CLASSIFICATION OF CARDIAC CONDITIONS

By

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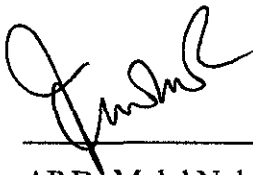Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nor Asyikin Bt Md Ghani

ABSTRACT

Human body needs heart to pump the blood throughout the body. Without heart, the organs in the body will not receive the oxygen thus they cannot function that will lead to death. Almost everyday we can see in the television, hear from the radio or even read from the newspapers that peoples around the world, especially those whom live in the rural area, suffered and died because of heart disease. There are many tools used by the doctor or physician to diagnose heart, such as ECG, SAECG, MRA, MRI, and many more. However these tools are quite expensive and impossible for the doctor from the small clinics and rural area can afford to buy them. What they can do is depend on the cheap acoustic stethoscope which require a sharp hearing capabilities. Stethoscope is a medical instrument that is used to detect the sound in the internal body. A study to identify and classify the cardiac conditions using stethoscope is proposed by designing a software based system. The study will focus on the analyzing the wave produced by the heart beat and classify them based on the amplitude, frequency and power spectrum.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

ECG	Electrocardiogram
FFT	Fast Fourier Transform
LPC	Linear Predictive Coding
MRA	Magnetic Resonance Angiography
MRI	Magnetic Resonance Imaging
PVC	Premature Ventricular Contraction
SAECG	Signal Average Electrocardiogram

CHAPTER 1

INTRODUCTION

1.1 Background of Study

From year 1990 until 2004, the statistic [1] show that every year, many Malaysian suffered from cardiovascular diseases such as rheumatic fever, ischaemic, hypertensive and many more . Heart disease was labelled as the major leading cause to death, where we can see that thousands of peoples died every year because of this disease. It is obvious that the serious action should be taken to control this situation. The proper diagnosis of the heart condition and immediate action taken by the doctors may help the patients to survive.

1.2 Anatomy

Human heart is located between the lung which is in the middle of chest, behind and slightly to the left of the breastbone. A pericardium, a double-layered membrane surrounds the heart. The outer layer of the pericardium surrounds the roots of the heart's major blood vessels and is attached to the spinal column, diaphragm, and other parts of the body. The inner layer of the pericardium is attached to heart muscle. A coating of fluid separates the two layers of membrane, letting the heart move as it beats, yet still attached to the body. The heart has four chambers. The upper chambers are called the left atria, and the lower chambers are called the left and right ventricles.
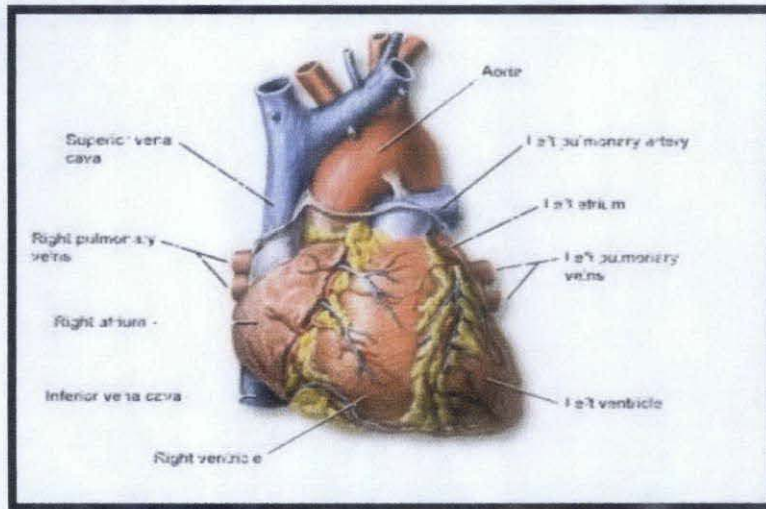
Figure 1: The Structure of Heart[2]

1.2.1 Cardiac Cycle

The heart has two-pumping phase, which called systole and diastole. For the first phase, when blood collects in the upper chambers, the electrical signal is send by the pacemaker (SA node) that causes the atria to contract. This contraction pushes blood through the tricuspid and mitral valves into the resting lower chambers. The second part of the pumping phase begins when the ventricles are full of blood. The electrical signals from the SA node travel along a pathway of cells to the ventricles, causing them to contract. As the tricuspid and mitral valves shut tight to prevent a back flow of blood, the pulmonary and aortic valves are pushed open. While blood is pushed from the right ventricle into the lungs to pick up oxygen, oxygen-rich blood flows from the left ventricle to the heart and other parts of the body.

After blood moves into pulmonary artery and the aorta, the ventricle relax, and the pulmonary and aortic valves close. The lower pressure in the ventricles causes the tricuspid and mitral valves to open and the cycle begins again. This process is repeated until the people die [3].

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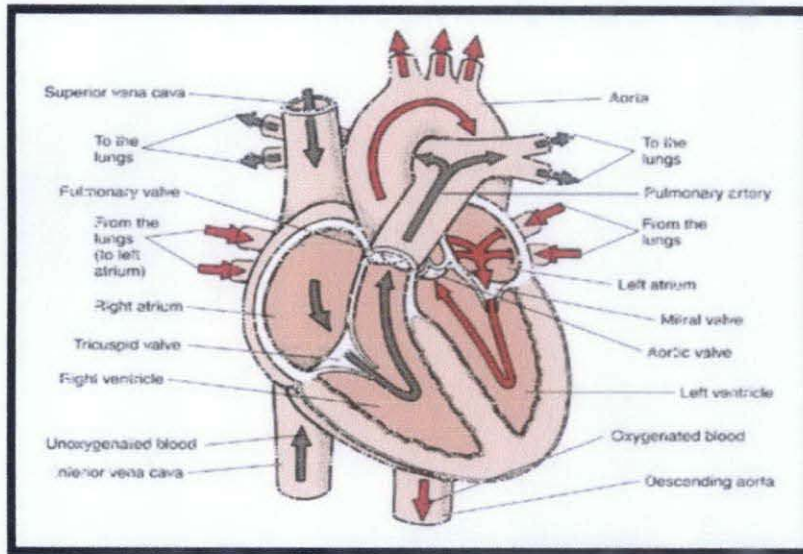
Figure 2 : The Flow of Blood in Heart[4]

1.2.2 Heart Sound

There are four valves in human heart such as tricuspid valve, pulmonary valve, mitral valve and aortic valve. Tricuspid valve is between the right atrium and the right ventricle, while pulmonary valve is between the right ventricle and pulmonary artery. The mitral valve is between left atrium and left ventricle while aortic valve is between left ventricle and the aorta. Each valve produces different sound [4].

1.2.2.1 First Heart Sound (S1)

The heart produces the first sound due to the enclosure of the atrioventricular valve at the beginning of the isometric ventricular contraction phase. This heart sound is a soft, low pitched and prolonged sound which is last for 0.15 second. The frequency of S1 is about 25-45Hz and sounds like "lub". The sound pitch for higher heart rate is louder than the sound of the lower heart rate.

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1.2.2.2 Second Heart Sound (S2)

The second heart sound is short, sharp and high-pitched where it produces sound like "dup" with the frequency of 50Hz and last for 0.12 second. It is due to the enclosure of the semi lunar valves at the beginning of the isometric ventricular relaxation phase. For children and young adults, the sound of S2 is split because the aortic valve closing earlier than the pulmonary valve.

