ENGO 629 - Advanced Estimation Methods and Analysis

Lab Assignment

Fall 2018

Instructor: Dr. Y. Gao

Lab: 1

Title: Least-Squares and Kalman Filter Implementation and Analysis

Due: Thursday, October 25, 2018

Overview

In this lab you are expected to implement Least Square and Kalman filter methods and analyze the difference between them. You will have to write your own code to read the data and perform all necessary computations.

Objectives

The objectives of this lab are as follows

- To implement Least Square and Kalman filter methods with application to GPS positioning of a moving land vehicle
- To gain insight into the difference between the Least Square and Kalman Filter methods
- To understand the use of different dynamic models for Kalman Filter

Programming Requirements

The software you develop for this lab can be written in MATLAB or C/C++.

Description of Input Data

A data file (satpos_meas.txt) containing GPS pseudorange (distance between GPS satellite and receiver) observations at a data rate of 1 Hz from a Trimble R8 receiver set up on a moving land vehicle will be provided. Since the computation of the satellite positions is not discussed in the course, the satellite coordinates at different time epochs will be computed and provided to you together with the pseudorange observations. Specifically, the format of the provided file is explained as follows.

Each line provides information for one satellite which includes the following values:

<GPS time of observation (seconds)>
<Satellite PRN>
<X Satellite Coordinate (m)>
<Y Satellite Coordinate (m)>
<Z Satellite Coordinate (m)>
<Pseudorange (m)>
<Carrier-phase (m)>
<Elevation (degree)>

For example, the following is the data at time epoch `77570` for ten observed satellites:

time	PRN	Satellite X	Satellite Y	Satellite Z	Pseudorange	Carrier-phase	Elevation
77570.0	13	13125901.321	-9014436.366	21144196.324	22567842.010	22567842.142	31.760
77570.0	15	6342280.036	-19576399.096	16508182.520	21231244.344	21231244.024	49.194
77570.0	16	-23320231.693	1188066.662	12920795.725	23604218.865	23604218.812	22.407
77570.0	18	-14908214.027	-15797313.304	15975571.690	21094095.082	21094095.724	63.945
77570.0	20	8268624.819	-14296821.479	20655190.549	21406654.071	21406654.273	47.470
77570.0	21	-7011609.712	-15363047.878	21160661.999	20707239.189	20707239.917	89.417
77570.0	22	-24405625.223	-9580045.494	5038359.449	23519181.594	23519181.880	23.339
77570.0	27	-13686557.513	6544671.336	21767038.539	23074603.568	23074601.854	26.605
77570.0	29	-4929438.417	-26091147.328	-1195828.690	23481782.114	23481781.944	22.347
77571.0	13	13126391.130	-9011770.488	21145013.289	22568119.348	22568117.618	31.757

Note: Since the provided pseudorange observations have already been corrected for un-modeled errors, no further GPS error corrections are needed before estimation. The standard deviation for the pseudorange measurements is determined by $\sigma_0/\sin(E)$ where E is the satellite elevation and $\sigma_0 = 1$ m.

Observation Equation

For the purpose of this lab, the observation equation for GPS positioning can be written as

$$P_i = \rho_i + cdt + \varepsilon = \sqrt{(x_i^s - x^r)^2 + (y_i^s - y^r)^2 + (z_i^s - z^r)^2} + cdt + \varepsilon \qquad (1)$$

where P_i is the pseudorange to the i-th satellite [m], ρ_i is the true geometric range between the satellite and the receiver [m], c is the speed of light [m/s], dt is the receiver clock offset [s] and ε is the measurement error, $(\bullet)^r$ is coordinate component for the receiver and $(\bullet)_i^s$ is coordinate component for the i-th satellite.

Tasks

This lab consists of the following tasks.

Task 1 – Least Square Implementation

1.1 Implement Least Square method to estimate the GPS receiver's position (latitude, longitude and height) and clock offset at each epochs.

Task 2– Kalman filter Implementation

2.1 Implement the Kalman Filter method to estimate the state vector (GPS receiver's position and clock offset) at each epoch by modeling the dynamics of the receiver's position and clock offset as a random walk process.

2.2 Expand the state vector in 2.1 to include the receiver's velocity and clock drift to estimate the state vector (receiver's position, velocity, clock offset and drift) by modeling the dynamics of the receiver's velocity and clock drift as a random walk process.

Task 3– Result Comparison and Analysis

3.1 Calculate the positioning errors of different processing results in the East, North and Up (ENU) directions. Reference receiver positions are provided in the file "refpos.txt" with the following format.

time	X	Y	Z
78465	-1642640.912	-3664659.040	4939862.395
78466	-1642640.912	-3664659.039	4939862.398
78467	-1642640.913	-3664659.038	4939862.399
78468	-1642640.912	-3664659.035	4939862.399

3.2 Compare and analysis the results of Least Squares and Kaman Filter in Task 1 and task 2.

3.3 Compare and analysis the results of Kalman Filter using different dynamic models from 2.1 and 2.2 of Task 2.

What to Submit

Each report must be professionally written. Be concise but thorough. Explanations should accompany all plots.

Please submit the following by uploading in D2L dropbox

- Source code (but be sure to clean your project first)
- Soft copy of Lab 1 report in *.doc or *.docx format, which:
  - Provide a description of data used including vehicle trajectory and lab objective
  - Explain the method of each implementation along with mathematical equations and parameter settings
  - Show positioning errors of each implementation using graphs and tables along with analysis
  - Show comparison and analysis of results using graphs and tables along with analysis.

Combine all of your files into a ZIP file and use the following naming convention:

ENGO_629_Lab1_Date_(*your name*).zip