ECE 2066: How the Android/iPhone Works

Spring 2017

Lab 9: Trilateration and GPS

Objective: This lab will explore how the iPhone locates itself on earth. Specifically, this lab considers trilateration and triangulation and explores time synchronization correction for GPS.

Note: The code files have comments (green text) to help you understand the techniques mentioned above. Please take a look at them.

Getting Started

1. Downloading files: In the Lab 9.zip file containing this document, you should find the MATLAB files trilaterate.m, coords2latlong.m, set_diameter.m, random_GPS.m, and GPSdata.mat. Place these files in a local directory (such as C:\LocalData) and navigate to this directory after launching MATLAB (use the navigation bar near the top of the screen).

Trilateration and Time Synchronization

File description:

Load the workspace file GPSdata.mat into MATLAB. This file contains three variables, "satcoords", "t", and "c". The "satcoords" matrix contains 4 rows, where each row contains the 3D coordinates (x,y,z) (in meters) of a different GPS satellite orbiting ~20,000 km above the earth. The "t" vector contains four values corresponding to time measurements, in milliseconds. The variable "c" is the value, in meters/millisecond, of the speed of light (in a vacuum) used to switch between distances and times.

The function coords = trilaterate(satcoords,ds) takes as inputs three rows of the "satcoords" matrix, and a vector of distances for the corresponding three values in the "t" vector, and outputs the trilaterated 3D coordinate closest to the earth (assuming the earth is a sphere).

The function [lat,long] = coords2latlong(coords) takes the 3D coordinates as an input and computes two outputs: the latitude and longitude, in degrees, again assuming the earth to be a sphere. You will not use this file as it is inherently used by trilaterate function.

The script "GeneratePlots.m" is the file that you will modify to perform exercises.

2. Using these functions, take the first three rows of "satcoords" and "t" i.e. `satcoords(1:3,:)` and `t(1:3,:)`. Convert the times to distances, and report the latitude and longitude of the trilaterated object coordinates. Open your favorite map website (e.g., Google Maps can do this) and input the GPS coordinates to find its location on the globe. <u>What US state is the coordinate in? Describe roughly where it is relative to any major landmarks you see on the map. (Note: you may need to zoom out the map a bit.)</u>

3. Having an extra satellite allows us to correct for our receiver being out-of-sync with the satellites. When the wrong time offset is used, different choices of 3 satellites would give

different positions. Modify the "GeneratePlot.m" file and turn in a plot of the latitude and longitude points for each group (there are four of them) of 3 out of 4 satellites, without time correction. Did all of the combinations report the same location?

4. Due to the receiver not being synchronized with the satellites, the received times "t" are all off by an unknown constant value, between -1 and 1 millisecond. A simple procedure to time synchronization involves steadily changing the t values by different constants and repeating the computations in Step 3 until the different groups of 3 satellites yield approximately the same 3D coordinates. For simplicity, you have been given 3 different time correction offsets: **[-0.434, -0.147, 0.2].** Which one would you choose?
   Hint: Observe the plot.

   Input these coordinates on the map – approximately how far did the coordinates move (in km) relative to the location in Question 2?