19CCE204

Signal Processing

Group 6

Noise Reduction using Matched filters for Radars

1.Members of the group:

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2. Objective:

The main objective of this project is to use Matched filter to reduce the noise which is obtained from a Received Signal using the reference of the initial generated or transmitted signal to find if its noise or a real object to be detected.

3. System description with application:

- **System Description:** This is a Matched filter that correlates to remove Noise from a Signal. This is described and implemented using python with the support of the following libraries and methods:

Python Libraries involved:

1. Matplotlib - used for plotting signals.
2. Numpy – used for performing complex mathematical operations.
3. Scipy – used to perform functionalities of Digital Signal Processing.

Methods involved:

1. Correlation: Comparing two signals to remove Noise from a signal
2. Matched filters: This is a filtering technique used in Digital Signal Processing that uses correlation for filtering the signal

Program code:

```
import matplotlib.pyplot as plt

import numpy as np

import scipy.signal as sp



#Matplotlib is a library that enables functionalities that

#         helps us to visualize the signals


#Numpy is a library that deals with complex mathematical calculations

#      and constants that are required in forming and manipulating signals.


#Scipy is a Scientific library that enables funnctionalites that are required

#      for analyzing the signal and other Digital Signal processing methods.


n=int(input("Enter the no of elements in the signal: "))

sig=[int(input("Enter element {}: ".format(i))) for i in range(n)]


# the signal is extended with some zeros on each side for a better interpretation.

extendedInput=np.hstack([np.zeros(5),sig,np.zeros(5)])


#plotting the extended input signal on the graph.

plt.plot(extendedInput,label="Input Signal")


# Random White Noise is being added to the signal to test the filtering.
```

```
signoise = np.random.uniform(0,2,10+len(sig))*(min(sig)+max(sig))/2+extendedInput

#The  Signal with added Noise(The recieved signal) is being plotted.
plt.plot(signoise,label="Signal with Noise(Recieved Signal)")
plt.xlabel('Time')
plt.ylabel('Amplitude')
plt.title('Transmitted and Recieved Signals')
plt.axhline(0, color='black')
plt.legend()
plt.ylim(min(sig)-3,max(sig)+3)
plt.grid()
plt.show()



h = sig[::-1] # This is the inverse signal of the original signal

#lfilter is a filtering techinque similar to matched filters where the signal
#     with noise is beign correlated with the inverse of the inital signal.
signoisemf = sp.lfilter(h,1,signoise)[::-1]/10

# Signal with Noise(Recieved Signal) is plotted for reference.
plt.plot(extendedInput,label="Initial Signal without noise")
plt.xlabel('Time')
plt.ylabel('Amplitude')
plt.title("Extended Input Signal")
plt.plot(signoisemf,label="Signal after Filtering")
plt.xlabel('Time')
plt.ylabel('Amplitude')
```

```
plt.title('Signal in Noise after Matched Filtering')
plt.axhline(0, color='black')
plt.legend()
plt.grid()
plt.show()
```

- **Radar applications:**

There are multiple applications based on Radar which are commonly used in real life some of them are mentioned below:

1. Air Traffic Control (ATC): RADARs are used for the safety control of air traffic. It is used around airports to guide aircraft for proper landing in adverse weather conditions. Generally, high resolution RADAR is used for this purpose. RADARs are used in conjunction with the ground control approach (GCA) system for the safe landing of aircraft.

2. Aircraft Navigation: Air avoidance RADARs and ground mapping RADARs are used to accurately navigate aircraft in all conditions. The radio altimeter and Doppler navigator are also a form of RADAR. These RADARs provide aircraft security from possible collisions with other aircraft and objects.

3. Ship Navigation and Security: High-resolution Shore-based RADARs are used as a lighthouse and navigation aid. RADAR ensures safe travel by warning of potential threats in poor visibility due to harsh weather conditions. They are also used to find the depth of the sea.

4. Space: RADARs are used for the docking and safe landing of spacecraft. Satellite sourced RADARs are also used for remote sensing. Ground-based RADARs are used to track and detect satellites and spacecraft.

