Parametric Spectral Estimation (Practice)

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In this assignment we make spectral estimation by using method with autoregressive model. We will compare the performance of nonparametric method that is periodogram, and parametric method with AR modeling for each problem.

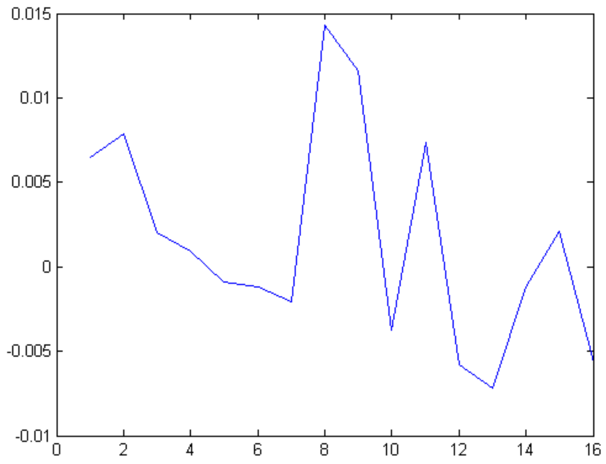
Problem 1:

The given signal is

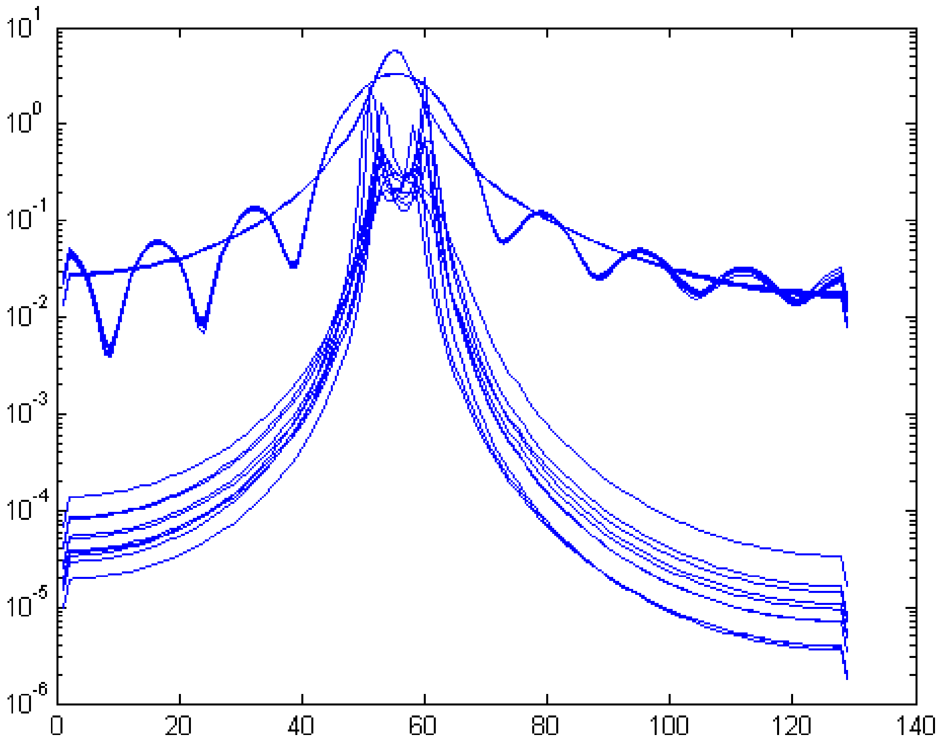
$$\mathbf{x(n) = cos(0.4\pi n) + cos(0.45\pi n) + z(n), n = 0, . . . , 15}$$

There are several parameters for this problem which are required to clarify. First, zero-mean Gaussian white noise with variance of 0.0001. Secondly, the data length is 16. In addition, we need plot ten examples for solving the problem by comparing the different functions.

