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

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Experiment No. - 9

<u>Weiner Noise Cancellation Filter</u>

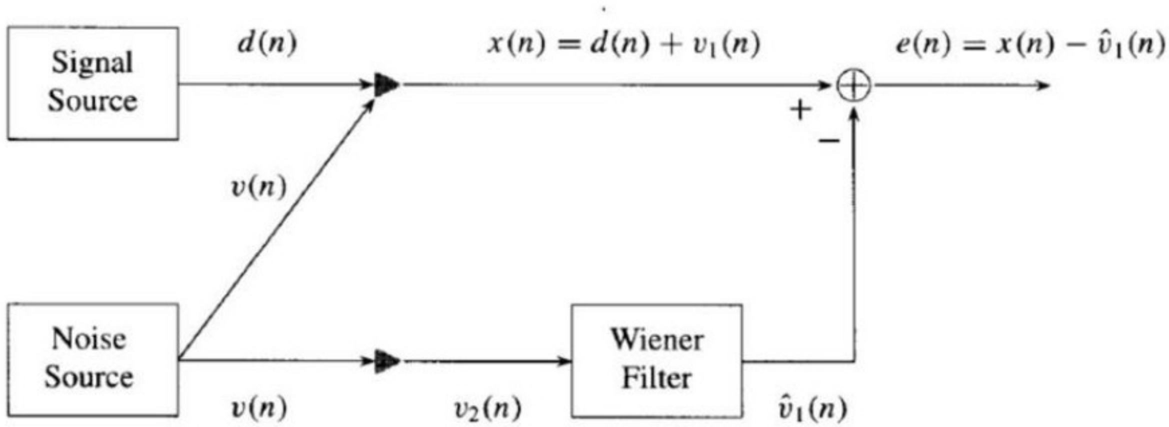


Fig.1 : Wiener noise cancellation using a secondary sensor to measure the additive noise v1(n).

Suppose that the desired signal d(n) in Fig.1 is a sinusoid $d(n) = \sin(n\omega 0+\phi)$

with $\omega 0=0.05\pi$, and that the noise sequences $\upsilon 1(n)$ and $\upsilon 2(n)$ are AR(1) processes that are generated by the first-order difference equations

$\upsilon 1(n)= 0.8\, \upsilon 1(n-1) + g(n)$
$\upsilon 2(n)= -0.6\, \upsilon 2(n-1) + g(n)$

Note: You can assume $\varphi= 0$ or some other value also.

Where g(n) is Gaussian white noise. Plot $x(n)$, $v_1(n)$, $v_2(n)$ for n = 0, 1…199. Observe the signals.

Write a matlab program to estimate $\widehat{v_1(n)}$ using Weiner Filter for two different filter orders a) p=6 and b) p =12.

Obtain the estimate of d(n) as $\widehat{d(n)} = x(n) - \widehat{v_1(n)}$ for the two cases of Wiener Filter p=6 and p=12.

