# Lab2 of ENGO 625


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# Objectives

1. To implement GPS-based positioning solutions.
2. To become familiar with analysis accuracy using measurement residuals.
3. To improve programming skills with regards to Geomatics Engineering (C/C++, MATLAB, or Python only, please).

# Data Description

Each student will be given three data files.

• A binary file containing 1 Hz GPS observations from a static NovAtel OEMV remote receiver.

• A binary file containing 1 Hz GPS observations from a static base station. You will be given the
true coordinates of both receivers

• A binary file containing the satellite coordinates and velocity components in the Earth-Centred-Earth-Fixed (ECEF) frame, also at 1 Hz.

# Tasks

**1.Load the satellite coordinate file and the rover observation file from lab 1.**

Load the data in the same way as Lab1

**2.Use parametric least-squares (PLSQ) and pseudorange measurements to estimate the 3D single point position and clock offset (either X, Y, Z, cdT or geodetic latitude, longitude, height above the ellipsoid and cdT) for each epoch.**
**a. This is non-linear parametric LS, so you will need to iterate the solution. You can start at [0,0,0,0] or at the solution from the last epoch.**

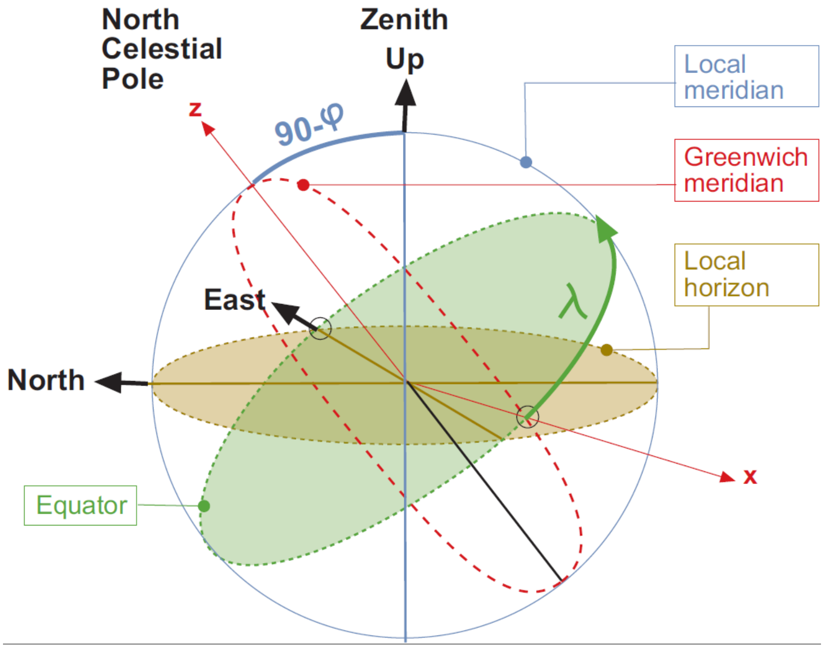
Because the data from the receiver file and satellite file are not always correspond. Firstly I defined a function to find the common satellites they have for each epoch. Then apply least-squares and pseudorange measurements to estimate the solution for each epoch.

$$\bar{x} = \left(H^T C_z^{-1} H\right)^{-1} H^T C_z^{-1} z$$


```
492.006124348, 9.757065068375482], [-1633493.3063434279, -3651631.703019005, 4952492.375466475, 10.09618708585878], [-1633492.813476103, -3651631.229406736, 4952490.869107585, 8.8783
73613446456], [-1633492.8207866312, -3651631.229767068, 4952490.75693136, 8.89598222615611], [-1633492.357531639, -3651630.8385299975, 4952490.657856696, 8.3678263963484], [-1633492.
9753163876, -3651631.5771940425, 4952491.983838131, 9.585141033025106], [-1633492.0314305243, -3651630.776879874, 4952488.1982526, 7.028138331255885], [-1633492.8203785587, -3651631.
416154588, 4952491.597656059, 9.144102998486765], [-1633492.5607746278, -3651631.079071128, 4952490.14208301, 8.27706761024506], [-1633492.8231442708, -3651631.125239482, 4952490.888
637356, 8.67988942593142], [-1633492.9025400146, -3651631.133629038, 4952491.637485251, 9.231806492242841], [-1633492.1178418582, -3651630.701403361, 4952488.799812872, 7.52451958149
118], [-1633492.4284217837, -3651631.170950484, 4952491.603063047, 9.461921514403015]]
```

**b. Using the true position provide, determine the position errors in the East-North-Up (ENU) frame. If you have estimated in the ECEF frame you will need to transform your errors to the ENU frame).**

Then calculate the position errors based on the true position and transfer the errors to the ENU frame.




The error shows that the solution is quite close to the true position.