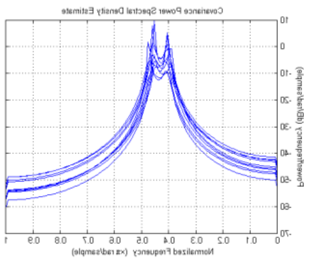
Figure 1 shows the result of white noise,

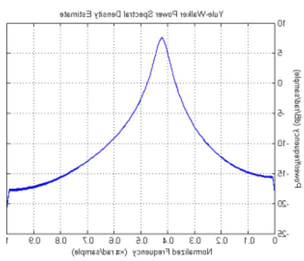


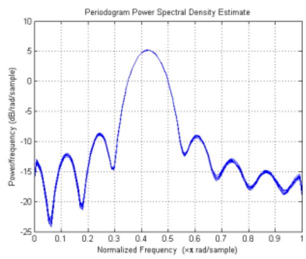
and figure 2 shows the gathering PSD estimation result of periodogram, AR modeling with autocorrelation method and covariance method in the same diagram.



For analyze the three methods clearly, I also plot them respectly which are periodogram method, autocorrelation method and covariance method.







From the variability of the PSD estimation above, we can observe that the main lobe of blue curve which corresponding to periodogram is wider and smoother than other curvse which represent AR modeling results. In another word, It is indicated that AR modeling has much thinner main lobe that indicate AR modeling has higher frequency resolution than periodogram.

In addition, by comparing the first and second waveforms above, we can easily identify two spikes on the main lobe that corresponding to phase 0.4pi and 0.45pi of the signal x(n) in the first diagram which is the result of covariance method, therefore the result verify that covariance method can identify the composition of x(n).

However, In the second waveform we cannot find the difference between cos(0.45pi*n) and cos(0.4pi*n).

In summary, AR modeling main lobe is smaller than periodgram method which contribute high frequency resolution, practically, covariance method can show spikes that represent the components of the signal.

Matlab code 1

```
clear all;
clc;
N=16;
%AR mode order estimation
n=[0:N-1];
%generate noise sequence
z=(sqrt(0.0001))*randn(1,N);
figure(1)
plot(z)
figure(2)
hold off
for K = 1:10
  z=(sqrt(0.0001))*randn(1,N);
  x=cos(0.4*pi*n)+cos(0.45*pi*n)+z;

  pxx0=periodogram(x)
  semilogy(pxx0)
        hold on

  pxx1= pyulear(x,4)
  semilogy(pxx1)
        hold on
  pxx2=pcov(x,4)
  semilogy(pxx2)
  hold on
end
```

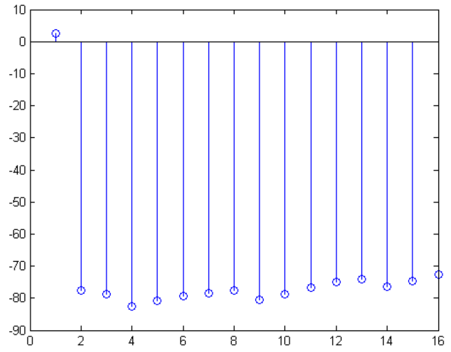
Problem 2:

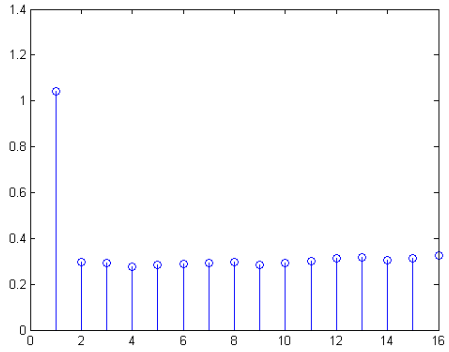
In this case, we use Aikake's information criterion(AIC) and the final prediction error criterion(FPE) to estimate the model order of the signal. The signal is:

$x(n) = \cos(0.4\pi n) + \cos(0.45\pi n) + z(n),\ n = 0, \ldots, 15$

When build the AR model, it is very important to have an appropriate model order to fit in the given signal. We try to find the suitable model orders by using AIC and FPE criterion, the minimum AIC or FPE corresponding to the best model order. According to the problem, we set the length of x(n) as 64 and variance of noise z(n) is bigger than 0.25. Respectively, I use arcov() and aryule() to estimate AR model parameters to find the value of model-order.