5. Military field: RADARs have a wide range of applications in military operations. They are used for defense in air, sea, and land. They are also used for tracking, surveillance, and detection of the target. Weapon control, Fire control and missile guidance are often used with various types of RADAR. Long range RADAR is very useful for many purposes. It is often used to track space objects. It is also used in ballistic missiles. Figure 5, broadcast, detection, etc. It shows a multi-Purpose RADAR system antenna that can serve various purposes such as

Figure 5: Multipurpose RADAR Antenna

6. Other Applications: Ground penetrating RADARs are commonly used by geologists to study the earth's position for earthquake detection. Scientists use RADAR to better study the movements of animals, birds, and insects. Archaeologists use it to detect buried artifacts. Many industries and factories use it for security purposes. During World War II, the Signal Corps Radio-270 or Pearl Harbor RADAR was used as the US military's long-range RADAR. It plays a vital role in detecting incoming raids half an hour before the start of the attack and is most useful RADAR waves open wide avenue for rescuers to search for people in need during the earthquake and detect the heartbeats of those stranded in buildings destroyed and damaged after the recent Nepal Earthquake with locator search options. Shape. 625 shows the use of RADAR by the rescue team during the Nepal Earthquake of April 2015.

4. Methodology

Matched filters:

Connection with a known delayed signal or a fundamental signal is used for an evaluation to obtain the pattern in the unknown signal. This is equivalent to introductory wrapping with a conjugated time-inverted version of contact. Matched filter, additional routing-noise (SNR) optimal evaluation for the top target.

Matched filters are commonly used in radar, where a known signal is sent and the reflected signal is examined for common elements of the outgoing signal. Pulse compression is an example of matched filtering. It is named because the pulse response matches the input pulse signals. Two-dimensional matched filters are commonly used in image processing, e.g., to improve the SNR of X-ray observations. Matched filtering is a demodulation technique with LTI (linear time invariant) filters to maximize SNR. It was originally also known as a North filter.

Example:

Assume: $x(n)$ is the original signal, $y(n)$ is the distorted signal.

$y(n)=x(n)+v(n)$, where $v(n)$ is assumed to be independent white noise.

Matched filter: $h(n)$: $y(n)*h(n)$ --> $x(n)*h(n)$ (no signal fidelity, just high SNR for detection, in communication applications, where you would like to detect a 0 or 1, or any given known signal, usually a deterministic signal; object recognition in images, face recognition)

$$y(n) * h_M(n) \rightarrow x(n+n_d) * h_M(n)$$

with some signal delay nd (no signal fidelity, just high SNR for detection), where y(n) = x(n+nd)+v(n) is our (delayed) signal with additive noise v(n).

Application examples are in communication where you want to detect 0 or 1, for example in CDMA, where each user receives a unique pseudo-random 1/0 sequence (pseudo-chip sequences) to represent 0 or 1, which different users and signals match filters separated using. Another example is for detecting known signals or patterns in images, such as object or face recognition. In general, we want to detect deterministic signals x(n).

This means our goal is to maximize the SNR at the moment of detection, with our original signal x(n) and noise v(n),

$$SNR = \frac{|\, x(n) * h_M(n) \,|^2}{E(|\, v(n) * h_M(n) \,|^2)}$$

We would like to maximize this SNR at the time of detection, using h(n). To do that, first we assume v(n) to be independent white noise. Then the denominator of the SNR expression is just a scaled fixed power expression. Using our formulation of a matrix V for the noise signal and the row vector **h** for our filter (again, it contains the time reversed impulse response), we obtain

$$E(|\, v(n) * h_M(n) \,|^2) = \sigma_v^2 \cdot \boldsymbol{h}_M \cdot \boldsymbol{h}_M^T$$

(Remember: the autocorrelation function of noise is a weighted delta function, since noise samples are uncorrelated to all their neighboring samples, they are only correlated with themselves, and the correlation with itself is simply the noise power σ^2. The autocorrelation matrix $E(\boldsymbol{V}^T \cdot \boldsymbol{V})$ hence has all zero entries, except on the diagonal, where it is the noise power, hence noise power times the identity matrix $\sigma^2 \cdot$I)

The last expression is simply the squared norm (the sum of the squares of its coefficients) of our vector of our filter coefficients **h** multiplied with the noise power σ_v^2 .

