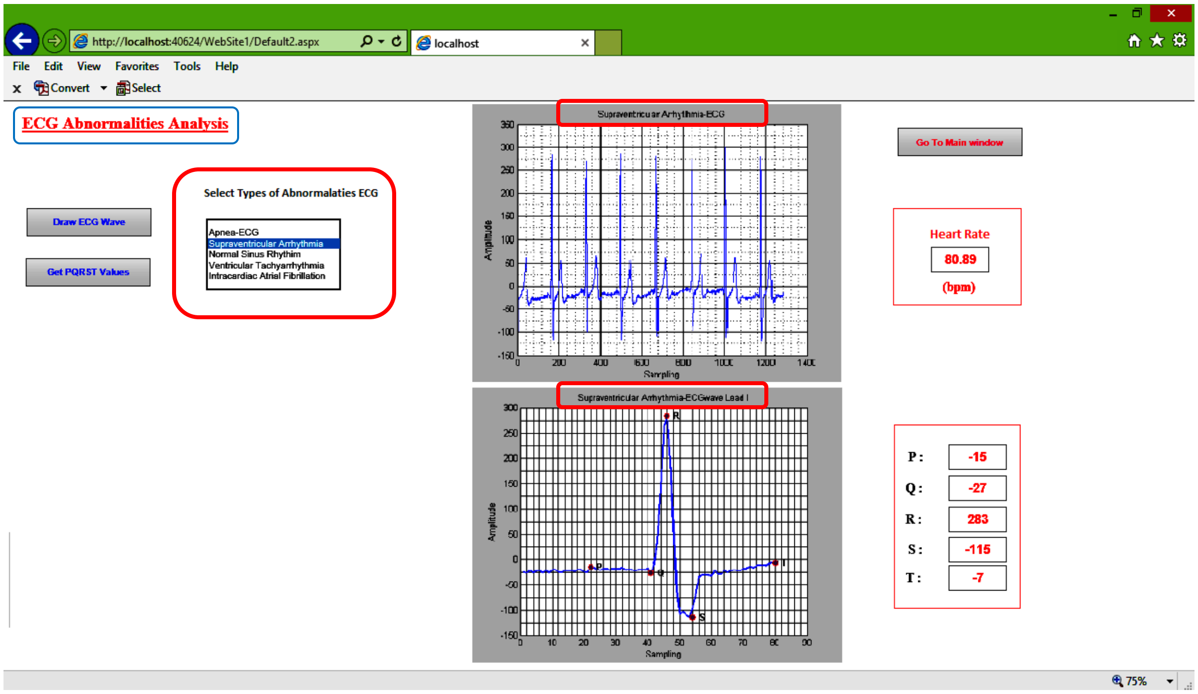


Figure 5.17 ASP .NET web site of ECG abnormalities analysis page

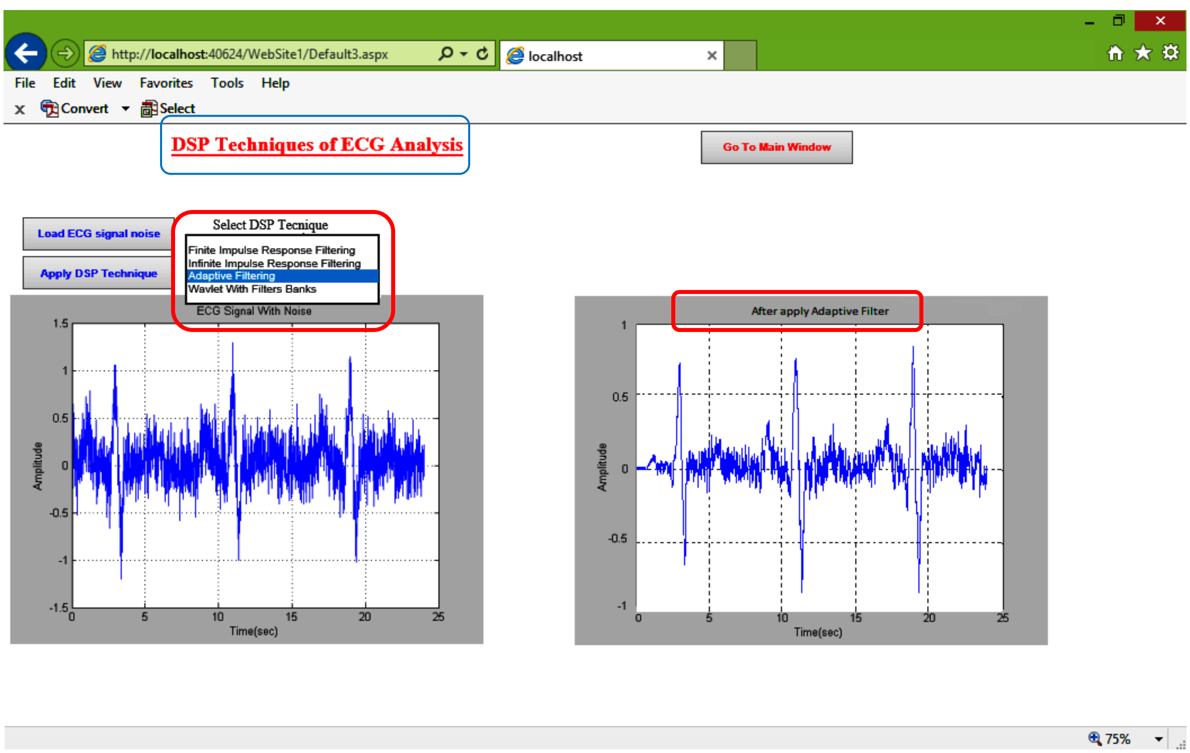


Figure 5.18 ASP .NET web site of DSP techniques of ECG analysis page

CHAPTER 6

CONCLUSION AND FUTURE WORKS

This chapter will introduce conclusion and future work of this thesis with entitled ECG signal processing techniques by using ASP.NET application based on GUI in MATLAB that deals with following points are:

- Remove multi types of noises in ECG signal
- Detecting heart rate for normal ECG signal and abnormal ECG signals
- Investigation to calculate the PQRST values for normal ECG signal and abnormal ECG signals by proposing a simple mathematical algorithm
- Detecting of Arrhythmia problems
- How To build a project package (windows standalone application)
- Introduces three Digital Signal Processing (DSP) techniques for removing noise in the ECG signal
- Crate package software system by designing graphical user interface (GUI) using MATLAB
- Create .NET application package

6.1 Conclusion

This thesis presents new software packages using a MATLAB GUI and shares the package results to website by using ASP NET, which it is very easy and important at the same time to use for clinicians and engineers in research studies as well as to students who works in the medical section. This software package covers all ECG signal analysis, which includes removing ECG noises, heart rate detection and calculates of PQRST values; therefore this system package contains five sections.

In the first section that titled ECG noises and filtrations removes all types of noises in ECG signal by using multi types of filters. In the second part of system package which titled ECG normal analysis for detecting heart rate and calculate PQRST values by using a simple mathematical calculation by MATLAB equations, while the most of earlier methods for detecting PQRST values of ECG signal analysis was based on DSP technique, for example (Wavelet Transform and Fast Fourier Transform) and Artificial Neural networks, while this thesis presents a developer program is a flexible and thorough tool for calculate P, Q, R, S and T from ECGs and detect heart rate.

