University of Al Mustaqbal

Biomedical Engineering Department

Biomedical Signal Analysis Lab

Title: ECG spectral analysis

Variant 2

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Work # 3. ECG spectral analysis

Theory basics

Spectral analysis is used to obtain the signal frequency content quantitative estimations. Most widely used method is spectral analysis based on the discreet Fourie transform, determined by the equation:

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-j2\pi/N\, nK}$$

where x(n) – discreet signal samples, N – number of samples, k = 0, 1, …, N–1 – numbers of spectral components. Fast Fourie transform (FFT) is a special algorithm used for reduction of the calculation complexity.

In this work, FFT is used for the spectral analysis of three types of ECG rhythm: normal rhythm (curve "a" at the figure below), ventricular tachycardia (curve "b") and ventricular fibrillation (curve "c").

a

b
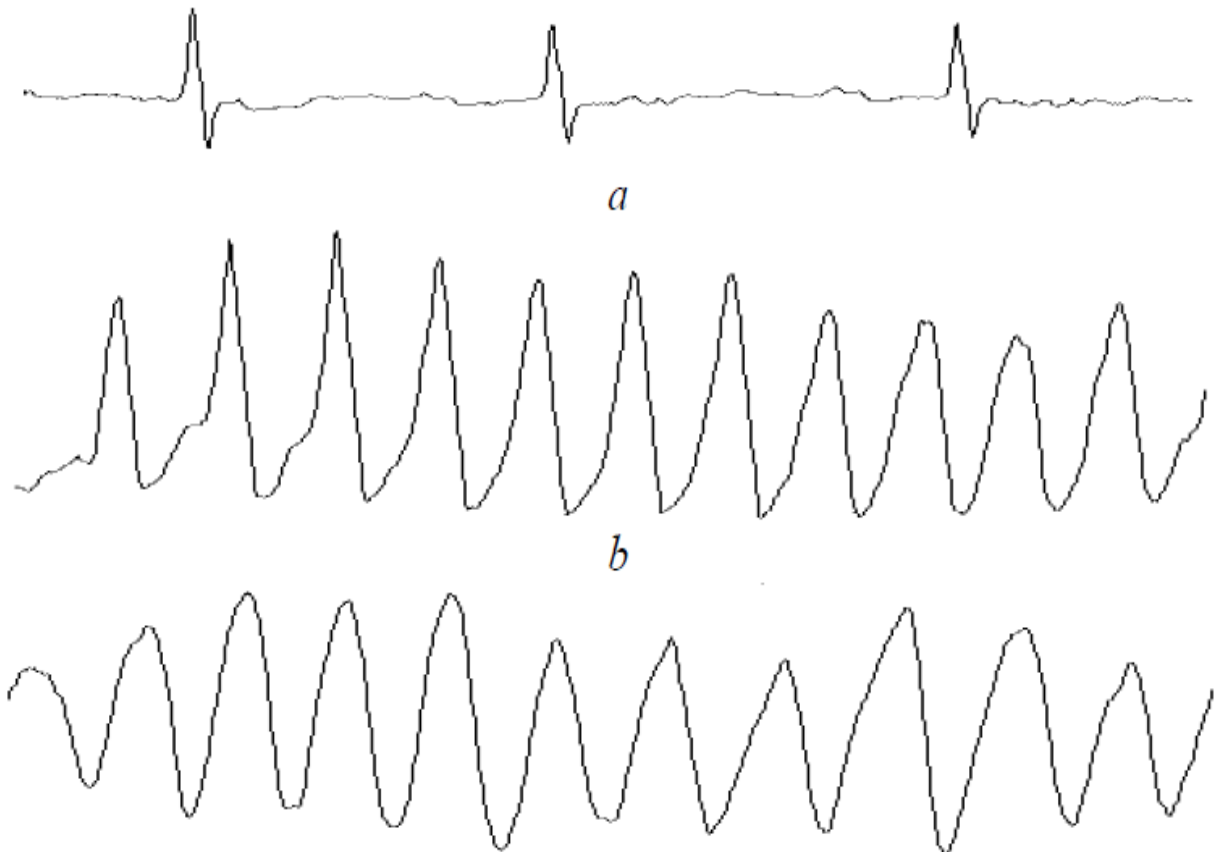
Main tasks of the work

- Calculation of the test signal spectral estimations. Plotting the test signal and also its magnitude spectrum and power spectral density (PSD).
- Calculation of spectral estimations for the ECG fragments containing three different types of heart rate.

