Advanced Digital Signal Processing (ADSP) Lab - Python Lab Manual

> **Course Code:** EEE G613
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Experiment No. - 6

Power Spectrum Estimation

Consider N=64 samples for an AR(4) process x(n) that is generated by filtering a unit variance Gaussian Noise v(n) with the filter transfer function given below

$$H(z) = \frac{b(0)}{1+\sum_{k=1}^{4} a(k)z^{-k}}$$

where b(0) = 1, a(1)= 0.7348, a(2) =1.8820, a(3) = 0.7057, a(4) = 0.8851

1 a) Obtain the autocorrelation for the signal x(n) which is the estimate

$$\hat{r}_x(k) = \frac{1}{N}\sum_{n=0}^{N-1} x(n)x(n-k)$$

b) Generate the power spectrum for the above signal. Power spectrum equation given below

$$\hat{P}_x(e^{jw}) = \sum_{-N}^{N} \hat{r}_x(k)e^{-jkw}$$

2) a) Using the estimated autocorrelation of x(n) by adapting Yule-Walker equations, obtain the filter coefficients b(0), a(1), a(2), a(3) and a(4)

b) Calculate the power spectrum using the expression given below which is based on the filter coefficients

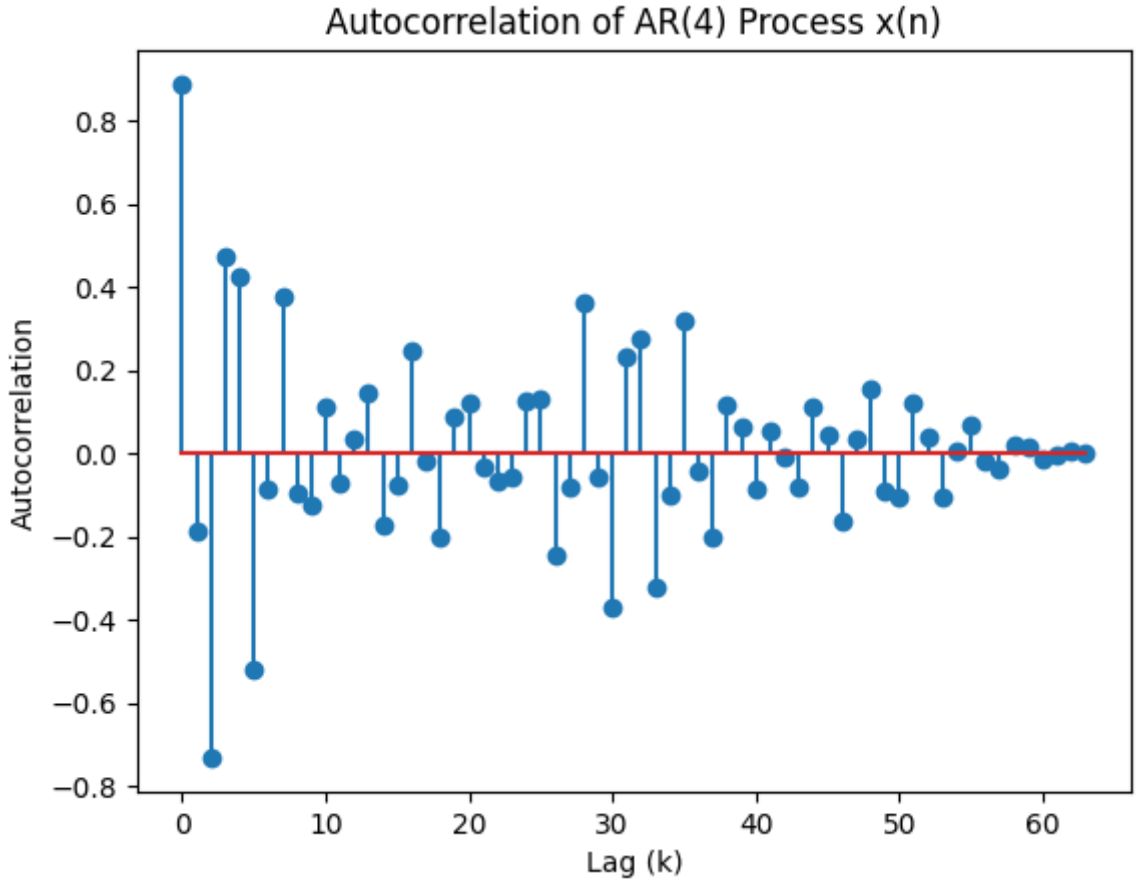
$$\hat{P}_x(e^{jw}) = \frac{|b(0)|^2}{\left|1+\sum_{k=1}^{p} a(k)e^{-jkw}\right|^2}$$

