CMSC 715: Wireless and Mobile Systems for the IoT

Assignment - II

Fall 2021 Due: October 22nd, 2021

Instructions

1. This assignment is due on October 22nd, 2021 at 11:59 PM.
2. There are total 100 points to score and additional 20 points as extra credit.
3. Please submit an electronic copy of your answer sheet through ELMS-Canvas. Contact the TA if you face any technical difficulties in submitting the assignment.
4. Your report should contain plots, source code, along with short descriptions of the operation for each part separately.
5. You may discuss ideas with others in the class, but your solutions and presentation must be your own. Do not look at others' solutions or copy from anywhere.

Assignment description

The goal of this assignment is to get familiarized with the basic signal detection, spatial filtering, and array processing techniques. You can use any programming platform for this assignment, however the instructor and the TA will provide programming specific help for Matlab only.

Task 1: Signal Detection [30 points]

You are lost in a forest and want to return to your base station. You have lost your location tracking device. However, you have a special receiver that receives a signal transmitted from the base station. The receiver is synchronized with the transmitter at the base station, i.e., the device is turned on when the base station starts the transmission. Of course, depending on your distance from the base station, the transmitted signal will be recorded after some delay. Moreover, the received signal is very noisy. Imagine the transmission is using acoustic signal and the speed of the signal is 340 m/s.

(a) You are provided with a data folder containing signal files. The template of the transmit signal is in the file named 'transmitSignal.wav'. The name of the files containing the received signals are in numbers. If the last digit of your UID is 'x', then use the file 'x.wav' for your received signal. You will get time series of the transmitted/received signals from these files along with the sample rates. Plot the transmit and received signals. The x-axis of the plot should be properly labeled with time in seconds. [5 Points]

(b) Compute your distance from the base station using the transmitted and the received signals. Report the distance in meters. [5 Points]

(c) Explain the steps of your computation for the above question. [15 Points]

(d) Submit your codes. [5 Points]

You are provided with a Matlab file named '$generateTestData\_task1.m$' that we used to generate the received signal simulating different time delays of arrival of the transmitted template signal. You can use this file to generate test data and verify the correctness of your code before submission.

Task 2: Directional Gain of ULAs [40+20 points]

Consider a Uniform Linear Array (ULA) of microphones (sound sensors). Each microphone is omnidirectional and identical, unless mentioned otherwise. Speed of sound is 340 m/s.

(a) Write a program to plot the directional gain of a 10-element ULA for the target frequency 2kHz. The ULA has the inter-element distance equal to the half of the wavelength of the target signal. Submit your code and plot. [15 Points]

(b) Write a program and plot the directional gain of a 10-element ULA for the target frequency 2kHz. The ULA has the inter-element distance equal to the twice of the wavelength of the target signal. Submit your code and plot. [15 Points]

(c) Point out the differences in the directional gains of the above two configurations of the array and explain the reasons for the differences. [10 Points]

(d) Consider that the 2nd, 3rd, and 4th microphones of the 10-element ULA are faulty and not recording any sound (output is zero for each sample). (a) Plot the directional gain of this faulty ULA for target frequency 2kHz and inter-element distance equal to the half of the wavelength. (b) Explain the difference of the gain of this faulty ULA compared to a standard ULA with the same configuration. [10+10 Bonus Points]

Task 3: Direction of Arrival [30 points]

Consider a ULA of microphones (sound sensors) with 100 elements for the target frequency 2kHz. The ULA has the inter-element distance equal to the half of the wavelength of the target signal. Speed of sound is 340 m/s.

(a) You are provided with a data folder containing an array snapshot i.e., the samples of the incoming signal from all the elements of the array at a given instance of time. The data is in form of a complex vector. If the last digit of your UID is 'x', then use the file 'x.csv' for your array snapshot. Plot the real and imaginary values of the array snapshot. The x-axis of the plot should be properly labeled with the element index. You can use 'csvread' Matlab function to read the array snapshot as a complex vector. [5 Points]

(b) Use the Delay-Sum method to find the direction of arrival (DoA) of the signal from the array snapshot. (a) Report the DoA in degrees. (b) Plot the angular spectrum with x-axis properly labeled with possible directions of arrival in degrees. The plot should show a clear peak at the estimated DoA. (c) Submit your codes. [5+15+5]

You are provided with a Matlab file named '$generateTestData\_task3.m$' that we used to generate the array snapshots for different DoA for this task. You can use this file to generate test data and verify the correctness of your code before submission.

What to submit

Please submit a single document file (.pdf format is preferable) containing the following:

(a) Your name and UID

(b) The answers/output/results/plots etc. for each of the questions above.

(c) The source code or scripts you used for this programming assignment.

List of Matlab functions useful for this assignment

Use 'help ⟨ function-name ⟩' on the Matlab console to get information about the input/outputs of these functions.

(a) audioread

(b) xcorr

(c) max

(d) deg2rad

(e) rad2deg

(f) exp

(g) csvread

(h) abs

(i) sin

(j) asin

(k) polarplot