Supplement #3:

<div align="right">**Table W.3**</div>

Variant	*Fs*, Hz	*A1*	*F1*, Hz	*A2*	*F2, Hz*	*C*	*t*max, s	File
1	100	1.5	5.0	0.8	13.0	0.2	1.0	W3_01.txt
2	120	1.2	10.0	0.5	17.0	0.3	3.0	W3_02.txt
3	150	1.4	8.0	0.9	14.0	0.25	1.5	W3_03.txt
4	180	0.8	10.0	1.5	16.0	0.15	2.5	W3_04.txt
5	200	0.7	5.0	0.9	10.0	0.35	1.2	W3_05.txt
6	240	0.7	11.0	1.5	19.0	0.4	1.0	W3_06.txt
7	250	2.5	5.0	1.5	20.0	0.45	0.8	W3_07.txt
8	300	1.5	3.0	2.0	7.0	0.5	5.0	W3_08.txt
9	350	2.5	6.0	1.0	14.0	0.2	0.5	W3_09.txt
10	400	1.0	23.0	1.5	35.0	0.3	3.0	W3_10.txt

We will use **Variant Nº 2**

Part 1: Calculation of the test signal spectral estimations

Code

```
tmax=3;
C=0.3;
A1=1.2;
A2=0.5;
Fs=120;
F1=10;
F2=17;
T=1/Fs;
t=(0:T:tmax);
Y=A1*sin(2*pi*F1*t)+C;
Y1=A2*sin(2*pi*F2*t)+C;
Y2=Y+Y1;
subplot(3,3,1);
plot(Y2);
grid on;
ft=fft(Y2);
N=tmax*Fs;
for j=1:N;
```

```
    if (j==1)
       ms(j)=sqrt(real(ft(j))^2+imag(ft(j))^2)/N;
       else
          ms(j)=sqrt(real(ft(j))^2+imag(ft(j))^2)/N*2;
       end
end
df=Fs/N;
for j=1:(N/2)
   f(j)=df*(j-1);
end
subplot(3,3,2);
stem(f,ms(1:(N/2)),'.')
grid on;
for j=1:N
   if (j==1);
      psd(j)=1/N*(real(ft(j))^2+imag(ft(j))^2)/Fs;
   else
      psd(j)=2/N*(real(ft(j))^2+imag(ft(j))^2)/Fs;
   end;
end;
subplot(3,3,3);
plot (f,psd(1:(N/2)));
grid on;
m=mean(Y2);
Yo2=Y2-m;
subplot(3,3,4);
plot(Yo2);
grid on
w=hamming(N);
for j=1:N
   sw(j)=Yo2(j)*w(j);
end
subplot(3,3,7)
plot(sw)
hold on
plot(w)
grid on
ft1=fft(Yo2);
for j=1:N;
   if (j==1)
      ms2(j)=sqrt(real(ft1(j))^2+imag(ft1(j))^2)/N;
   else
      ms2(j)=sqrt(real(ft1(j))^2+imag(ft1(j))^2)/N*2;
   end
end
subplot(3,3,5);
stem(f,ms2(1:(N/2)),'.')
for j=1:N
   if (j==1);
      psd2(j)=1/N*(real(ft1(j))^2+imag(ft1(j))^2)/Fs;
   else
      psd2(j)=2/N*(real(ft1(j))^2+imag(ft1(j))^2)/Fs;
   end;
end;
subplot(3,3,6);
plot(f,psd2(1:(N/2)));
grid on;
```

```
ft2=fft(sw);
for j=1:N;
    if (j==1)
        ms3(j)=sqrt(real(ft2(j))^2+imag(ft2(j))^2)/N;
    else
        ms3(j)=sqrt(real(ft2(j))^2+imag(ft2(j))^2)/N*2;
    end
end
subplot(3,3,8);
stem(f,ms3(1:(N/2)),'.')
grid on
for j=1:N
    if (j==1);
        psd3(j)=1/N*(real(ft2(j))^2+imag(ft2(j))^2)/Fs;
    else
        psd3(j)=2/N*(real(ft2(j))^2+imag(ft2(j))^2)/Fs;
    end;
end;
subplot(3,3,9);
plot (f,psd3(1:(N/2)));
grid on;
```
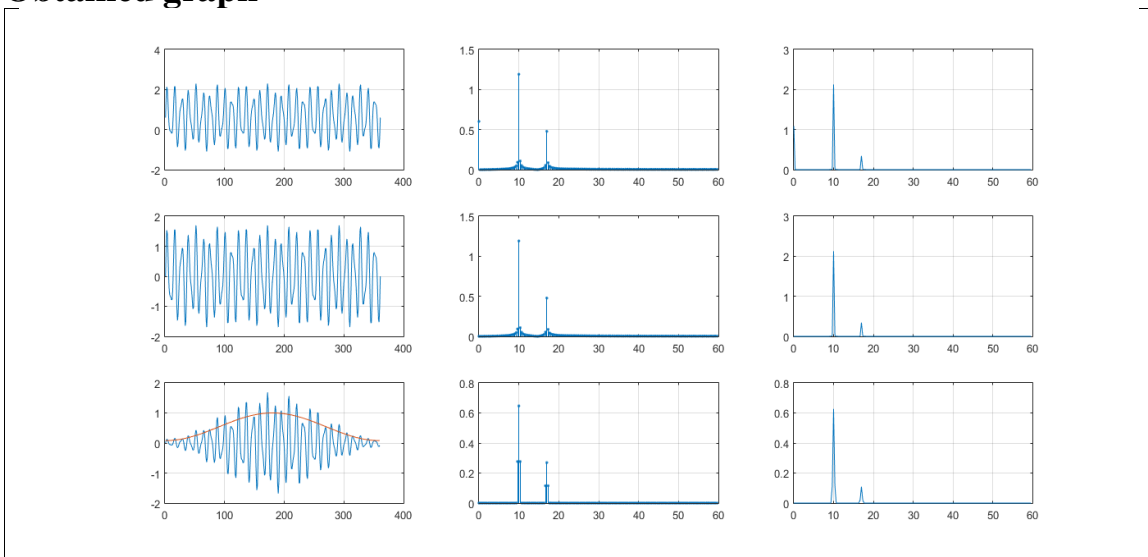
Obtained graph

