AMATH482 HW1 Finding Submarine

Dean Wang

Abstract

Given a series of noisy acoustic data from a new submarine, we need to find the path of the submarine. I first use the Fourier Transform to find the averaged frequency spectrum. Then I use the 3D gaussian filter to find the noise trach. Finally, by implementing the transform in the space to determine the exact location of the submarine.

Introduction and Overview

Since the submarine use a new tech that emits an unknown acoustic frequency that I need to track the data. What we have is the board spectrum to obtain the data through 24 hours. Since it and lots of biotics are moving around in the water, there will be lots of noise. I need to use the 49 columns of data over the 24 hours to find the moving track of the submarine.

In order to get the final result, I first find average frequency spectrum and get the signature frequency. Then, I adopt a Gaussian filter to decrease the white noise. Finally, finding submarine location on X-Y plane.

Theoretical Background

In this project, I derive the Fourier Transformed Function from the Fourier Function. The original Fourier Function is:

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty}(a_n * cosnx + b_n * sinnx) \qquad x \in (-\pi, \pi] \tag{1}$$

In the transform, I scale the frequencies by 2π/L since the FFT assumes 2π periodic signals. Then we have:

$$F(k) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-ikxf(x)dx} \tag{2}$$

$$f(k) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-ikxF(x)dx} \tag{3}$$

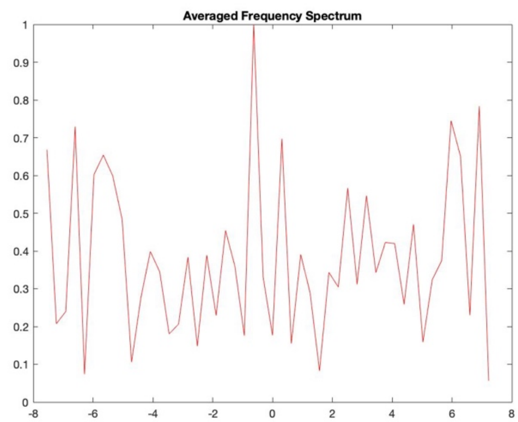
We first assume that people work in the 2 π domain, and by keeping the possible maximum speed and accuracy in the calculation, we need to use fast Fourier Transform modify the shift happened itself. Then, filtering the unimportant data out of the model is what we want to do next. At here, we use gaussian filter to generate the function:

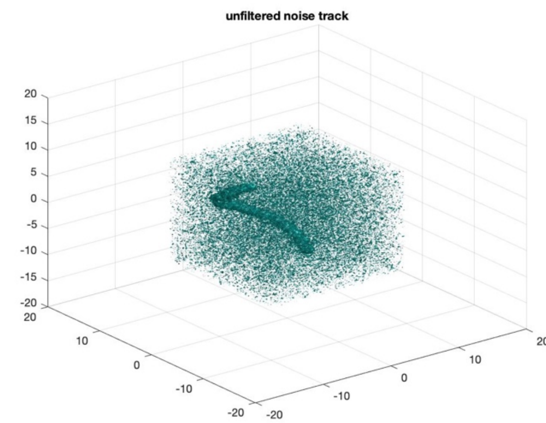
$$F(k) = \exp\left(-r(k-k_0)^2\right) \tag{4}$$

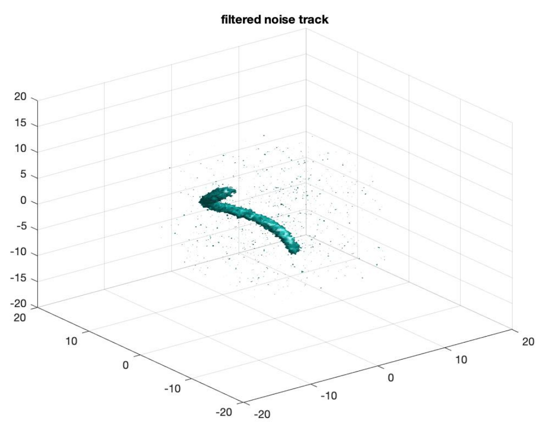
Algorithm Implementation and Development

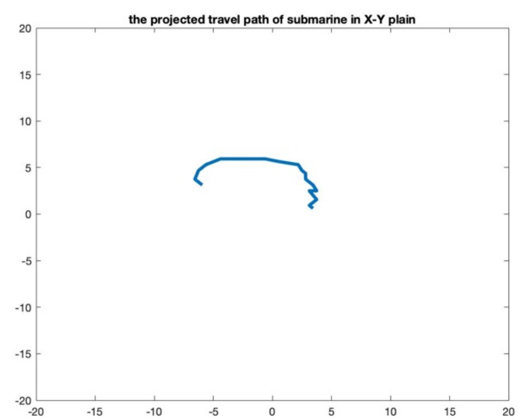
I first import the data as the 262143x49 (space by time) matrix called “subdata”. Then, I set up a 64*64*64 space, in the code “20/64” mean to transfer 64x64 space in to 20*20, “-10” mean to move the coordinate center to the corner of the square space.