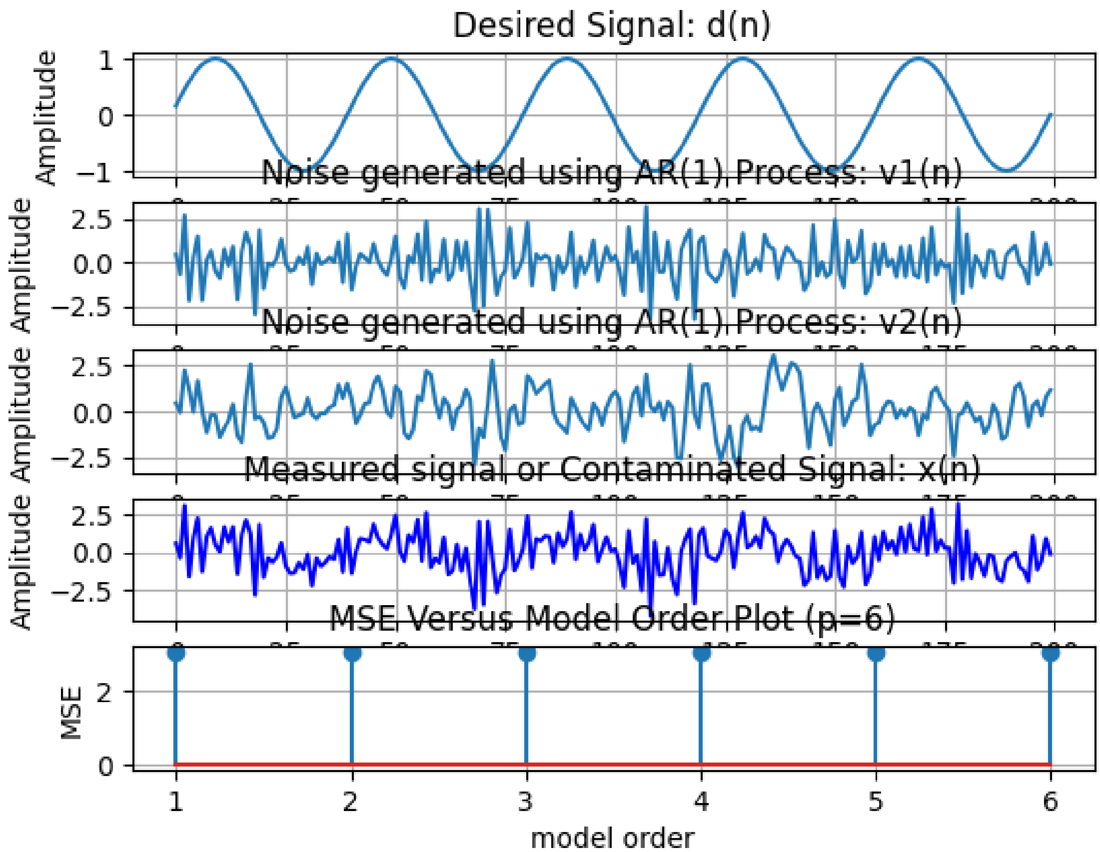
Plot the $\widehat{d(n)}$ for the two cases of Wiener Filter p=6 and p=12.

Hint: Refer **<u>7.2.6 Noise cancellation (pg.no 350)</u>** from monsoon H. Hayes