Figure 1: **Calculation of the test signal spectral estimations**

Part 2: Calculation of spectral estimations for the real ECG fragments

Code

```
ECG=load('W3_02.txt');
Fs=250;
N=length(ECG(:,1));
T=1/Fs;
t=0:T:(N-1)*T;
Norma=ECG(:,1);
VTach=ECG(:,2);
VFibr=ECG(:,3);
subplot(3,3,1)
```

```matlab
plot(t, Norma);
title('Norma');
subplot(3,3,4);
plot(t, VTach);
title('VTach');
subplot(3,3,7);
plot(t, VFibr);
title('VFibr');
m=mean(Norma);
m1=mean(VTach);
m2=mean(VFibr);
Y=Norma-m;
Y1=VTach-m1;
Y2=VFibr-m2;
w=hamming(N);
for j=1:N
    sw(j)=Y(j)*w(j);
    sw1(j)=Y1(j)*w(j);
    sw2(j)=Y2(j)*w(j);
end
subplot(3,3,1)
plot(t, Norma);
title('Norma');
hold on
plot(t,sw,'r');
subplot(3,3,4);
plot(t, VTach);
hold on
plot(t,sw1,'r');
title('VTach');
subplot(3,3,7);
plot(t, VFibr);
title('VFibr');
hold on
plot(t,sw2,'r');
ft=fft(sw);
ft1=fft(sw1);
ft2=fft(sw2);
for j=1:N;
    if (j==1)
        ms(j)=sqrt(real(ft(j))^2+imag(ft(j))^2)/N;
        ms1(j)=sqrt(real(ft1(j))^2+imag(ft1(j))^2)/N;
        ms2(j)=sqrt(real(ft2(j))^2+imag(ft2(j))^2)/N;
    else
        ms(j)=sqrt(real(ft(j))^2+imag(ft(j))^2)/N*2;
        ms1(j)=sqrt(real(ft1(j))^2+imag(ft1(j))^2)/N*2;
        ms2(j)=sqrt(real(ft2(j))^2+imag(ft2(j))^2)/N*2;
    end
end
df=Fs/N;
for j=1:(N/2)
    f(j)=df*(j-1);
end
subplot(3,3,2);
stem(f,ms(1:(N/2)),'.')
title('Norma Mag.');
grid on;
```

```
subplot(3,3,5);
stem(f,ms1(1:(N/2)),'.')
title('VTach Mag.');
grid on;
subplot(3,3,8);
stem(f,ms2(1:(N/2)),'.')
grid on;
title('VFibr Mag.');
for j=1:N
    if (j==1);
        psd(j)=1/N*(real(ft(j))^2+imag(ft(j))^2)/Fs;
        psd1(j)=1/N*(real(ft1(j))^2+imag(ft1(j))^2)/Fs;
        psd2(j)=1/N*(real(ft2(j))^2+imag(ft2(j))^2)/Fs;
    else
            psd(j)=2/N*(real(ft(j))^2+imag(ft(j))^2)/Fs;
            psd1(j)=2/N*(real(ft1(j))^2+imag(ft1(j))^2)/Fs;
            psd2(j)=2/N*(real(ft2(j))^2+imag(ft2(j))^2)/Fs;
    end;
end;
subplot(3,3,3);
plot (f,psd(1:(N/2)));
grid on;
subplot(3,3,6);
plot (f,psd1(1:(N/2)));
