Vehicle Positioning, Velocity, and Heading Determination via Raw Satellite Data and DGPS Ground Truth

(Revision: Original)

1 Introduction

GPS is a vital element of the global services which has become a next big revolution after the internet and cell phones. The free, open, and dependable nature of GPS has led to the development of hundreds of applications affecting almost every aspect of modern life. GPS technology is present in everything from cell phones and wristwatches to bulldozers, shipping containers, and ATM's. This technology boosts productivity across a wide swath of the economy which includes communication networks, banking systems, financial markets, power grids, safety of life services. GPS is vital to the Next Generation Air Transportation (NextGen) that will enhance flight safety and increase airspace capacity.

There are more than 30 GPS satellites encircling the Earth in medium Earth orbit (MEO). The GPS receiver gets a signal from each visible GPS satellite which includes the exact transmission times. By subtracting the transmission time from the reception time of the signal and multiplying it with the speed of light, the GPS receiver can compute receiver-satellite ranges. These ranges tell how far a GPS receiver is from each satellite. The GPS receiver also computes the exact position of the satellites which is included in the received signal. Given the ranges of the GPS receiver from more than three satellites and their exact position in the sky, the GPS receiver can determine the user position. It can also compute the user velocity based on Doppler values of the signals and render the heading information as well.

There are different ways of calculating the vehicle's position from the given receiver-satellite ranges. The most used methods are the least squares algorithm and Kalman filter. Each of these has its own pros and cons. There are various kinds of Kalman filter based estimators, which use stationary receiver, low dynamics, and high dynamics models for the receiver motion that are commonly used in GPS receivers, and cover a wide range of applications.

2 Objectives

The objectives of this project are:

1. Learn basics of GPS and its raw data which includes pseudorange measurements and Doppler values.

2. Collect the raw data from GPS receivers using:
   (a) A stand-alone GPS receiver
   (b) A mobile phone equipped to provide raw GPS data
   (c) Base/reference GPS station
3. Collect the raw data GPS from online sources to be used as a Base/Reference Station for Differential GPS (DGPS)
4. Process the data to arrange it in a suitable format for computational algorithms.
5. Develop an efficient navigational algorithm to compute following parameters using pseudorange measurements from *four* satellites:
   (a) the GPS satellite position
   (b) the GPS receiver position
   (c) the GPS receiver velocity
   (d) the GPS receiver direction of travel (angle from north called Yaw/Azimuth angle)
6. The navigation algorithm will be based on the method of "Least Squares" and subsequently on "Kalman Filtering"
7. Extend the above mentioned algorithm to compute the above mentioned parameters using pseudorange measurements from all the available satellites.
8. Compute the reference parameters data using DGPS which would be used as ground truth to check the effectiveness of the algorithm. This will require:
   (a) Setting up of a Base/reference station
   (b) Setting up of a fixed GPS antenna free of obstructions
   (c) Setting of related hardware and software for data collection
   (d) Processing of data suitable for DGPS
9. Design a user-friendly interface (front end) to present the track of the moving platform
10. Write User Manuals (preferably in Latex) for the following:
    (a) Data Collection and processing for the stand-alone GPS receiver.
    (b) Data Collection and processing for mobile phone.
    (c) Data Collection and processing for online sources.
11. Design a visually appealing poster depicting the salient aspects of the project.

3 Requirements

1. Strong background in mathematics especially in linear Algebra. Basics of GPS is preferred.
2. Solid foundation in software development and programming. Use of Matlab is preferred.
3. Proficiency in working with microcontrollers and single-board computers (such as Arduino, ESP32, or Raspberry Pi)
4. Strong analytical ability and writing skills. Use of Latex software is preferred.