1.2.2.3 Third Heart Sound (S3)

This third heart sound commonly can be heard in the children and young adults. The sound exists approximately 0.10-0.15 seconds after S2. The pitch of the sound is soft due to vibrations that occur when blood rushes into the ventricle as soon as atrioventricular valves open at the beginning of the filling phase. For people above the age of 40, the existence of S3 sound is considered abnormal case.

1.2.2.4 Fourth Heart Sound (S4)

The fourth heart sound occurs simultaneously with atria systole. For normal and healthy people, the S4 is never audible. The existence of S4 shows the abnormal conditions of the heart such as hypertension, conduction block or ventricular failure. For these cases, S4 can be heard just before S1.

1.2.3 Factors Affecting Heartbeat signal

The heartbeat produces the sound that can be heard and analyzed by looking at the sound signal. The heartbeat rate varies between individuals based on age, gender, disease and fitness [5].

a) Age

c) Disease

b) Gender

d) Fitness

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1.2.3.1 Age

Children have smaller heart, and therefore, their heart need to beat faster in order to pump the blood. The faster the heart beats, the higher the frequency and the sound become louder. The normal heartbeat rate for infants is 120 times per minute, for a child is about 90 to 110 times per minute and for adult above 18 years old is about 50 to 100 times per minute.

1.2.3.2 Gender

The average resting heartbeat rate for adult male is about 70 times per minute, while for adult female is about 75 times per minute.

1.2.3.3 Disease

The heartbeat rate also varies for normal and abnormal heart. This is because for normal heart, the four valves functions properly and the blood can flow smoothly while for abnormal heart, there are various problems that affecting the heartbeat rate.

1.2.3.4 Fitness

A physically active person such as athletes have lower heartbeat rate. Usually the rate is about 50 times per minute.

1.3 Tools to Diagnose Heart Disease

There are many tools and methods that are used to diagnose heart disease such as Electrocardiogram (ECG), stethoscope, Signal-average Electrocardiogram (SAECG), holter monitor, Echocardiogram, Magnetic Resonance Imaging (MRI), and Magnetic Resonance Angiography (MRA) [6].

1.3.1 Stethoscope

Stethoscope is a common tool that is used by doctors and physicians to diagnose the patient condition. This stethoscope is cheap and very affordable, however it strongly depends on the doctor's hearing capabilities. Nowadays, there are many electronic stethoscopes in the market that can diagnose the heart condition with noise reduction, but it is quite expensive. The stethoscope has two modes, which are bell mode and diaphragm mode. The bell mode is useful to picking up low pitches sound such as S3 and S4 sounds, where diaphragm mode is useful to picking up high pitches sound such as S1 and S3 sounds.

Figure 3: Electronic Stethoscope

1.4   Problem Statement

There are four sites on the human body that need to be checked in order to detect any problem in heart such as aortic area, pulmonary area, tricuspid area and mitral area (apex). The cheapest method used to check the cardiac condition is using the acoustic stethoscope. The stethoscope is not too convenient because it produces the extremely low sound level. This gives a problem to the doctors and clinicians because it requires full concentration and accuracy. The new technology that can check the heart conditions is electrocardiogram (ECG). The operation is based on the detection of the electrical current produced by the flow of blood throughout the body. Since the cost is very expensive, a lot of hospitals and clinics cannot afford to buy the ECG. Therefore, if we could collect the data produced by the sound wave and analyze that signal to produce a readable signal that can classify the heart condition, it will benefit many peoples especially those who are in medical field.

1.5   Objectives and Scope

The objectives of the project are to identify and classify the medical conditions of the patients based on the acoustic wave from the heart sound and design a software based system that can produce a readable signal. The sound wave will be collected using electronic stethoscope and upload them into the computer to be read by the stethoscope system software. The generated wave sound will be exported into MATLAB to be analyzed using signal processing technique. In order to achieve these goals, a lot of studies and tasks need to be carried out by studying the heart condition, fundamental function of the stethoscope, the interpretation of the signal, the measurement of the signal and the signal classification using MATLAB.

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CHAPTER 2

LITERATURE REVIEW

A number of researches have been conducted using various approaches in order to analyze and classify the heart beat signal [7]-[11]. Most of these efforts focus on recording the heart sound signal and segment that signal to analyze the relation between the activity of the heart and the signal.

The work describe in [7] was about ECG processing, where they have investigated the QRS complex, extracted from the electrocardiogram (ECG) data using fuzzy adaptive resonance theory mapping (ARTMAP). They also analyzed the normal and abnormal conditions of premature ventricular contraction (PVC). The extracted data of QRS complexes were filtered then the data were scaled and hamming windowed to yield a sample sequence for 100 samples for each QRS segment. Burg's maximum entropy method was used to generate the Linear Predictive Coding (LPC) based on the sequence. The fuzzy ARTMAP neural network was used to test the LPC coefficients and as a result, they found that the fuzzy ARTMAP neural network can be used to classify the cardiac condition.
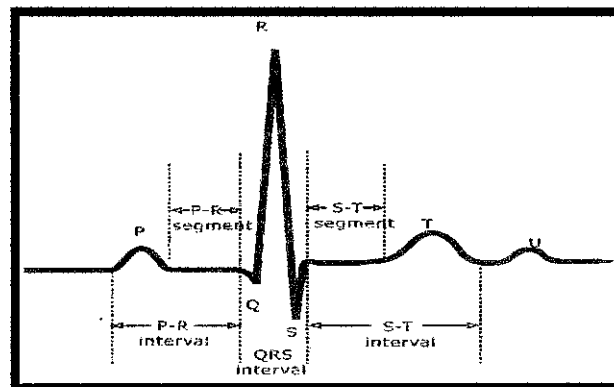

Figure 4 : ECG waveform [8]

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In [8], the work was about recording the acoustic signal produced by the heartbeat using an electronic stethoscope. This work involved for three process which are data acquisition and preprocessing, segmentation, and detection of heart disease. The data of the heart beat was collected in the wave sound format and uploaded in the computer. Using MATLAB software, the signal was uploaded and each segment was analyzed by filtering the signal to reduce the noise. The signal for normal and various abnormal conditions of the cardiac were produced and the characteristic of the signal were recognized. They were various signals showing the condition of the heart. Figure 7 shown the heart beat signal of a normal condition while figure 8 is one of the signal produced by abnormal cardiac condition.
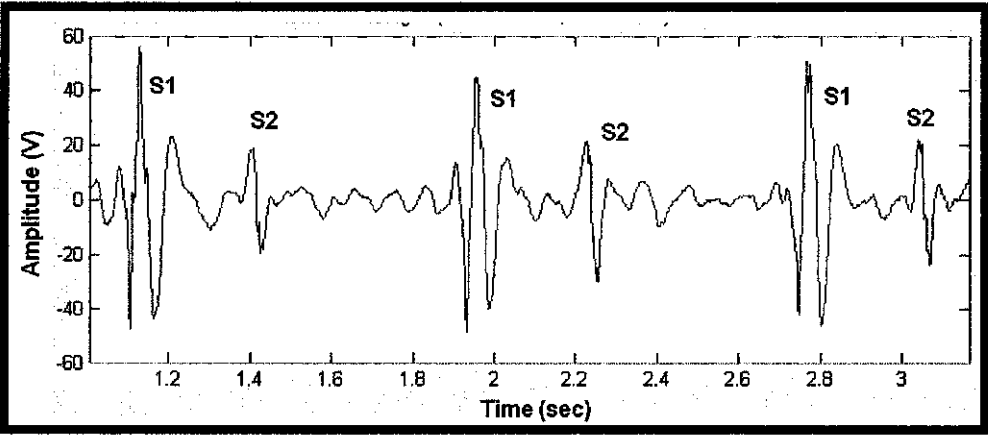

