Homework 1

AMATH 582/482, Winter 2026

Due on Jan 20, 2026 at midnight.

Directions, Reminders and Policies

Read these instructions carefully:

- **You are required to upload a PDF report to Gradescope along with your code in the form of a Jupyter notebook or a zip file of your main scripts and functions. The report and the code are to be submitted under separate assignments. DO NOT INCLUDE YOUR CODE IN THE REPORT.**
- The report should be a maximum of 10 pages in accordance with the template on Canvas including references. Minimum font size 11pts and margins of at least 1inch on A4 or standard letter size paper. The report should be formatted as follows:
  - Title/author/abstract: Title, author/address lines, and short (100 words or less) abstract. This is not meant to be a separate title page.
  - Sec. 1. Introduction and Overview
  - Sec. 2. Theoretical Background
  - Sec. 3. Algorithm Implementation and Development
  - Sec. 4. Computational Results
  - Sec. 5. Summary and Conclusions
  - Acknowledgments (no more than four or five lines, also see the point below on collaborations)
  - References
- **Recall our late policy: If you plan to use your tokens please send an email to Saba (`heravi@uw.edu`). If you do not use a token you will lose 1/3 of your grade for each day the submission is late. WE WILL NOT AUTOMATICALLY APPLY TOKENS. YOU MUST INFORM US IF YOU PLAN TO USE THEM.**

Problem Description: Finding Submarines

Your goal in this homework is to locate a submarine in the Puget Sound using noisy acoustic data. We do not know much about this submarine as it is a new technology that emits an unknown acoustic frequency that you need to detect. Unfortunately the submarine is moving so its location and path need to be determined.

Broad spectrum recording of acoustics data obtained over 24 hours in half-hour increments is available to you. You can download the data from Canvas; either of the data files `subdata.npy` for Python users, `subdata.mat` for MATLAB users or `subdata.csv` in text format if previous two formats are insufficient. These files contain a matrix with 49 columns of data corresponding to the measurements of acoustic pressure taken over 24 hours. The measurements themselves are 3D and taken on a uniform grid of size $64 \times 64 \times 64$. The provided notebook will visualize this data for you. *If the 3D plots are slow and you cannot see the dynamic behavior of the data consider downloading the GIF file `subdata.gif` on Canvas. This should help you better understand the information in the data set.*

Some comments and hints

Here are some useful comments and facts to guide you along the way.

1. First, observe that you are provided three dimensional dynamic data, that is acoustic pressure measurements in 3D and as a function of time. This makes visualization difficult as the data set is truly four dimensional. If you would like to see temporal variations then I suggest looking at 2D slices of the data as a function of time.
2. On the same note, we only saw 1D and 2D Fourier transforms in class but nothing changes in the 3D setting except that you need to use the `fftn` function. `fftshift` remains valid and is still needed.
3. Here is a useful fact about noise and Fourier transform that will help you in this assignment and in many applications.

   > *It is known that adding mean zero white noise to a signal is equivalent to adding mean zero white noise to its Fourier series coefficients.*

   This fact enables one to devise a very simple and effective noise filtering technique in situations where multiple measurements are available that are subject to the same noise. Such is the case in many imaging or acoustics applications like our submarine problem. Since the noise is random and mean zero it should average to zero over many samples. Hence, averaging the measurements in the Fourier domain should already reduce the noise.

   The more measurements you have the better the effect of this averaging. But in the case of the submarine data you only have few measurements so you still need to do some kind of filtering.

Tasks

Below is a list of tasks to complete in this homework and discuss in your report.

1. Determine the frequency signature (center frequency) generated by the submarine.
2. Design and implement a Filter to extract this frequency signature in order to denoise the data and determine the path of the submarine and plot the 3D path of the submarine.
3. Determine and plot the x, y coordinates of the submarine during the 24 hour period. This information can be used to deploy a sub-tracking aircraft to keep an eye on your submarine in the future.
4. The theoretical background section of your report must have a clear and complete explanation of your methodology, including how you denoised and filtered the data using mathematical equations and appropriate descriptions, akin to a mini research paper.

5. The computational results should address the above tasks but also include extra results as needed to convince the reader that your method is working.
6. Your code will NOT be graded directly, but it should produce all of the results and figures in your report. We will not grade the code directly. So if there are results you want us to see, make sure they are in the report.