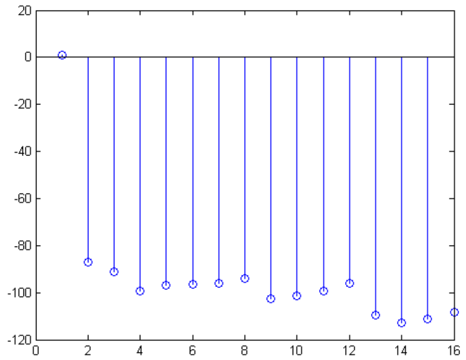
In addition, I set zn = 0.35*randn(1,N) for white noise signal and K=1:16.

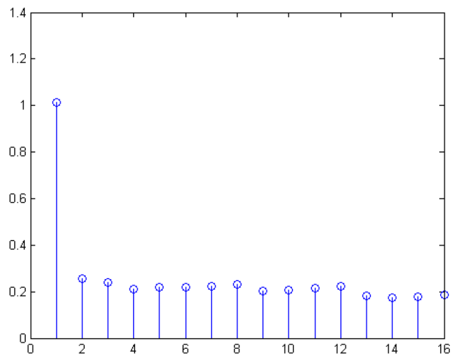




AIC FPE

For the diagrams above, I use stem() function to form these diagrams. According to the two diagrams, I find that the value of order is 4 in Yule-Walker method.





AIC FPE

As covariance method, I find that the suitable order is 14.

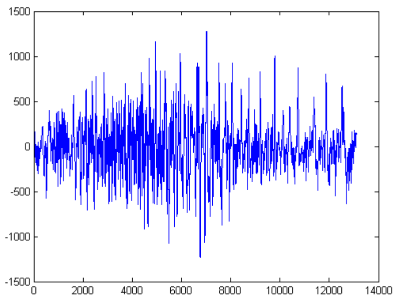
Matlab code 2

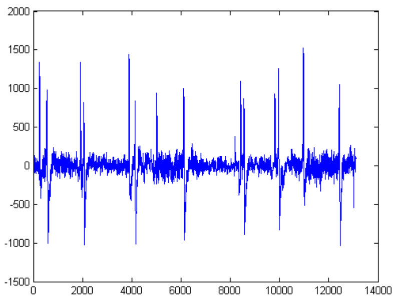
```
clear all;
clc
N = 64;
n=[0:N-1];
```

```
zn = 0.35*randn(1,N);
x = cos(0.4*pi*n) + cos(0.45*pi*n) + zn;
for k=1:16
        [A sigmaw2]=aryule(x,k);

      AIC1(k) = N*log(sigmaw2) + 2*k;
      FPE1(k) = ((N+k)/(N-k))*sigmaw2

end
figure(1)
stem(AIC1)
figure(2)
stem(FPE1)

for k = 1:16
[B sigmaw3]=arcov(x,k)
AIC2(k) = N*log(sigmaw3) + 2*k;
FPE2(k) = ((N+k)/(N-k))*sigmaw3
end
figure(3)
stem(AIC2)
figure(4)
stem(FPE2)
```

Problem 3:

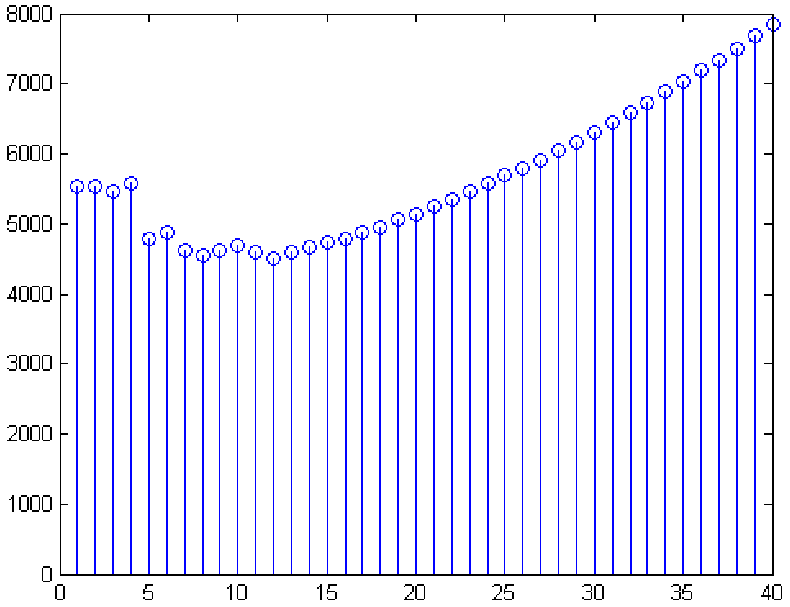
To solve this problem, I load a seizure signal data and a non-seizure date to find the different properties of these two signals so that we can recognize seizure signal. I use chb01_03edfm.mat seizure data and chb01_05_edfm.mat non-seizure data.