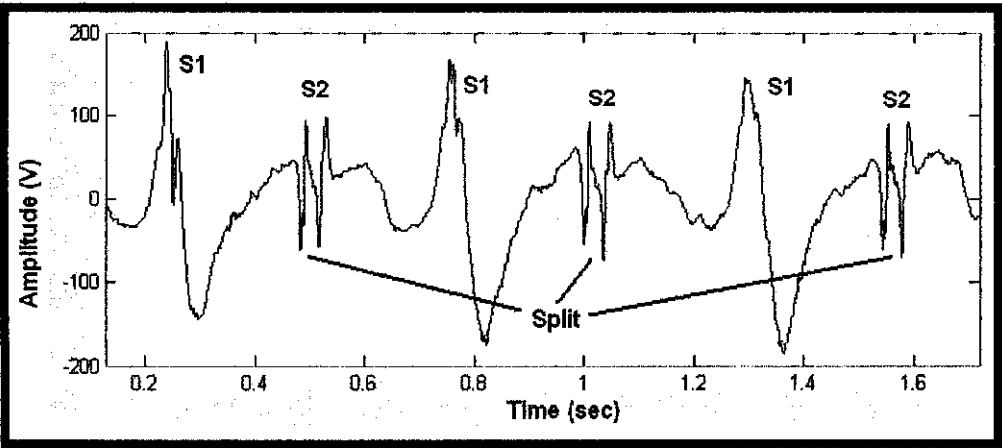**Figure 5 : Example of Normal Heartbeat Signal [8]**

Figure 6 : Example of Abnormal Heartbeat Signal [8]

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The study of the features for heartbeat sound signal for normal and pathological was describe in details in [9]. This work focused on the synthesis study of the fast Fourier transform (FFT) and the wavelet transform in analyzing the heart signal. The abnormal heart sound may contain more signals, in addition to S1 and S2. In studying the physical characteristic of the sounds and human hearing, it is hard to detect the patient cardiac condition due to poor hearing capabilities. The ECG machine is the best method to check the cardiac condition, but it is expensive. The relationship between heart sound and ECG was analyzed. S1 is corresponding in timing with QRS complex and the sound S2 follows the systolic pause in the normal cardiac cycle.
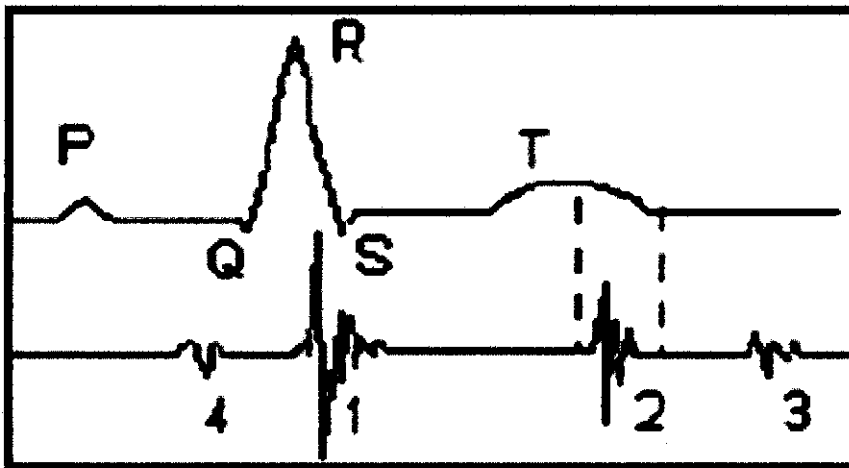
Figure 7 : Relationship between ECG Signal and Heartbeat Sound Signal [10]

In Seoul [10], researches were about the detection of abnormality using Cardiac Sound Characteristics Waveform (CSCW) with data clustering. This method used an analytical model based on mass-spring-damper system for extracting the CSCW from the sound signals. The time taken from the first and second heart sound is induced with a passive threshold value (THV) to find any abnormalities in heart. The data clustering techniques was introduced to determine the adaptive and reliable THV ranges. The heart sound was identified automatically by using the cost function and two cluster centers.

The sound separation using independent component analysis technique was also introduced in [11]. To improve the heartbeat analysis, they have investigated the possibility of the heart sound analysis, especially the separation and localization of heartbeat signal using this technique. They have put several probes on the body surface to record the heart sound and the sound is then separated to two major beat sequences, S1 and S2. The experiment was done with a healthy 29 years old man and the results showed that this technique can help us analyze S1 and S2 in details.

CHAPTER 3

METHODOLOGY

3.1 Procedures

Towards developing a system for detecting heart diseases, the project was divided into two phases. The first phase was about studying the function of the stethoscope and the heart. The heart is divided into four parts where each part produces different sound based on the flow of blood in the heart. The acoustic stethoscope is commonly used by the doctors and physician to hear the sound produced by heart, however this stethoscope cannot record the sound. In this project, the electronic stethoscope produced from 3M Littmann company was used to record the sound and transfer it to the computer for analyzing purpose. 3M Litmann Sound Analysis software is used to analyze the sounds.

For the second phase, which had been done in this semester, a few samples of heart sound were taken from the patients in Hospital Taiping and Hospital Tanah Merah. From the stethoscope, the sounds were transferred using infrared port into the computer to be read using 3M Littmann Sound Analysis Software. The recorded heart sounds were in .e4k format which cannot be read by MATLAB software. The sounds then were converted into .wav files and digitized into 16bps, 8 kHz PCM. These sounds were filtered using band pass Butterworth filter with the cut off frequencies of 350Hz and 500 Hz.. The purpose of filtering is to reduce the noise so that the signal can be seen clearer. A sample of one cycle of heart beat (lub dub) was taken from each signal to be compared to each other. From this comparison, the data such as the time taken from S1-S2 and S2-S1, the amplitude of the signal during S1-S2, and S2-S1, and also the amplitude in between S1-S2, and S2-S1 were measured.