Keeping the above norm of our filter vector $\boldsymbol{h}_M \cdot \boldsymbol{h}_M^T$ constant, we only need to maximize the numerator of our SNR fraction to maximize the SNR,

$$| \, x(n) * h_M(n) \, |^2$$

The filter function implemented in the lfilter function above is a direct II transposed structure. This means that the filter implements:

```
a[0]*y[n] = b[0]*x[n] + b[1]*x[n-1] + ... + b[M]*x[n-M]
                      - a[1]*y[n-1] - ... - a[N]*y[n-N]
```

where M is the degree of the numerator, *N* is the degree of the denominator, and *n* is the sample number. It is implemented using the following difference equations (assuming M = N):

```
a[0]*y[n] = b[0] * x[n]               + d[0][n-1]
  d[0][n] = b[1] * x[n] - a[1] * y[n] + d[1][n-1]
  d[1][n] = b[2] * x[n] - a[2] * y[n] + d[2][n-1]
...
d[N-2][n] = b[N-1]*x[n] - a[N-1]*y[n] + d[N-1][n-1]
d[N-1][n] = b[N] * x[n] - a[N] * y[n]
```

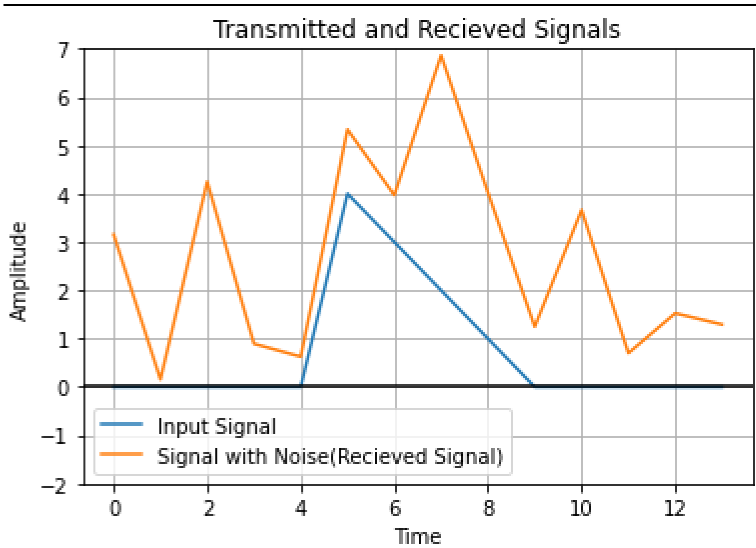
where *d* are the state variables.

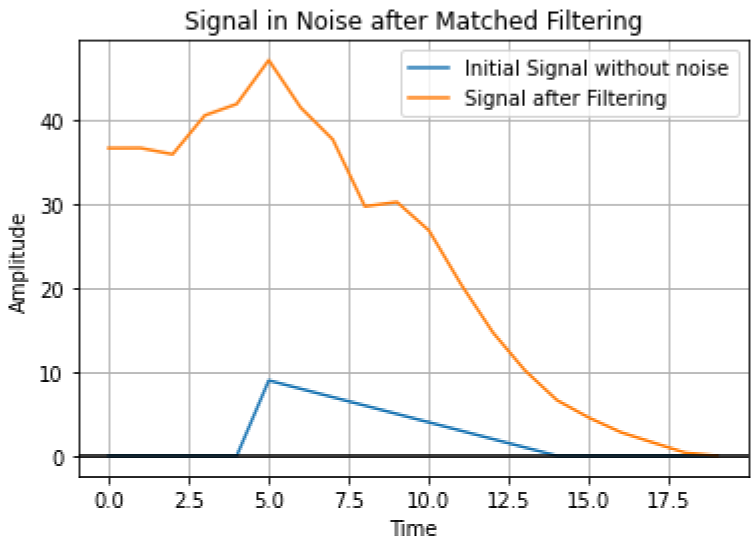
The rational transfer function describing this filter in the z-transform domain is:

```
                      -1              -M
        b[0] + b[1]z  + ... + b[M] z
Y(z) = -------------------------------- X(z)
                      -1              -N
        a[0] + a[1]z  + ... + a[N] z
```

5. Simulation results:

```
In [113]: runfile('C:/Users/HP/Desktop/Signal processing/sp lab/termProject/
type1.py', wdir='C:/Users/HP/Desktop/Signal processing/sp lab/termProject')

Enter the no of elements in the signal: 4

Enter element 0: 4

Enter element 1: 3

Enter element 2: 2

Enter element 3: 1

In [114]: 
```





6. Conclusion:

Advantages of Matched filters:

1. Robust against noise uncertainty.
2. Proper detection in low SNR
3. Less samples for detection.

Disadvantages of Matched Filters:

1. Prior knowledge about PUs.
2. More running time.
3. Different receivers for different signal.

- So, from the above conclusions, it is clear that this method of using matched filters has both advantages and disadvantages of its own and each method of filtering has its own best application.
- Therefore, Matched filters are best for Radar as in which a known input signal is transmitted, and the reflected signal is checked for common elements of the transmitted signal.

7. References:

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