I first find average the frequency spectrum and get the signature frequency by use the Fourier Transform to import the data and plot the frequency spectrum without the noise. Commend ave is prepared for the combination of all the matrix together in order to get plot1. Then, I adopt a Gaussian filter to decrease the white noise from the transform function before. By signature frequency we have in the previous question, it is 0.6283. After knowing the exact information of each point, the next step is to plot the original sound field, and the filtered sound field, and get the projection of submarine location on X-Y plane.









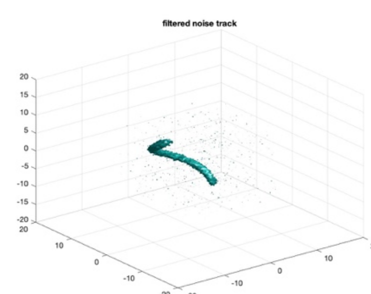
Computational Results

I will answer the three questions in the assignment.

1. This question is “Through averaging of the spectrum, determine the frequency signature (center frequency) generated by the submarine.”

The answer is 0.6283.

2. The question is “Filter the data around the center frequency determined above in order to denoise the data and determine the path of the submarine.”



The graph on the right

3. The question is “Where should you send your P-8 Poseidon subtracking aircraft? Give the x and y coordinates in a table to follow the submarine.”

x coordinates	34	34	35	37	40	40	40	42	42	42	44	44	46	47	47	49	50	50	50	50	51	51	51	51	51	51	51	51	51	51	51	50	50	49	49	47	47	47	47	44	44	43	42	42	42	42	42	42
y coordinates	43	43	42	44	42	42	44	43	43	43	42	42	42	40	40	39	34	34	34	34	30	29	29	29	24	24	24	24	18	18	18	16	16	14	14	12	12	12	12	11	11	12	13	13	13	13	13	13

Summary and Conclusions

The process of the project is to find average frequency spectrum and get the signature frequency, and then adopt a Gaussian filter to decrease the white noise. Finally, generating the location of the submarine in the X-Y plane. In the real life application, the location of the track can help us know when should we fight back.

Appendix

```
% Clean workspace
% clear all; close all; clc
close all
load subdata.mat % Imports the data as the 262143x49 (space by time) matrix
called subdata

L = 10; % spatial domain
n = 48; % Fourier modes
%

k = (2*pi/(2*L))*[0:(n/2 - 1) -n/2:-1]; %frequency components
ks = fftshift(k);
%%
%this part mean to average the frequency spectrum and get the signature
%frequency
datasize=size(subdata);
ave=zeros(1,n);
 for locate=1:datasize(1)
% for locate=1:5
u=subdata(locate,1:n);%each point time domain
ut=fft(u);%frequency domain
ave=ave+ut;

 end
ave=abs(fftshift(ave))/datasize(1);
figure(1)
plot(ks,ave/max(ave),'r-')
title('Averaged Frequency Spectrum')
%%
%this part adopt a Gaussian filter to decrease the white noise
tau=0.2;
k0=-0.6283;%from above plot, we can see the signature frequency is at 0.6283
k = (2*pi/L)*[0:(49/2 - 1) -49/2:-1];
filter= exp(-tau*(k - k0).^2);

unf=zeros(datasize(1),48);
for locate=1:datasize(1)
u=subdata(locate,1:48);
ut=fft(u);
```

```
unft=filter.*ut;
unf(locate,:)=ifft(unft);
end

%%
%plot the original sound field
nn=64;%spacial domain
x2 = linspace(-L,L,nn+1); x = x2(1:nn); y =x; z = x;
[X,Y,Z]=meshgrid(x,y,z);
[Kx,Ky,Kz]=meshgrid(ks,ks,ks);

figure(2)
for j=1:49
Un(:,:,:)=reshape(subdata(:,j),nn,nn,nn);
M = max(abs(Un),[],'all');
isosurface(X,Y,Z,abs(Un)/M,0.5)
axis([-20 20 -20 20 -20 20]), grid on, drawnow
pause(0.01)
title("unfiltered noise track")
end

%%
%plot the filtered sound field and get the projection of submarine location
%on X-Y plane
figure(3)
noisesum=zeros(64,64,64);
topox=zeros(1,48);
topoy=zeros(1,48);
for j=1:48
% for j=1
Un(:,:,:)=reshape(unf(:,j),nn,nn,nn);

M = max(abs(Un),[],'all');
isosurface(X,Y,Z,abs(Un)/M,0.5)
noisesum=noisesum+abs(Un)/M;
axis([-20 20 -20 20 -20 20]), grid on, drawnow
pause(0.01)
title("filtered noise track")
ztopo=sum(abs(Un)/M,3);%to get the projection of noise on XY plane.
ztopo=ztopo/max(max(ztopo));
[topox(j),topoy(j)]=find(ztopo==1);
end
figure()
plot(topoy*20/64-10,topox*20/64-10,'Linewidth',3)
%*20/64 mean to transfer 64x64 space in to 20*20,-10 mean to move the
%cordinate center to the corner of the square space
axis([-20 20 -20 20])
title('the projected travel path of submarine in X-Y plain')
%%
%to generate the coordinates table
tablename={'x coodinate','y coordinate'};
table(topox',topoy','VariableNames',tablename)
```