This proposed software tool is based on finding a mathematical relationship between the highest values (peaks and valleys) of the ECG waveform and time. This developed program can be utilized in training for clinicians and engineers working together in the same field which related to ECG abnormalities.

In the third part which entitled ECG analysis for the abnormalities, also introduce some analysis for detecting heart rate and PQRST values, but for some cases of ECG abnormalities such as Supraventricular Arrhythmia, Apnea, Normal Sinus Rhythm, Ventricular Tachyarrhythmia and Intracardiac Atrial Fibrillation which analyzes of abnormalities ECG recordings for detecting an arrhythmia and calculate P, Q, R, S, and T as well as detect heart rate of ECG abnormalities. In the fourth part that titled DSP techniques of ECG analysis which introduces three techniques are as follows: digital filters (FIR and IIR), wavelet processing (filters banks technique) and adaptive filter signal processing. These three techniques have used for removing ECG noises were implemented in this part of the system by using MATLAB and perform completely successful in removing most types of the ECG noises. The output results have shown that the performance of IIR filters better than FIR filters that used it for ECG noise cancellation. While in the second technique which entitled adaptive filter processing, introducing an application of adaptive line enhancer that applied to ECG signal where the LSM recursive algorithm used to implement the ALE filter in order to eliminate broadband noise from a narrowband signal.

The last technique is wavelet processing that applied of ECG signal which have low and high frequency noises by passing this signal through a filter bank which consists of subbands series of low pass and high pass filters. The ECG signals that generated by the analysis filter bank with the topmost plot showing the outputs of the first set of filters with the finest resolution, the next from the top showing the outputs of the second set of a set of filters, etc.