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From the sound data, the frequency spectrum of the signal was generated. After that, the power of each of the sample data were calculated and the power graphs were generated. Then the classification based on the signals shape, frequency spectrum, and power spectrum were done. A few test had been conducted in order to find the accuracy of the classification. Lastly a software using GUI in MATLAB software was designed.
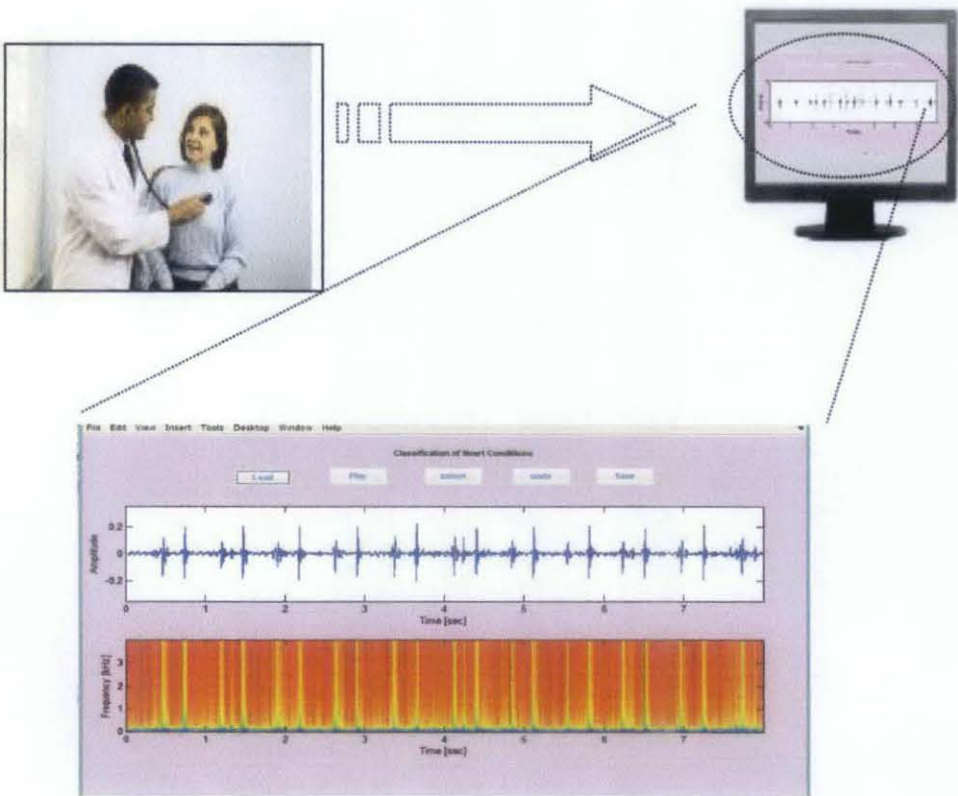

Figure 8: Model of Heart Analysis Program
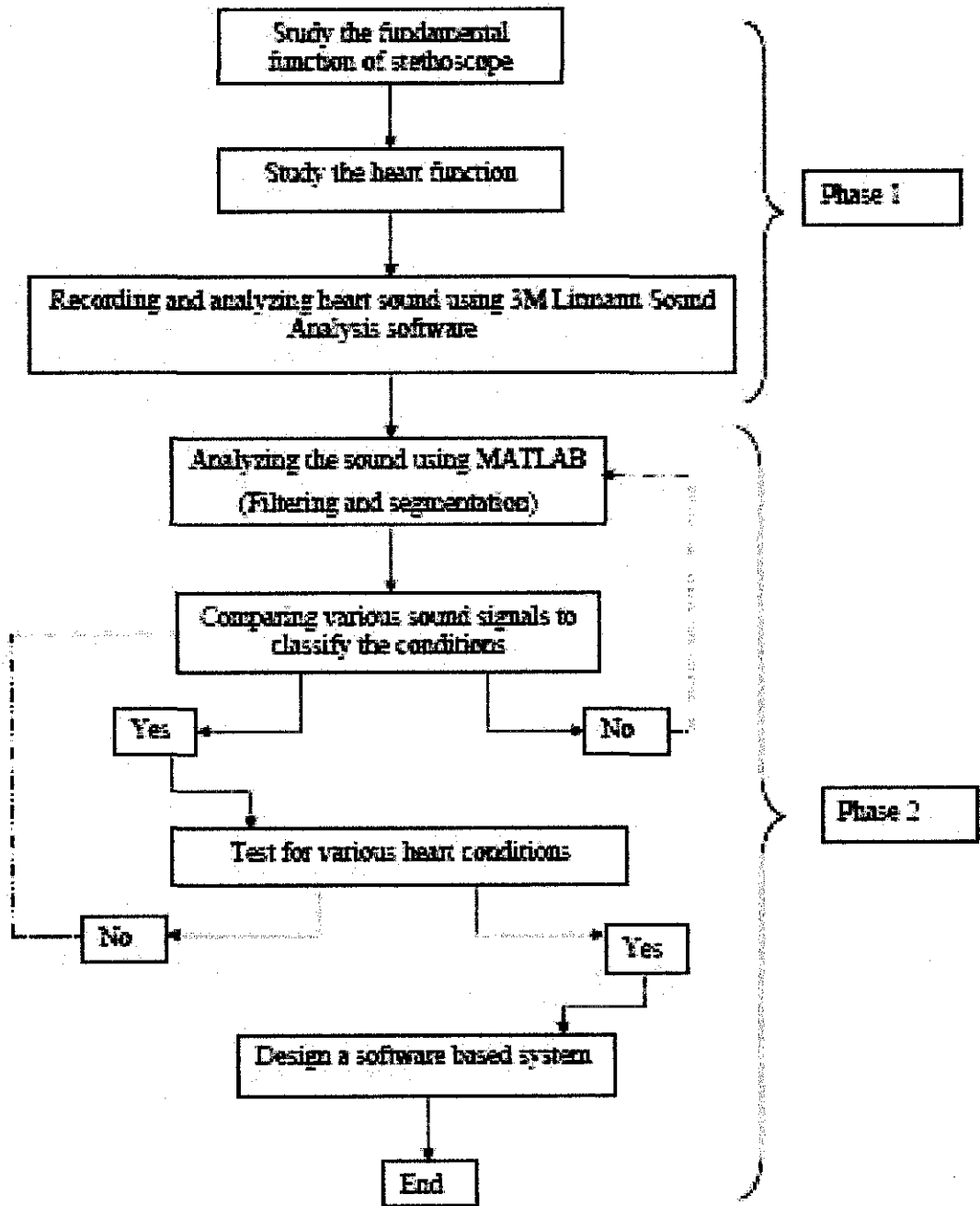
3.2 Project Flow Chart

Figure 9 : Project Flow Chart

3.3   Tools

1) 3M Littmann Electronic Stethoscope
2) 3M Littman sound analysis software
3) MATLAB software

CHAPTER 4

RESULTS AND DISCUSSION

4.1   Loading and Filtering the Sounds

The sounds were loaded into MATLAB Workspace by using the following command;

```
>> wavread ('sound1.wav');
```

Upon loading the sound into Matlab, Matlab automatically generate the information of the sound in the workspace such as the length of the sounds and the sampling frequency (fs). In this case, the length are 64000 and fs = 8kHz.

The original sound signals were full of noises, so the **sptool** command was used to reduce those noises. **SPtool** is a built in GUI that can be used to filter the sounds. After that, the sounds were exported back into MATLAB workspace to be further analyzed.
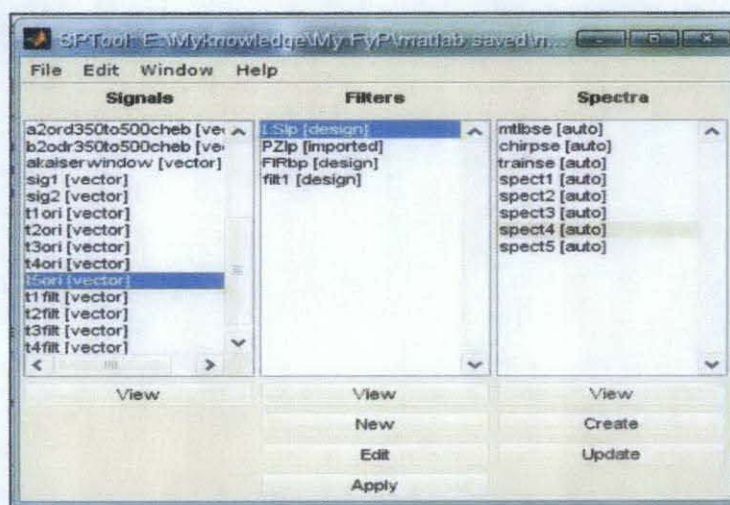