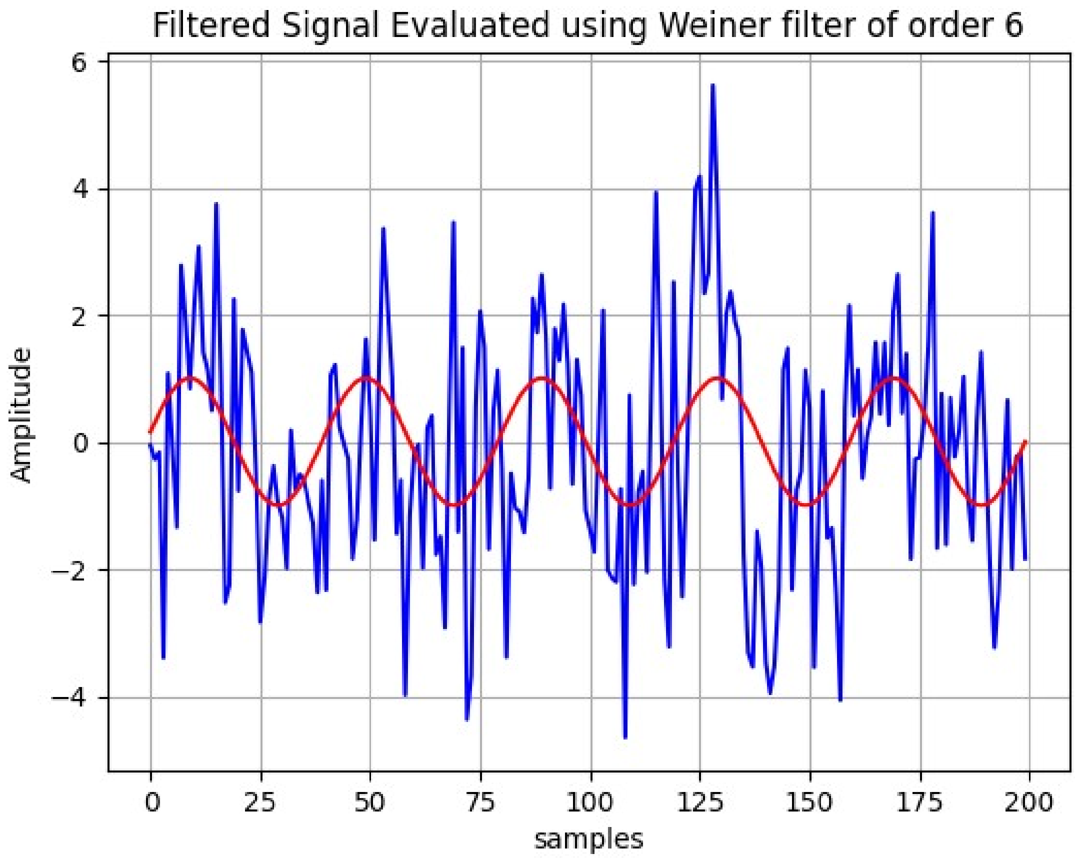
Python Code-

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

# Function to calculate the covariance matrix
def covar(x, p):
  x = x - np.mean(x)
  m = len(x)
  R = np.dot(convm(x, p).T, convm(x, p)) / (m - 1)
  return R

# Function to create convolution matrix
def convm(x, p):
  return np.convolve(x, x[::-1], mode='valid')[:, None]

# Part a
np.random.seed(5)
l = 200
w = 0.05 * np.pi
d = np.sin(w * np.arange(1, l + 1))
g = np.random.randn(l)
v1 = np.convolve(g, [1, -0.8], mode='full')[:l]
v2 = np.convolve(g, [1, 0.6], mode='full')[:l]
x = d + v1
N=l
P=6
MSE = []
for p in range(1, P + 1):
  rv = covar(v2, p)
  rxv2 = np.dot(convm(x, p).T, convm(v2, p)) / (N - 1)
  w = rxv2[0, :] / rv
  w = w.flatten() # Flatten the 'w' array
  v1hat = signal.convolve(w, v2, mode='full')[:l]
  filtered_signal = x - v1hat
  MSE.append(np.mean((d - filtered_signal) ** 2))

#Plotting
plt.figure(1)
plt.subplot(5, 1, 1)
plt.plot(d)
plt.xlabel('Samples')
plt.ylabel('Amplitude')
plt.title('Desired Signal: d(n)')
plt.grid(True)
plt.subplot(5, 1, 2)
plt.plot(v1)
plt.xlabel('Samples')
```