Only the lowest (i.e., smoothest) low pass subband signal is included in the output of the filter bank, the rest are used only in the determination of low pass and high pass subbands. The lowest plots show the frequency characteristics of the low and high pass filters. Finally, all these works that designed in one graphical user interface (GUI) have created in .NET applications for publishing and sharing them as an ASP .NET web site by using visual studio .NET. ASP.Net application introduces a lot of new features which include:

- Sharing applications with others who do not have MATLAB
- Integrating MATLAB algorithms into other applications such C# , and having many concurrent users work with MATLAB algorithms
- ASP.NET drastically reduces the amount of code required to build large applications
- The ASP.NET framework is complemented by a rich toolbox and designer in the Visual Studio integrated development environment. WYSIWYG editing, drag-and-drop server controls, and automatic deployment are just a few of the features this powerful tool provides
- Provides simplicity as ASP.NET makes it easy to perform common tasks, from simple form submission and client authentication to deployment and site configuration
- The source code and HTML are together therefore ASP.NET pages are easy to maintain and write. Also the source code is executed on the server. This provides a lot of power and flexibility to the web pages
- All the processes are closely monitored and managed by the ASP.NET runtime, so that if process is dead, a new process can be created in its place, which helps keep your application constantly available to handle requests
- It is purely server-side technology so, ASP.NET code executes on the server before it is sent to the browser
- Web application exists in compiled form on the server so the execution speed is faster as compared to the interpreted scripts
- ASP.NET 2.0 ships with a Web Parts Framework that provides the infrastructure and the building blocks required for creating modular web pages that can be easily customized by the users

6.2 Future Work

Nowadays the analysis of ECG for detecting heart rate, cardiac arrhythmia and the magnitude and intervals of the P-QRS-T is one of the most significant subjects in the biomedical field so there is a lot of work must be developed for this thesis are as follows:

- The work in this thesis can be developed by applying to the telemedicine application area. So cardiac arrhythmia detecting through remote access of ECG diagnosis is a highly effective and beneficial service for each of the medical sections and patients. The remote access control between patient and hospital or research center to transmit ECG information 24 hours a day of patient, especially from one clinic or patient's home for chronic patients to a remote site. So by using this service will be a part of homecare service center for tele homecare and as well as create link between nurses for consultation with specialists doctors in the event that an abnormality is found in the patient. In general, an ECG diagnosis research by applying the telemedicine application area is very significant in the future.
- Automatic cardiac abnormality detection by detecting heart rate, the QRS complex is necessary for real time application.
- Automatic detection of R-peaks and feature extraction techniques of ECG signal in real time.
- Calculate ST segment and other sensitive intervals in the ECG signal are best and most important for detecting an arrhythmia and the frequency spectrum of these segments.
- Other techniques can be used and apply of ECG signal like Artificial Neural networks, to test by applying for it and see the result.

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Education

[1992 – 1996] **University of Technology** Baghdad, Iraq.
B.Sc. Degree / Electrical & Electronic Engineering Department
In 1st and 2nd year, studying the General of Engineering Sciences.
In 3rd, Specialization in the Electrical & Electronic Engineering.
In 4th year, Specialization in the Electrical Engineering.
2013 Yildirm Beyazit university (now I'm doing master degree in Electronic and communication engineering)

Work experience

[1996 - 1999] **AL NADA Company (**Iraqi company**)** **Baghdad, Iraq.**
[1999 - 2005] **MDS Company** (Jordanian company**)** **Baghdad, Iraq.**
[2005 - 2013] **CCMED Company (**Japanese company**)** **Baghdad, Iraq.**

Training Certificate

I have a training certificate from the following companies :

Kontron Co., Ltd France Company (in Iraq 2001).
Drager Co., Ltd Germany Company (in Iraq 2002).
Al-Tabiaa Computer Training Center (in Iraq 2004).

CPA MOH (in Iraq 2003)
Furuno Electric Co., Ltd (in Japan 2006).
Jokoh Co., Ltd (in Japan 2006).
Inami Co., Ltd (in Japan 2006).
Kubota Corporation (in Japan 2006).
Paramount Bed Co., Ltd (in Japan 2006).
Nakamura Medical Industry Co., Ltd (in Japan 2006).
Furuno Electric Co., Ltd (in Japan 2007).
Jokoh Co., Ltd (in Japan 2007).
Sysmex Corporation (in Japan 2007).
NIHON KOHDEN Company (in Japan 2008).
ACOMA company (in Japan 2008).
Furuno Electric Co., Ltd (in Japan 2008).
Jokoh Co., Ltd (in Japan 2008).
Sysmex Corporation (in Japan 2008).
Furuno Electric Co., Ltd (in Japan 2009).
Jokoh Co., Ltd (in Japan 2009).
Sysmex Corporation (in Japan 2009).
NIHON KOHDEN Company (in Japan 2009).
Sakura Company (in Japan 2009).
Hitachi company (in Turkey 2011) sales training about MRI & CT devices.

Languages	Arabic (mother language), second language (English) and I am continuing in taking Turkish courses in TAD center.
Hobbies	Sports and Reading.
Professional memberships	I have been Memberships in the Iraqi Engineer Union from 1996 till now. IEEE Member.
Dissemination	Journal and Conference : Hussain A. J. AL-Ziarjawey and I. Çankaya, "Heart Rate Monitoring and PQRST Detection Based on Graphical User Interface with Matlab",7th international conference on computer science and information technology (ICCSIT), Barcelona, Spain, December 22-24, 2014, International Journal of Information and Electronics Engineering, Vol. 5, No. 4, July 2015.