Compare the power spectrum obtained in 1 b) with 2 b)

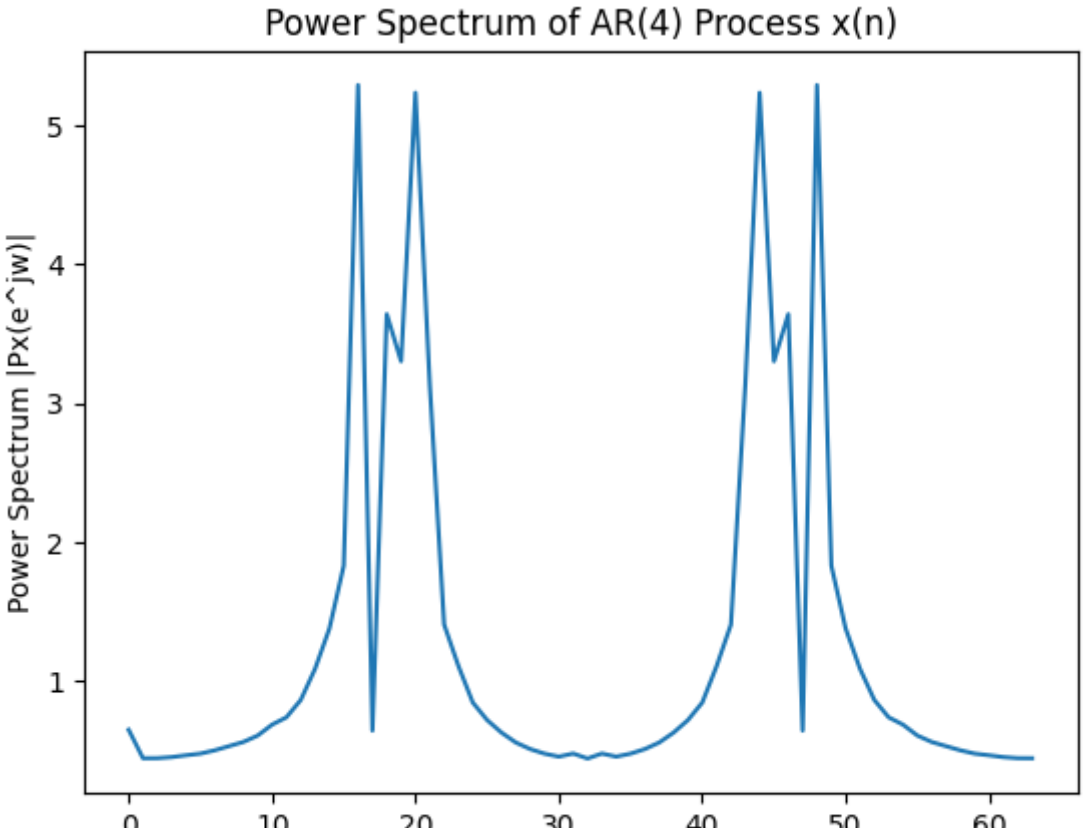
Python Code-

```
#import libraries
import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter
```

```
#part-1(a)
#obtain the autocorrelation for the signal x(n)
np.random.seed(0) # Set a random seed for reproducibility
a = [1, 0.7348, 1.8820, 0.7057, 0.8851]
b = [1]
N = 64
v = np.random.rand(N)
x = lfilter(b, a, v) # Filter the random signal
acv = np.correlate(x, x, mode="full") # Calculate the autocorrelation
acv = acv[N - 1:]
acv = acv/100
plt.stem(acv)
plt.xlabel('Lag (k)')
plt.ylabel('Autocorrelation')
plt.title('Autocorrelation of AR(4) Process x(n)')
plt.show()
```




```
#part-1(b)
#generate the power spectrum for the above signal
psd = np.fft.fft(acv)
plt.figure()
plt.plot(np.abs(psd))
plt.xlabel('Frequency (w)')
plt.ylabel('Power Spectrum |Px(e^jw)|')
plt.title('Power Spectrum of AR(4) Process x(n)')
plt.show()
```


Power Spectrum of AR(4) Process x(n)
Power Spectrum |Px(e^jw)|
5
4
3
2
1
0
10
20
30
40
50
60

```
#part-2
import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import freqz
np.random.seed(0) # Set a random seed for reproducibility
a = [1, 0.7348, 1.8820, 0.7057, 0.8851]
b = [1]
N = 64
v = np.random.rand(N)
x = lfilter(b, a, v) # Filter the random signal
acv = np.correlate(x, x, mode='full') # Calculate the autocorrelation
acv = acv[N - 1:]
```