```python
plt.ylabel('Amplitude')
plt.title('Noise generated using AR(1) Process: v1(n)')
plt.grid(True)
plt.subplot(5, 1, 3)
plt.plot(v2)
plt.xlabel('Samples')
plt.ylabel('Amplitude')
plt.title('Noise generated using AR(1) Process: v2(n)')
plt.grid(True)
plt.subplot(5, 1, 4)
plt.plot(x, 'b')
plt.xlabel('samples')
plt.ylabel('Amplitude')
plt.title('Measured signal or Contaminated Signal: x(n)')
plt.grid(True)
kk = np.arange(1, P + 1)
plt.subplot(5, 1, 5)
plt.stem(kk, MSE)
plt.xlabel('model order')
plt.ylabel('MSE')
plt.title('MSE Versus Model Order Plot (p=6)')
plt.grid(True)
plt.figure(2)
plt.plot(filtered_signal, 'b')
plt.plot(d, 'r')
# Write a python program to estimate vˆ1 (n) using Weiner Filter for
two different filter orders a) p=6
plt.xlabel('samples')
plt.ylabel('Amplitude')
plt.title('Filtered Signal Evaluated using Weiner filter of order 6')
plt.grid(True)
plt.show()
```



Desired Signal: d(n)
Amplitude
Noise generated using AR(1) Process: v1(n)
Amplitude
Noise generated using AR(1) Process: v2(n)
Amplitude
Measured signal or Contaminated Signal: x(n)
Amplitude
MSE Versus Model Order Plot (p=6)
MSE
model order



(b) Try it yourself.

Consider the desired signal as a multicomponent sinusoid d(n)=sin(nω0+φ) + sin(nω1+φ), where ω1=0.10π, and φ=0.

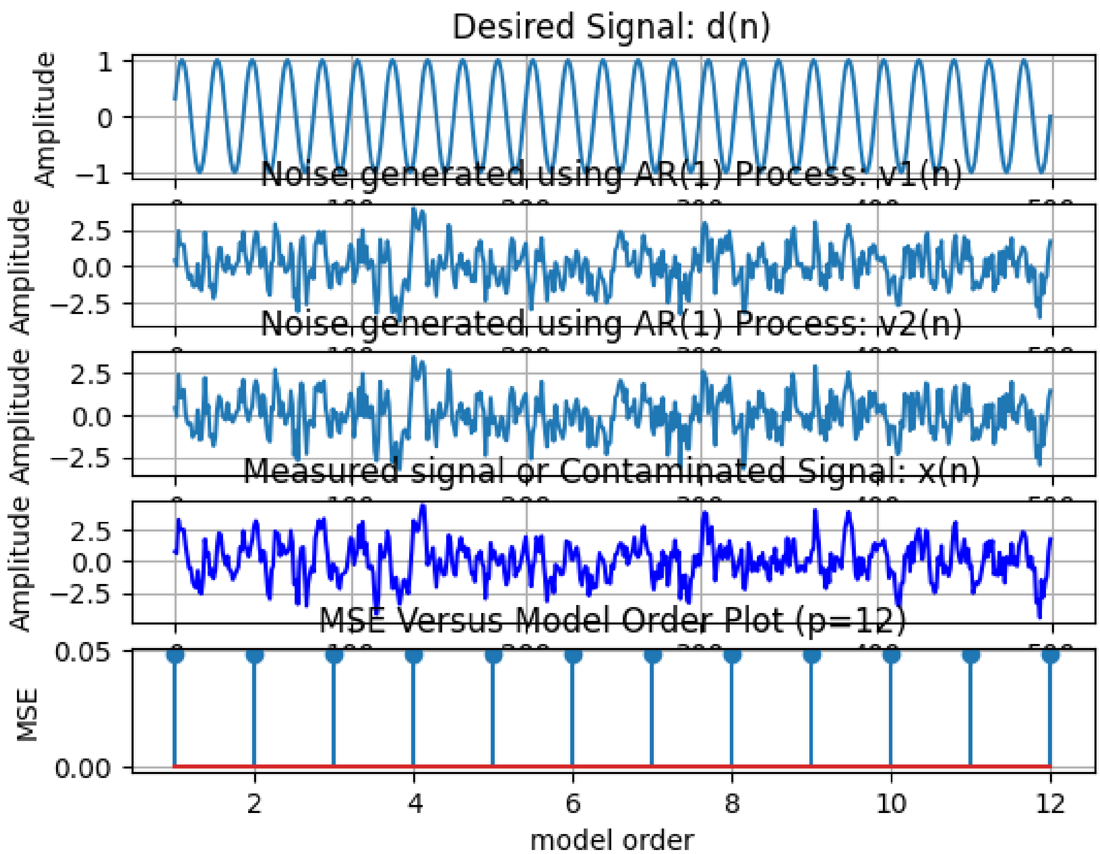
$$v_1(n) = -0.8v_1(n-1) - 0.65v_1(n-2) + g(n)$$
$$v_2(n) = -0.6v_2(n-1) - 0.45v_2(n-2) + g(n)$$

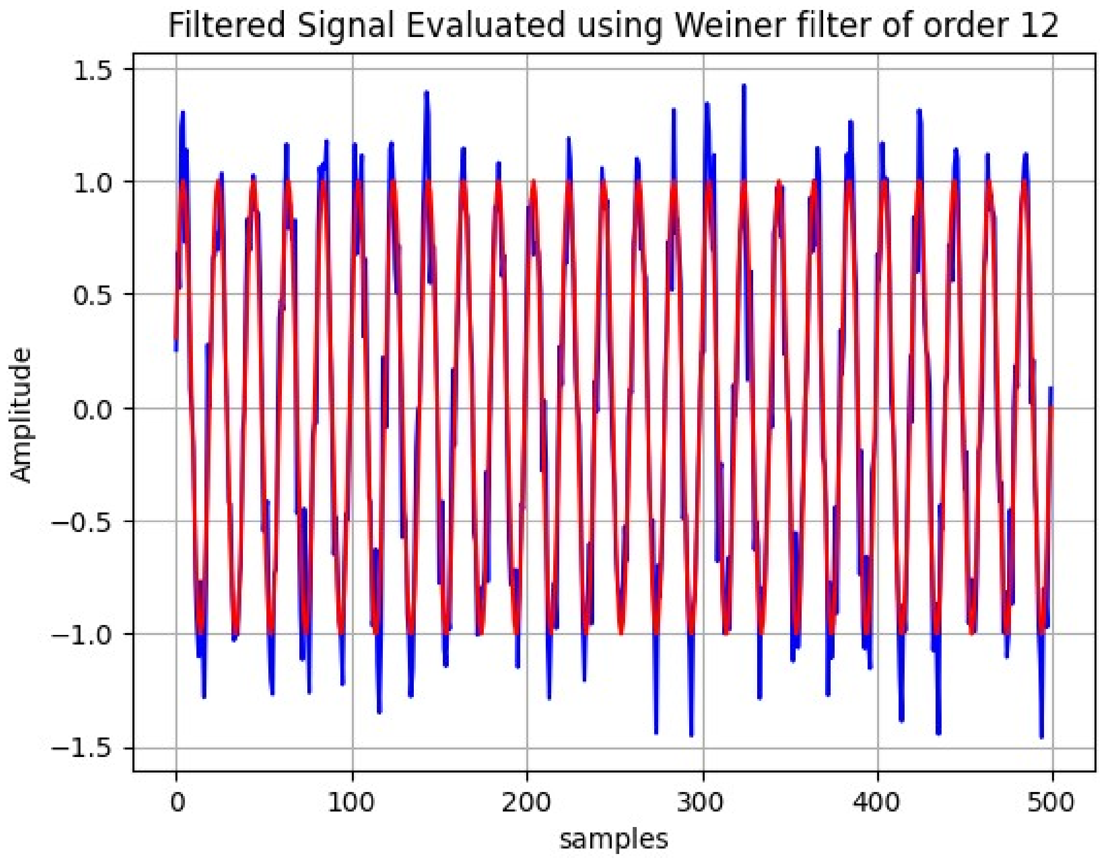
Consider the length of the signal as 500.

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

# Function to calculate the covariance matrix
def covar(x, p):
  x = x - np.mean(x)
  m = len(x)
  R = np.dot(convm(x, p).T, convm(x, p)) / (m - 1)
  return R
```

```python
# Function to create convolution matrix
def convm(x, p):