Figure 11 : MATLAB SPtool

The samples of sound were taken from various types of peoples, man, woman, kid, and old man. The first observation was different genders have different heart rate, and so in this case, the heart sound for man was chosen to be analyzed. After filtering the samples sound in Matlab, the first differentiation between each sample, which is their signals shape. The normal heart produces a signal like this;
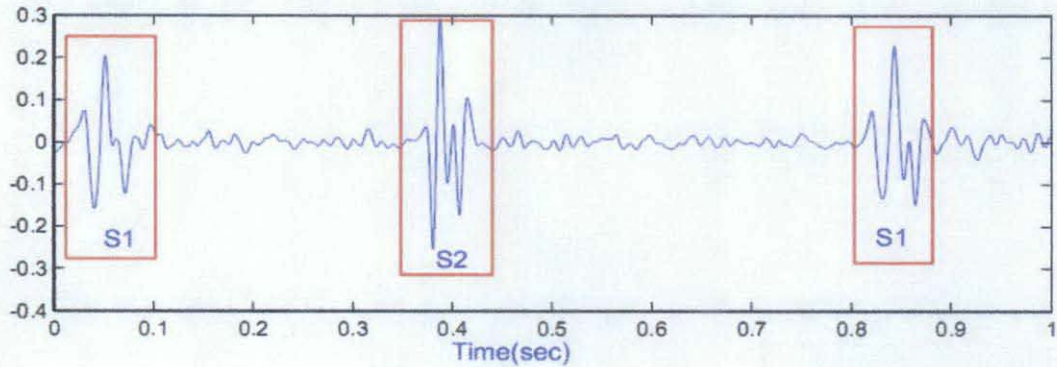
Figure 10: Normal Heart

S1 is the systole mode while S2 is diastole mode. For normal condition, the amplitude of the signals only high during S1 and S2 modes only. The average time taken between S1 and S2 is 0.336s while the time between S2 and S1 for the next cycle is 0.458s. The heartbeat rate can be determined by using the following formula;

Heart beat rate $= \dfrac{60s}{S}$ (beats per minute)

S = time taken for 1 beat cycle.

In this normal case, the heart beat rates are ;

$\dfrac{60s}{0.85s - 0.05s} = \textbf{75 bpm}$

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4.2 Signal Analysis

4.2.1 Amplitude   versus Time

In MATLAB workspace, the amplitude versus time signal can be obtained using the following commands;

```
>> load ('dataa');
>> plot(dataa),title('amplitude vs time');
```

4.2.2 Frequency versus Time

The frequency of the signals can be obtained using the following command;
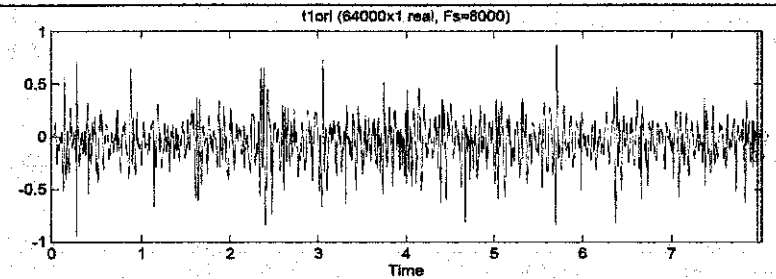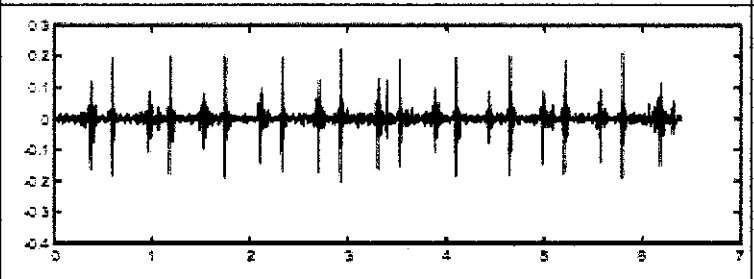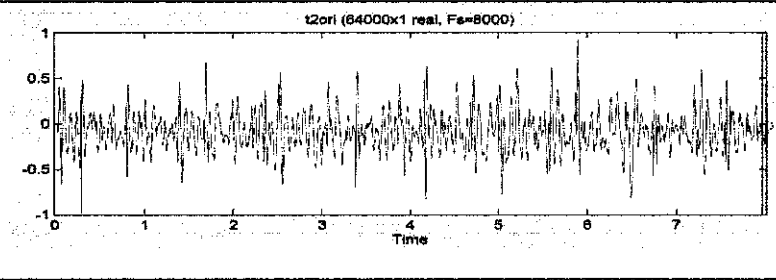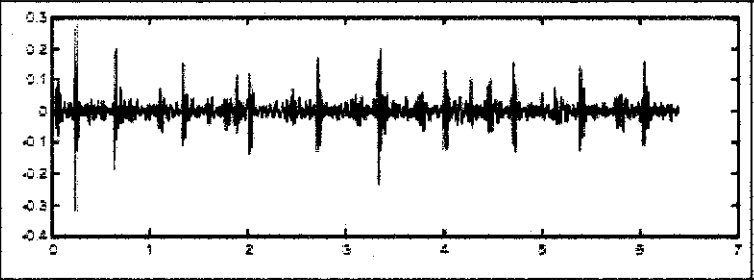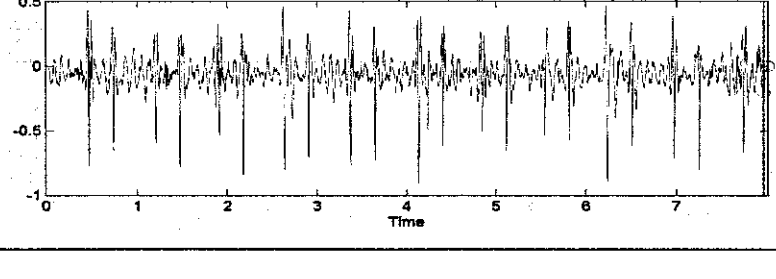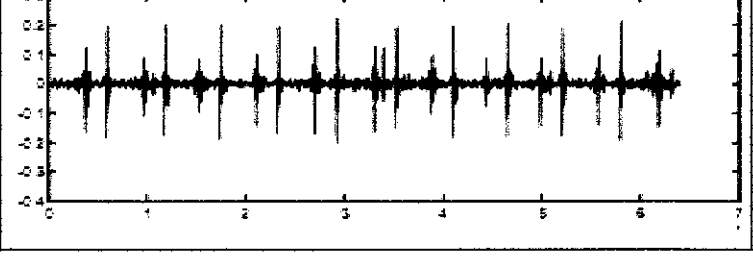
```
>>specgram(dataa,512,fs),title('frequency vs time');
```