grid on;
subplot(3,3,9);
plot (f,psd2(1:(N/2)));
grid on;
```
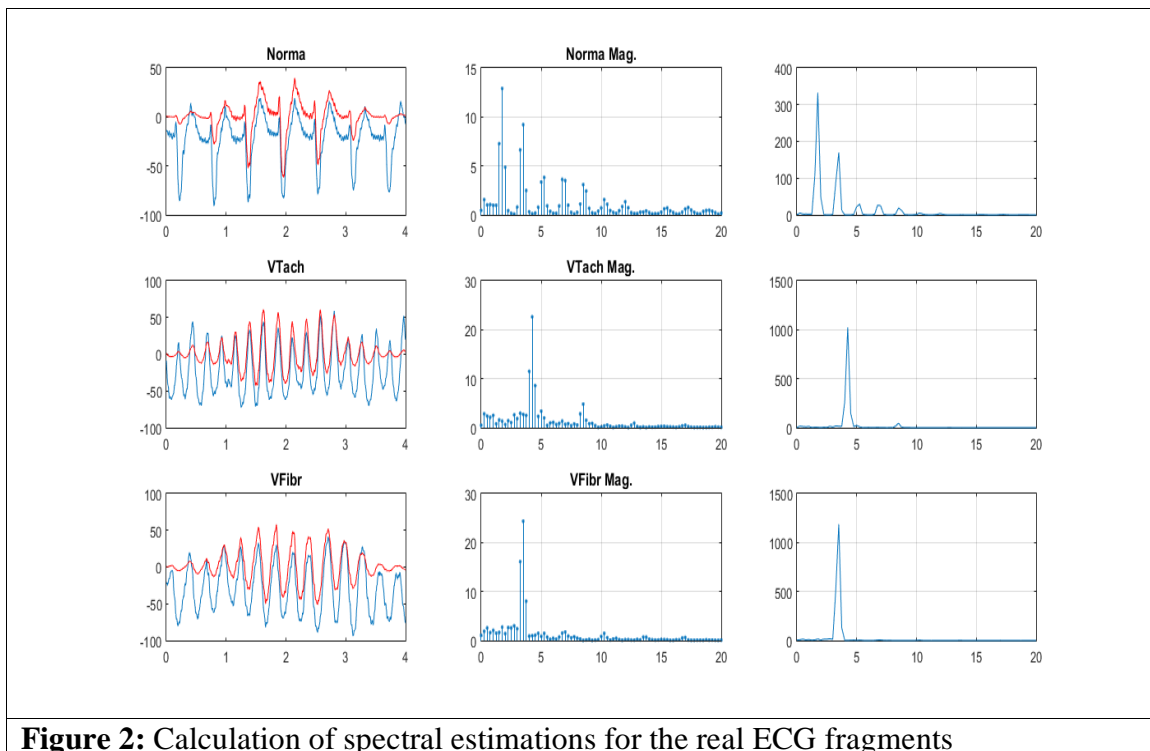
Obtained graph

Figure 2: Calculation of spectral estimations for the real ECG fragments

Conclusions

- Fourier transform states that any periodic signal can be plotted by using a set of pure sine waves. A square wave can be constructed by using a series of sine waves. The frequency of the sine waves is multiplied by the original frequency of the square wave. In order to achieve good results, the phase and the amplitude of the sine waves must be carefully be chosen. Increasing the number of the sine waves will produce better results, and the resultant wave will be more like a square wave.

- Windowing is a technique used to force non periodic signals to be periodic an to reduce leakage. The FFT calculation is restricted to the periodic signals. Most signals in time domain are not periodic. The windowing is used to make those non periodic signal periodic in order to calculate the fast Fourier transform (FFT). FFT of non-periodic signals will suffer from leakage. This leakage will result inaccurate calculations. In a time block, the windowing must be zero at the beginning and the end of the function and in between it will have a special shape depending on the function used. This function will be multiplied by the real time block. This process will force non periodic signal to be periodic. There are many types of windowing function, such as Boxcar, Henning, Hamming, force, etc.

- Although, the windowing technique reduce the leakage in the calculation of the signal magnitude, but it will reduce the magnitude of the peaks. This behavior will affect the accuracy of the calculation of the properties of the signals. This disadvantage are shown clearly in figure 1 & 2. Therefore the type of widowing function should be chosen carefully to match the required application (resonance frequency extraction, damping factor, displacement, etc.).