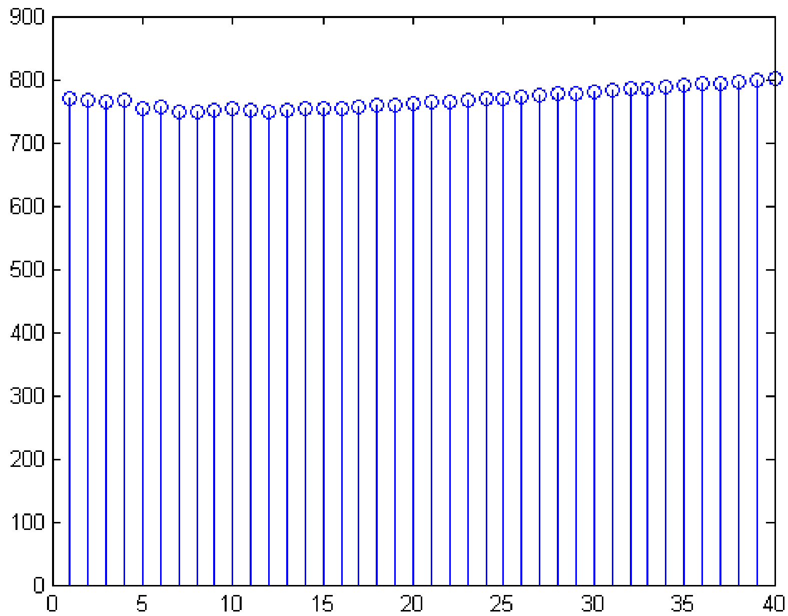


The waveform above shows the seizure and non-seizure signal that I extract from the original signals.

First of all, we need determine the proper model order by AIC criterion and FPE criterion. The proper order for seizure signal is 19 and proper order for non-seizure signal is 12. Also, according to the AIC criterion stem diagram, we find that the peak value of seizure signal is higher than non-seizure signal, which means that seizure signal is with higher energy of white noise. However, I have no idea to make computation to calculate the value of white noise.



Order-estimation for non-seizure signal(FPE)



Order-estimation for seizure signal(AIC)

After determine the model order for two signals, we use arcov() function to calculate the AR model parameters and variances of these two segment signals.

Parameters of seizure signal is:

Columns 1 through 10

1.0000 -1.0378 0.1529 -0.1332 0.5098 -0.3982 -0.4120 0.0648 0.4069 -0.1299

Columns 11 through 19

-0.2378 -0.0045 0.3044 0.0290 -0.1543 -0.0174 0.1106 0.0640 -0.0784

Parameters of non-seizure signal is:

