AMATH 482 Homework 1
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Abstract

The contents of this report will contain a descriptive explanation of how to locate a submarine in the Puget Sound using an acoustic signature. Through analyzing in MATLAB we aim to determine the frequency signature generated by the submarine, determine the path of the submarine, and give coordinates to follow the submarine.

Note to the Professor/TA

I contacted both Professor Bramburger and Roman (TA) about my situation regarding my housemate. To restate here, I gave myself around a week to work on this assignment but much of that time was redirected to taking care of my housemate whom was extremely sick. I ended up only getting time to barely finishing question 1. I hope to possibly get an extension on this assignment as I really want to do well in this class.

Section I. Introduction and Overview

There are three main goals to discover through this research: to determine the frequency of the submarine, the path of the submarine, and where the submarine is heading. In order to do this, we are given the dataset subdata.csv/subdata.mat to work around with in MATLAB.

Section II. Theoretical Background

The main topic that is being used and explored is time-frequency analysis. The bane of time-frequency analysis is the Heisenberg Uncertainty Principle that states that the position and the momentum of an object cannot both be known from a given signal. In other words, to know completely the position of an object, we must give up knowing about its momentum, and vice versa. Position and momentum translate to time and frequency respectively. That is, to find more about time, we must give up information on frequency and to know more information about frequency, we must give up a little info on time. However, both are crucial in knowing the location of the submarine and where it is heading. Thus, the problem is to find a solid middle ground where we can analyze and deduce the location and trajectory of the submarine from signals received.

Section III. Algorithm Implementation and Development

Part 1: Using Averaging to determine the frequency signature

The first hurdle was to find the frequency signature generated by the submarine. To do this we needed to first use the Fast Fourier Transform (FFT)

$$x_k = \frac{1}{N} \sum_{n=0}^{N-1} x_n e^{2\pi ikn/N} \quad (1)$$

to create frequency graphs from the location vs time data. However, each location has white noise that needs to be removed to get a clear picture of what is actually happening. To remove this white noise, we average multiple sets of data. Since the frequency lines up nicely after a FFT, by taking the average of the data, the white noise goes towards 0. Thus, we are left with a nice looking graph of frequency with minimal noise.

Part 2: Filter the data around the center frequency to denoise the data and determine the path of the submarine

Once we have the center frequency, we know where to look in terms of frequency, however, because of this, we lost information on time and position. Thus, we need to denoise the data through filtering methods such as the Gabor transform:

$$f_g(\tau, k) = \int_{-\infty}^{\infty} f(t)g(t-\tau)e^{-ikt}dt. \quad (2)$$

The Gabor Transform allows us to filter through the data in sections of time, allowing us to get a sense of both time and frequency. In equation 2 τ represents where the filter is centered in terms of time. There is also another variable a which is the width around the centered value. The size of a basically determines how much time-frequency information we get. The bigger the window size, the more info on frequency we get. In contrast, the smaller the window, the more information on time and the less of that on frequency.

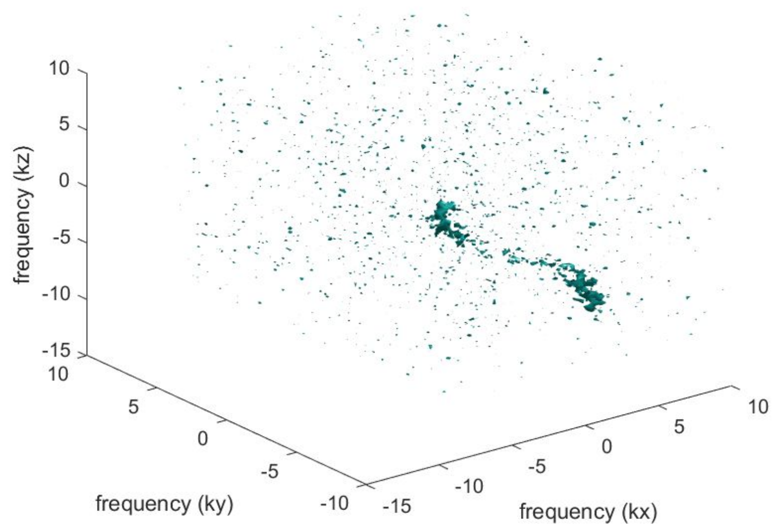
Part 3: Determine where to look for the aircraft

Based on the path of the submarine found in part 2, we are able to determine where to go to find the submarine in its path.

Section IV. Computational Results

Part 1

From the averaging done in part 1, we were able to see a clear plot with minimized noise:



To find the center frequency we need to find the indices of the maximum value in the averaged data. This is because the maximum value means it has the highest frequency which is what we are looking for. We get {19,52,25} as the indices of the max value in the Kx, Ky, Kz plane.

Section V. Summary and Conclusions

Unfortunately, I was unable to get far enough into the assignment to make any interesting summaries and conclusions.

Appendix A. MATLAB functions used and brief implementation explanation

Part 1

ftt()
To average the frequency data, we first have to use the function ftt() to get frequency data from the time vs location data that we get from subdata.

fftshift()
This function is used to fix the data shift that occurs when fft() is used. The second parameter is used for multidimensional data to specify which axis to shift by.

To implement this averaging frequencies code, we needed to go through each time and apply the fft() on the 64x64x64 data (Un). We sum up the frequency data that we get from fft() on all times and divide it by the number of times available, in our case 49. Thus we get the average of the frequency data. Finally we plot the averaged data on an isosurface to visually see the frequency data.

Appendix B. MATLAB codes

```
% code for averaging frequencies
% Code 1
avg = zeros(n,n,n);
for j=1:49
Un(:,:,:)=reshape(subdata(:,j),n,n,n);
ut = fft(Un);
avg = avg + ut;
end
avg = fftshift(abs(avg), 1)/49;
[val,idx] = max(avg(:));
dims = size(avg);
smax = cell(size(dims));
[smax{:}] = ind2sub(dims,idx);
smax
isosurface(Kx,Ky,Kz, avg, 0.7)
axis([-12 12 -12 12 -12 12]), grid on, drawnow
```