4.2.3 Power versus Frequency

The power versus frequency signals can be measured using the following command;

```
win = .5*(1 - cos(2*pi*(1:lwin)'/(lwin+1)));
        for k=1:n
                xwin(1:lwin,k) = win.*x(:,k);
        end
        f = fft(xwin);
        f(1+lwin/2:lwin,:) = [];
        ps = abs(f).^2;
    [m,n] = size(ps);
        if (m==1) || (n==1)
                psa = ps*(dt/lwin);
                psa(2:lwin/2) = psa(2:lwin/2)*2;
        else
                psa = sum(ps')*(dt/lwin);
                psa(2:lwin/2) = psa(2:lwin/2)*2;
        end
```

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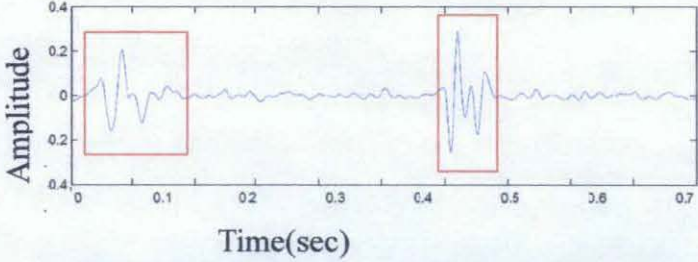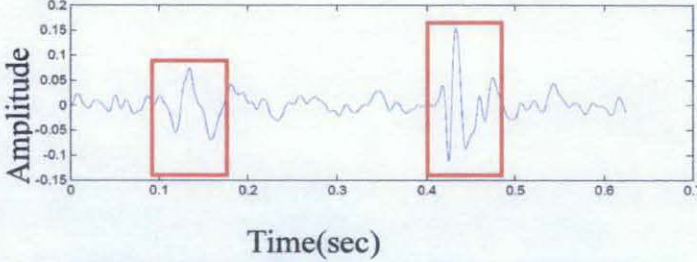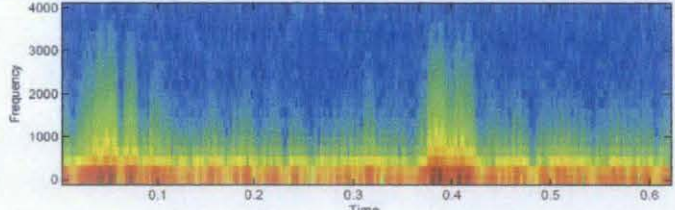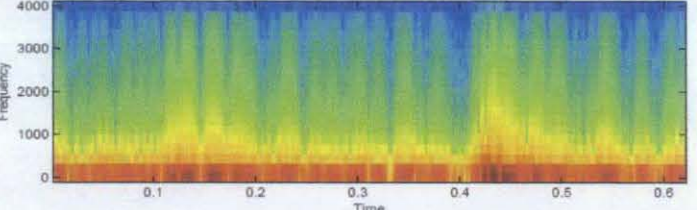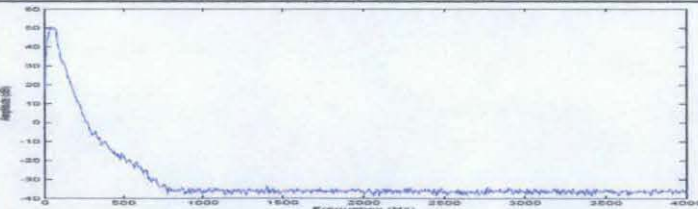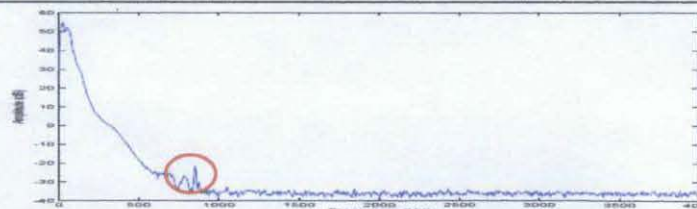
Table 1 : Samples of Heart Sounds

Original Sound Signal	Filtered Sound Signal	Comments
t1ori (64000x1 real, Fs=8000)		Normal
t2ori (64000x1 real, Fs=8000)		Abnormal
t3ori (64000x1 real, Fs=8000)		Normal

Normal

Abnormal

t4orl (64000x1 real, Fs=8000)

t5orl (64000x1 real, Fs=8000)

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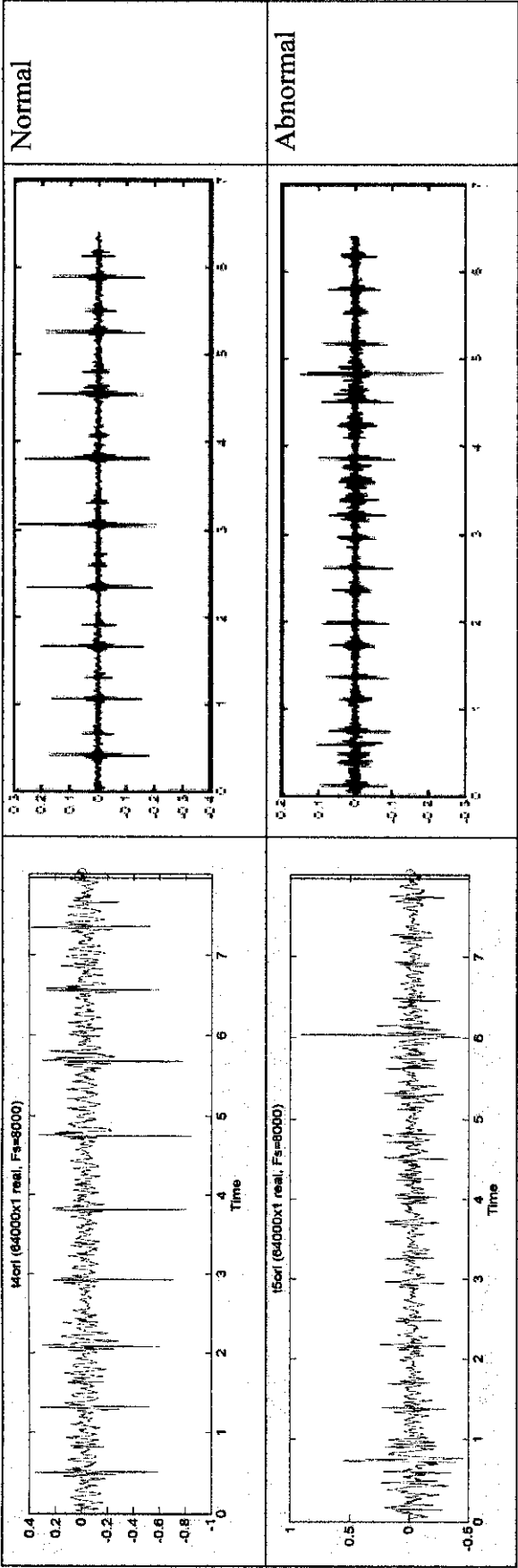
4.3 Signal Comparison

Table 2: Comparison between Normal and Abnormal Heart

	Normal	Abnormal
Amplitude vs. Time		
Frequency vs. Time		
Power vs. Frequency		

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4.4 Discussion

Based on the table 1, five samples of heart sounds were taken. The original signals were mixed with noise, so Butterworth bandpass filter was used to reduce the noise. This noise came from the lungs, where peoples breath during recording their heart sounds.