  return np.convolve(x, p, mode='valid')[:, None]

np.random.seed(5)
l = 500
w = 0.10 * np.pi
d = np.sin(w * np.arange(1, l + 1))
g = np.random.randn(l)
v1 = np.convolve(g, [1, 0.8, 0.65], mode='full')[:l]
v2 = np.convolve(g, [1, 0.6, 0.45], mode='full')[:l]
x = d + v1
N=l
P=12 #Order of filter
MSE = []
for p in range(1, P + 1):
  rv = covar(v2, p)
  rxv2 = np.dot(convm(x, p).T, convm(v2, p)) / (N - 1)
  w = rxv2[0, :] / rv
  w = w.flatten() # Flatten the 'w' array
  v1hat = signal.convolve(w, v2, mode='full')[:l]
  # v1hat = signal.lfilter(w, [1], v2)
  filtered_signal = x - v1hat
  MSE.append(np.mean((d - filtered_signal) ** 2))

#plotting
plt.figure(1)
plt.subplot(5, 1, 1)
plt.plot(d)
plt.xlabel('Samples')
plt.ylabel('Amplitude')
plt.title('Desired Signal: d(n)')
plt.grid(True)
plt.subplot(5, 1, 2)
plt.plot(v1)
plt.xlabel('Samples')
plt.ylabel('Amplitude')
plt.title('Noise generated using AR(1) Process: v1(n)')
plt.grid(True)
plt.subplot(5, 1, 3)
plt.plot(v2)
plt.xlabel('Samples')
plt.ylabel('Amplitude')
plt.title('Noise generated using AR(1) Process: v2(n)')
plt.grid(True)
plt.subplot(5, 1, 4)
plt.plot(x, 'b')
plt.xlabel('samples')
plt.ylabel('Amplitude')
plt.title('Measured signal or Contaminated Signal: x(n)')
```

```
plt.grid(True)
kk = np.arange(1, P + 1)
plt.subplot(5, 1, 5)
plt.stem(kk, MSE)
plt.xlabel('model order')
plt.ylabel('MSE')
plt.title('MSE Versus Model Order Plot (p=12)')
plt.grid(True)
plt.figure(2)
plt.plot(filtered_signal, 'b')
plt.plot(d, 'r')
plt.xlabel('samples')
plt.ylabel('Amplitude')
plt.title('Filtered Signal Evaluated using Weiner filter of order 12')
plt.grid(True)
plt.show()
```





Filtered Signal Evaluated using Weiner filter of order 12
Amplitude
samples
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
100
200
300
400
500