CS/ECE 434 Homework 2

Due Apr 10, 11:59 pm

Problem 1: State true or false with a 1 line justification [24 points]

a. The DFT spectrum of a signal is symmetric around $F_s/2$, where F_s is the sampling frequency.

b. GPS location estimation also synchronizes the clock of the mobile device with the satellite clock.

c. Signal strength is a good indicator of distance in indoor environments.

d. In RADAR, more the number of access points (APs), better will be the accuracy.

e. For a static object, estimating gravity well can determine the orientation of the object.

f. If a transmitter is in the near field, then the location of the object can be determined from a receiver array.

g. If phase can be measured precisely, then it is adequate to measure the distance between a transmitter and a receiver.

h. In free fall, an accelerometer will record 0 on all three axes.

i. Since white noise has a zero mean, we can keep tracking an object's location by integrating IMU data over long period of time.

j. Order of rotations does not matter. That is: $R_x(R_y(R_z)) \equiv R_y(R_z(R_x))$.

k. A model based localization approach based on RSS (such as that explored by second part of RADAR) will work well in outer space.

l. Localization approach used in UnLoc will fail in an open area since it will have no remarkable landmarks to reset.

Problem 2: Explain or argue briefly [21 points]

a. Explain (5 points): Why is clock synchronization between GPS satellites so crucial to localize mobile devices on the ground.

b. Argue (5 points): There is some order in which the UnLoc landmarks get estimated (i.e., the ordering is not random).

c. Argue (5 points): KNN is not always better than NN localization. If so, give an example, if not, argue why not.

d. Argue both for and against (6 points): In a 2-antenna AoA setup, Alice wants to separate the antennas by 2λ distance. What are the benefits and drawbacks over a separation of $\lambda/2$?

Problem 3: Math nuggets and derivations [20 points]

a. Derive the Nyquist sampling theorem from first principles.

b. Derive the steering matrix for AoA estimation from first principles.

c. For HMMs, derive the expression for P(s_k — $m_{1:n}$). Show which one is the forward and which one is the backward algorithm.

d. Derive the chain rule for the joint probability, P (A, B, C, D)

Problem 4: 3D Orientation [15 points]

Assume that the magnitude of acceleration due to gravity is g and the magnitude of the earth's magnetic field is m. Also assume that we are at the equator. For a mobile phone assume x-axis is parallel to the phone's width (shorter side), y-axis is parallel to the phone's length (longer side), z-axis penetrates through the phone's glass surface.

a. A static mobile phone is supported on a table and shows accelerometer reading: [0, 1, 0]g. Does this represent the complete orientation of the phone? If yes, what is the orientation matrix. If no, give a reason why not.

b. The above phone is showing a magnetometer reading of [1, 0, 0]m. Is this possible? What is the orientation matrix for the phone?

c. A static mobile phone is reporting the following measurements on its accelerometer: [-0.3789, 0.2775, 0.8828]g. It is reporting the following magnetometer readings: [0.5829, 0.8125, -0.0053]m. What is its orientation matrix?

Problem 5: Programming module: Beamforming and AoA [20 points]

- Code up a small simulator which has a device X with N antennas (uniformly separated by distance DIS).
- Device X is receiving a signal from different angles THETA.
- The signal is at frequency FREQ = 100kHz and is being transmitted by a far field transmitter Y.
- Now, implement the basic AoA sensing algorithm.

a. Assuming you dont know THETA, plot the AoA spectrum for DIS = wavelength, half wavelength, and quarter wavelength (note that c = f * lambda).

b. Add increasing random noise to the received signal, and re-plot the AoA spectrum but this time for DIS = half wavelength only. What do you observe as you increase noise?

c. Now add a reflection signal coming from a different angle BETA and re-plot the AoA spectrum only for DIS = half wavelength. Can you still detect the AoA accurately?

d. Keep adding reflection signals and determine at which point the AoA becomes inaccurate.