From the table 2, the normal and abnormal heart sounds were compared based on the amplitude signal, frequency signal, and power signal. For the amplitude versus time signal, the differentiation between the normal and abnormal heart can be seen based on the shape for "lub" and "dub" condition. For normal heart, the amplitude is high during S1 (lub) and S2 (dub) mode, while in between these modes, the amplitude is very small or closely to zero. For abnormal heart, the amplitude is quite high outside the S1 and S2 mode showing that the blood cannot flow into valve normally.

For the frequency versus time signals, the frequency of abnormal heart is not clear because of the noise. This noise was not the normal noise, but it was caused by the problems in heart. For the third graph, the power versus frequency signals for normal man is very smooth, while for abnormal man, the graph is not smooth. In between 500 Hz to 1000 Hz, the power suddenly increases. This situation may be caused by the abnormality of heart. In medical term, the abnormality of the heart is called as murmur, which is defined as low, indistinct and continuous sound.

In this sample, the abnormal heart refers to the aortic stenosis, the abnormal narrowing of aortic valve. Based on these tables, a GUI was built using Matlab. This GUI can produce the amplitude, frequency, and power signals when we load the wave files into it. The coding for the GUI is attached in the appendices.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The heart health is very important to the human being. In order to control the heart disease, immediate action and advance treatment should be done by the doctor s or physicians. The acoustic stethoscope is not too convenient for heart diagnosis because it depends on the hearing capability of the doctors. For new doctors, it will take quite a long time to be familiar with the stethoscope. Studies about the detection of abnormalities of the heart based on the acoustic signals have been done by using MATLAB software.

3M Littmann Sounds Analysis Software can convert the original sounds which were in **.e4k** format into **.wav** format. The first **.wav** sounds were mixed with noises and were filtered using Butterworth bandpass filter. This filter can reduce the noise caused by the activities of the lungs. The filtered signals were imported into Matlab workspace and were analyzed. The result from the analysis showed that the signals that were produced which were in amplitude, frequency and power spectrum mode can be used to classify the heart conditions. The software which was written in M-files and using GUI based is hoped to help those peoples in medical field to do heart analysis more efficiently.

5.2 Recommendation

For future study, the acoustic stethoscope can be modified so that it can be used to record the heart sound and transfer it to the computer. This stethoscope must be cheaper than electronic stethoscope that already in the market nowadays and may have the additional functions such as implementation of filter to reduce the noise, so the heart sounds can be heard clearer and the recording function that can record the sound into **.wav** format.

The Matlab based software can have the additional functions such as the automatically detect the heart conditions and show the information regarding the disease so doctors may know the appropriate actions that should be taken.