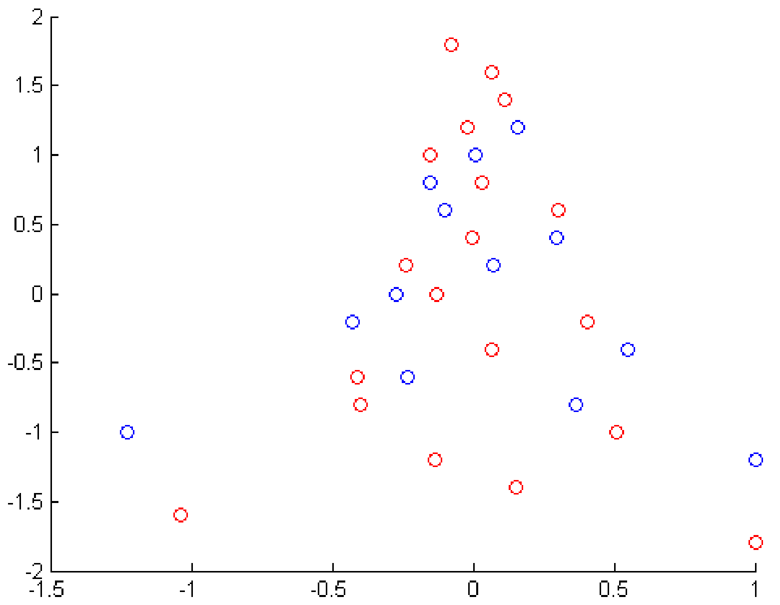
Columns 1 through 10

1.0000 -1.2247 0.3639 -0.2349 0.5511 -0.4294 -0.2748 0.0690 0.2965 -0.1006

Columns 11 through 13

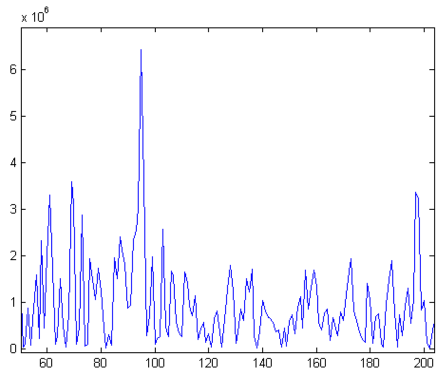
-0.1496 0.0075 0.1600

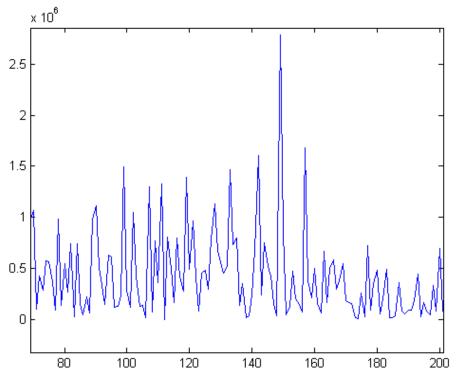
Finally, we use scatter() function to see the distribution of both signals.



The red points represent seizure signal and the blue ones represent non-seizure signal. According to the diagram above, the difference of two parameter groups is not obvious for observing and they are not separating into two clusters for this pares ictal and pre-ictal signals either. However, we observed that the ictal signal is more convergent than another one in the diagram.

I also plot periodiogram() for both signals,





I make a form to summary the properties of difference between seizure signal and non-seizure signal.

signals properties	ictal	Pre-ictal
Order-estimation	high	low
Energy of white noise variance	high	low
Distribution of parameters	Scattered	convergent
Separate into two clusters	Not obvious	Not obvious
PSD(periodogram)	high	low

Matlab code

```
clear all;
clc;
%%%seizure signal
load ('chb01_03_01edfm.mat')
%%%non-seizure signal
load('val222')
x=val;
y=val22;
figure(1)
```

```
plot(x)
%seizure signal
z1=x(1,767800:780900)
figure(2)
plot(z1)
N=100;
for k = 1:40
    [A sigmaw2] = arcov(z1,k);
    aic1(k) = N*log(sigmaw2) + 2*k;
    fpe1(k) = ((N+k)/(N-k))*sigmaw2
end
figure(3)
stem(aic1)
figure(4)
stem(fpe1)
% model order=18 for seizure signal
% model order=16 for non-seizure signal
z2=y(767800:780900)
figure(6)
plot(z2)
%nonseizure signal
for k = 1:40
    [B sigmaw4] = arcov(z2,k);
    aic2(k) = N*log(sigmaw4) + 2*k;
    fpe2(k) = ((N+k)/(N-k))*sigmaw4
end
figure(7)
stem(aic2)
figure(8)
stem(fpe2)
[A sigmaw2] = arcov(z1,18);
[B sigmaw4] = arcov(z2,12);
a = -1.8:0.2:1.8
b = -1.2:0.2:1.2
figure(9)
scatter(A,a,'r')
hold on
scatter(B,b,'b')
figure(10)
pxx1=periodogram(z1)
plot(pxx1)
figure(11)
pxx2=periodogram(z2)
plot(pxx2)
```