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APPENDIX A

MATLAB GUI A

```
inction heart(op)

.obal H_heart F_heart AXIS_heart data z_data R_fs

.obal select_data

' nargin == 0 % if no input argument, draw the GUI
   op = 0;
:d

)ec = 'narrowband';
.deband_time = 4e-3;
irrowband_time = 25e-3;
:t_pts        = 2048; % # of points in the FFT

iitch op

:se 0 % Draw figure

   clear global data  % erase any previously hearted data

   width = 950;
   height = 700;

   F_heart = figure('Position',[25 50 width height],...
       'NumberTitle','off',...
       'Color',[.8 .7 .8],...
       'Name','HEART ANALYSIS PROGRAM');

   H_heart(1) = uicontrol('Style','text',... % text
       'Units','normalized', ...
       'Position',[400/width (height-55)/height 200/width 35/height],...
       'ForegroundColor',[.2 .4 .2],...
       'BackgroundColor',[.8 .7 .8],...
       'FontWeight','bold',...
       'String','Classification of Heart Conditions',...
       'Enable','on',...
       'CallBack','off');

   H_heart(2) = uicontrol('Style','text',...
       'Units','normalized', ...
       'Position',[190/width (height-45)/height 80/width 20/height],...
       'BackgroundColor',[.8 .7 .8],...
       'String','        ');

   H_heart(3) = uicontrol('Style','pushbutton',... % play button
       'Units','normalized', ...
       'Position',[(width-655)/width (height-72.5)/height 75/width 25/height],...
       'ForegroundColor',[.3 .6 .9],...
       'FontWeight','bold',...
       'String','Play',...
       'Enable','off',...
       'CallBack',' ');
```

```matlab
H_heart(4) = uicontrol('Style','pushbutton',... % select  data
    'Units','normalized', ...
    'Position',[(width-535)/width (height-72.5)/height 75/width 25/height], ...
    'ForegroundColor',[.3 .6 .9],...
    'FontWeight','bold',...
    'String','Select',...
    'Enable','off',...
    'CallBack','heart(3)');

H_heart(5) = uicontrol('Style','pushbutton',...
    'Units','normalized', ...
    'Position',[(width-415)/width (height-72.5)/height 75/width 25/height], ...
    'ForegroundColor',[.3 .6 .9],...
    'FontWeight','bold',...
    'String','Undo',...
    'Enable','off',...
    'CallBack','heart(4)');

H_heart(6) = uicontrol('Style','pushbutton',... % Load data from wav file
    'Units','normalized', ...
    'Position',[180/width (height-75)/height 75/width 25/height], ...
    'ForegroundColor',[.3 .6 .9],...
    'FontWeight','bold',...
    'String','Load',...
    'Enable','on',...
    'CallBack','heart(5)');

H_heart(7) = uicontrol('Style','pushbutton',... % Save data to wav file
    'Units','normalized', ...
    'Position',[(width-300)/width (height-72.5)/height 75/width 25/height], ...
    'ForegroundColor',[.3 .6 .9],...
    'FontWeight','bold',...
    'String','Save',...
    'Enable','off',...
    'CallBack','heart(6)');

H_heart(8) = uicontrol('Style','pushbutton',... % power
    'Units','normalized', ...
    'Position',[(width-195)/width (height-72.5)/height 75/width 25/height], ...
    'ForegroundColor',[.3 .6 .9],...
    'FontWeight','bold',...
    'String','Power',...
    'Enable','off',...
    'CallBack','heart(7)');

ase 1 % heart button

    % make all buttons available
    set(H_heart(3),'enable','on');
    set(H_heart(4),'enable','on');
    set(H_heart(5),'enable','on');
    set(H_heart(7),'enable','on');
    set(H_heart(8),'enable','on');
        set(H_heart(9),'enable','on');
```

```
end

  if ymin < yaxis_limits(1)
      ymin = yaxis_limits(1);
  end

  if ymax > yaxis_limits(2)
      ymax = yaxis_limits(2);
  end

  % if the choosen select range is acceptable...
  if ~((ymin > ymax) || (xmin > xmax))

      axis([xmin xmax ymin ymax]);
      % define the last limits
      last_axis_limits = [xaxis_limits yaxis_limits];
      select_data = push(select_data,last_axis_limits);

      % limits to be the same as those of the time data
      axes(AXIS_heart(2))
      yaxis_limits = get(AXIS_heart(2), 'YLim');
      axis([xmin xmax yaxis_limits(1) yaxis_limits(2)]);

      % define the selected data
      imin = round(xmin*R_fs)+1;
      imax = round(xmax*R_fs)+1;
      z_data = data(imin:imax);

  end

se 4

  select_level = length(select_data);

  if select_level > 1
      [select_data,axis_limits] = pop(select_data);
  else
      axis_limits = select_data{1};
  end


  axes(AXIS_heart(1))
  axis(axis_limits);

  axes(AXIS_heart(2))
  ymin = 0;
  ymax = R_fs/2000;
  axis([axis_limits(1:2) ymin ymax]);

  % define the selected in data
  imin = round(axis_limits(1)*R_fs)+1;
  imax = round(axis_limits(2)*R_fs)+1;
  z_data = data(imin:imax);


se 5 % Load button
```

```matlab
[filename, pathname] = uigetfile('*.wav','Select Data File');

if filename ~= 0

    cd(pathname);

    %  Get data and sampling rate
    [data,R_fs] = wavread([pathname filename]);
    if min(size(data))>1
        error('Can''t load the data')
    end
% Make all buttons available
    set(H_heart(3),'enable','on');
    set(H_heart(4),'enable','on');
    set(H_heart(5),'enable','on');
    set(H_heart(7),'enable','on');
    set(H_heart(8),'enable','on');
       set(H_heart(9),'enable','on');

    z_data = data;

     % displays the time graph of the voice signal
    AXIS_heart(1) = timedata(F_heart,data,R_fs,0.06,0.50,0.88,0.30);
    xlims = get(AXIS_heart(1), 'XLim');
    ylims = get(AXIS_heart(1), 'YLim');
    select_data = [];
    select_data = push(select_data,[xlims ylims]);

      if strcmp(spec,'narrowband')
          window_width = round(R_fs*narrowband_time);
          step_size = round(window_width/8);
      elseif strcmp(spec,'wideband')
          window_width = round(R_fs*wideband_time);
          step_size = round(window_width/2);
      end

    % calculates the spectrum of the voice signal
    X = specgram(data,fft_pts,1,hamming(window_width),window_width-step_size);
    X = abs(X);

    % displays the spectrum of the voice signal
     AXIS_heart(2) = spectdata(F_heart,X,R_fs,step_size,window_width, ↙
06,0.11,0.88,0.30);
     axis([xlims get(gca, 'YLim')])

 end

se 6 % Save waveform

  [filename, pathname] = uiputfile('*.wav', 'Save Data to Wave File');
  if filename ~= 0
      wavwrite(z_data,R_fs,[pathname filename])
  end

se 7 %power waveform
```

```
.ear all
:ho off

[ilename, path] = uigetfile('*.wav');

[ filename==0
   else
   wavefile = [path,filename];
   eval('fid=fopen(wavefile,''rb'');');
ıd

` fid == -1
   error('Can''t open .WAV file for input!');
ıd;

` fid ~= -1
   % read riff chunk
   fread(fid,4,'uchar');
   fread(fid,1,'ulong');
   fread(fid,4,'uchar');

   % read format sub-chunk
   fread(fid,4,'uchar');
   fread(fid,1,'ulong');

   format(1)=fread(fid,1,'ushort');
   format(2)=fread(fid,1,'ushort');
   fs=fread(fid,1,'ulong');
   dt = 1/fs;
   format(3)=fs;
   format(4)=fread(fid,1,'ulong');
   format(5)=fread(fid,1,'ushort');
   format(6)=fread(fid,1,'ushort');

   % read header
   %header=fread(fid,4,'uchar');
   nsamples=fread(fid,1,'ulong');

   if format(6)==8 % 8 bit data
       d=fread(fid,nsamples,'uchar');
   elseif format(6)==16 % 16 bit data
       d=fread(fid,nsamples,'short');
   end

   fclose(fid);

   if format(2)==2
       chan1 = d(1:2:length(d));
       chan2 = d(2:2:length(d));
   elseif format(1)==1
       chan1 = d;
   end


   if format(2)==2
```

```matlab
lwin = 2048;
n = fix(length(chan2)/lwin);
x = reshape(chan2(1:lwin*n),lwin,n);
xwin = zeros(size(x));

% use a Hanning window
win = .5*(1 - cos(2*pi*(1:lwin)'/(lwin+1)));
for k=1:n
    xwin(1:lwin,k) = win.*x(:,k);
end

f = fft(xwin);
f(1+lwin/2:lwin,:) = [];
ps = abs(f).^2;

% scaled in terms of power spectral density, double +ve frequencies
[m,n] = size(ps);
if (m==1) || (n==1)
    %psa = ps*(dt/lwin);
    %psa(2:lwin/2) = psa(2:lwin/2)*2;
else
    %psa = sum(ps')*(dt/lwin); %#ok<UDIM>
    %psa(2:lwin/2) = psa(2:lwin/2)*2;
end


elseif format(2)==1

lwin = 2048;
n = fix(length(chan1)/lwin);
x = reshape(chan1(1:lwin*n),lwin,n);
xwin = zeros(size(x));

% use a Hanning window
win = .5*(1 - cos(2*pi*(1:lwin)'/(lwin+1)));
for k=1:n
    xwin(1:lwin,k) = win.*x(:,k);
end

f = fft(xwin);
f(1+lwin/2:lwin,:) = [];
ps = abs(f).^2;

[m,n] = size(ps);
if (m==1) || (n==1)
    psa = ps*(dt/lwin);
    psa(2:lwin/2) = psa(2:lwin/2)*2;
else
    psa = sum(ps')*(dt/lwin); %#ok<UDIM>
    psa(2:lwin/2) = psa(2:lwin/2)*2;
end

% display power spectrum
df = 1/(dt*lwin);
np = lwin/2;
f = 0:df:(np-1)*df;
```

```matlab
        % create new graphics window
        chan1figtitle = ['Power Spectrum - ',wavefile];
        hf = figure('Name',chan1figtitle,'NumberTitle','on','Color','white',...
        'Pointer','crosshair','Units','normal','Position',[0.3,0.2,0.65,0.65],...
        'InvertHardCopy','off');

        % position axes within figure window
        ht = axes('Parent',hf,'Position',[0.2 0.1 0.75 0.85]);

        plot(f,10*log10(psa(1:np)), '-b');

        htx = text(0,0,'Frequency (Hz)');
        set(htx,'Color','black');

        hty = text(0,0,'Amplitude (dB)');
        set(hty,'Color','black');
        set(hty,'Rotation',+90.0);

        set(ht,'XLabel',htx,'YLabel',hty);

        %textvar = 'FREQ';

    end



d

d


nction H = timedata(Fig,x,fs,left,bottom,width,height)

gure(Fig);

mp_len = length(x)/fs;
lta_t = 1/fs;
= 0:delta_t:(samp_len-delta_t);

display the signal
= subplot('position',[left bottom width height]);
ot(t,x), xlabel('Time [sec]'), ylabel('Amplitude')
is([0 t(length(x)-1) -0.35 0.35 ]);


nction H = spectdata(Fig,x,fs,step,ww,left,bottom,width,height)

gure(Fig);

frequency axis vector
len = size(x,1); % num of rows
= (0:y_len-1)*fs/y_len/2;
= f/1000; % kHz scale

time axis vector
```

```
len = size(x,2); % num of columns
= ((ww-1)/2:step:(x_len-1)*step+(ww-1)/2)/fs;


display the signal
= subplot('position',[left bottom width height]);
g_data = -log10(x+0.0001);
agesc(t,f,log_data), xlabel('Time [sec]'), ylabel('Frequency [kHz]')
t(gca,'YDir','normal')


nction s = push(s,new_item)
Function 'push' adds 'new_item' to stack 's'
 ~isempty(s)
  height = length(s);
 s{height+1} = new_item;
se
 s{1} = new_item;
d


nction [s,x] = pop(s)
Function 'pop' removes item from top of stack 's'
ight = length(s);
= s{height};
= s(1:height-1);
```