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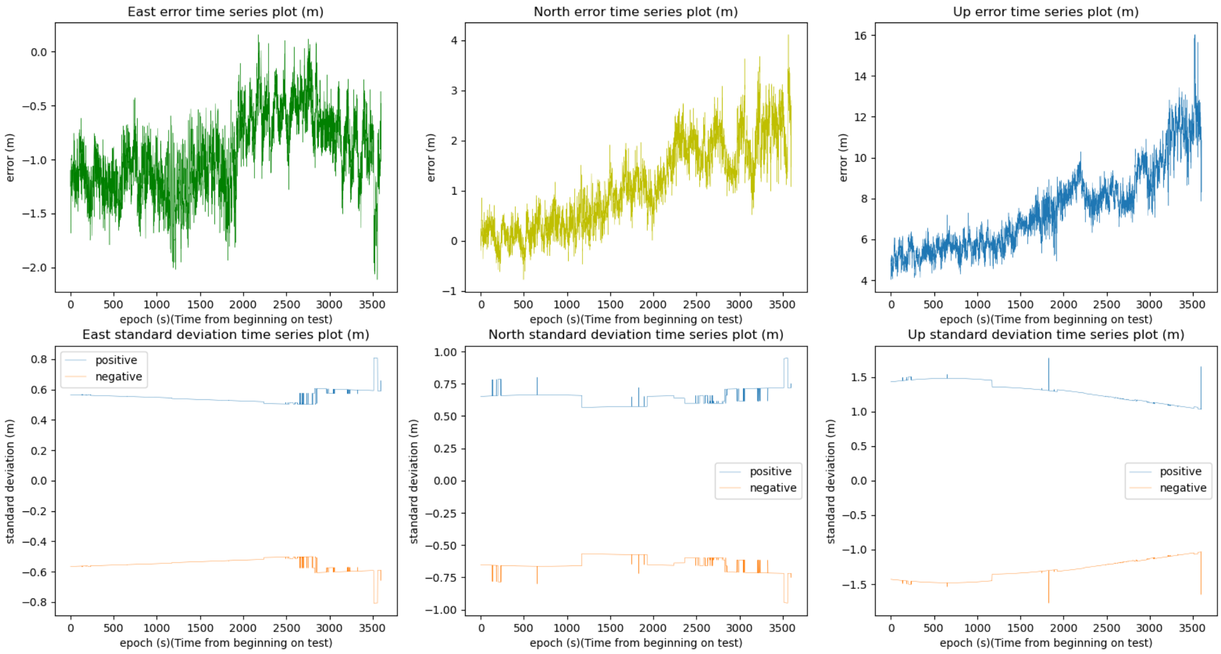
-1.2498992027821423 0.09530165420976866 5.105464656835171
```

**c. Plot the time series of each of these error components (East, North, Up) on separate subplots (use the subplot function in Matlab). On the same graphs, plot the time series of the estimated standard deviations. You must plot both the standard deviation (which is always positive) and the standard deviation multiplied by a negative one (which will then be always negative) in order to get the estimated accuracy "envelope".**

Plot the time series of each error component, then plot the standard deviation based on the covariance matrix.(both positive and negative).

$$C_{\bar{x}} = \left(H^T C_z^{-1} H\right)^{-1} = \sigma_o^2 \left(H^T Q_z^{-1} H\right)^{-1}$$




**d. Discuss the differences between the true and estimated accuracy. Comment on which assumptions you made may influence any discrepancies between the two. Justify your assumptions if necessary.**

The East and North error is relatively lower, which is around 2-4 meters. While the Up error is higher, its maximum value reaches about 16 meters. The assumption I made may influence the differences is that I assume the measurement covariance matrix is the identity matrix.

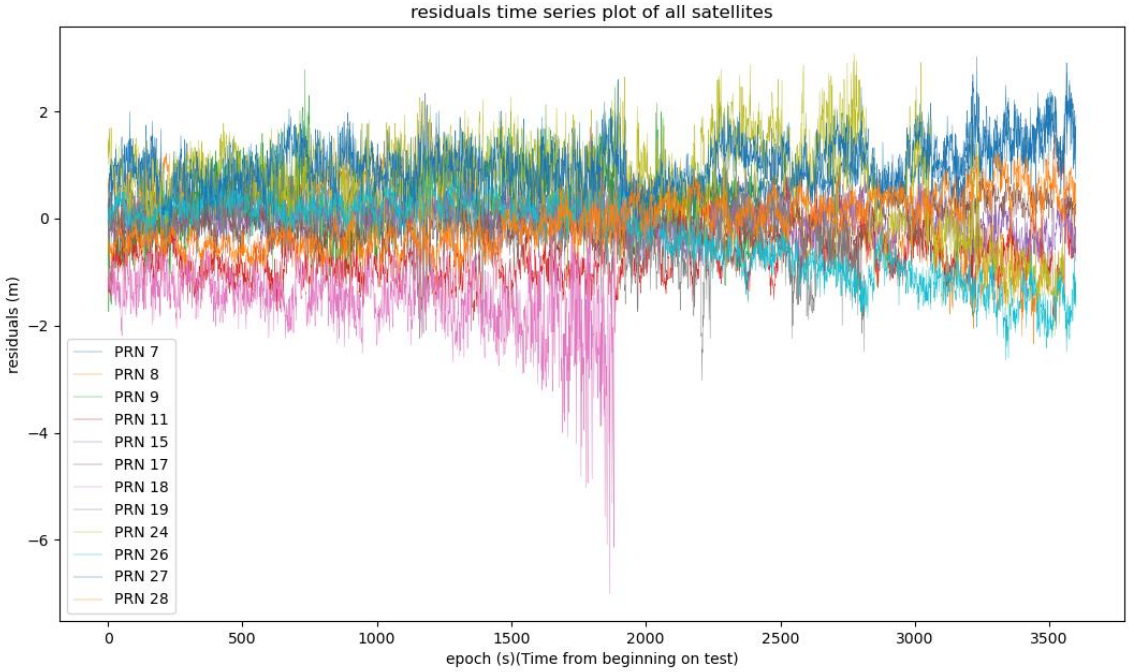
**3. Compare the plots from 2b/c with the DOP values you obtained in Lab 1.**
**a. Discuss the role of DOP in analyzing solutions.**

Normally, DOP is a term used in satellite navigation and geomatics engineering to specify error propagation as a mathematical effect of navigation satellite geometry on positional measurement precision. Lower DOP means better accuracy of the solution. However, current graphs did not show this trend perfectly in the North error and Up error, because the observations we get still has bias and multipath.

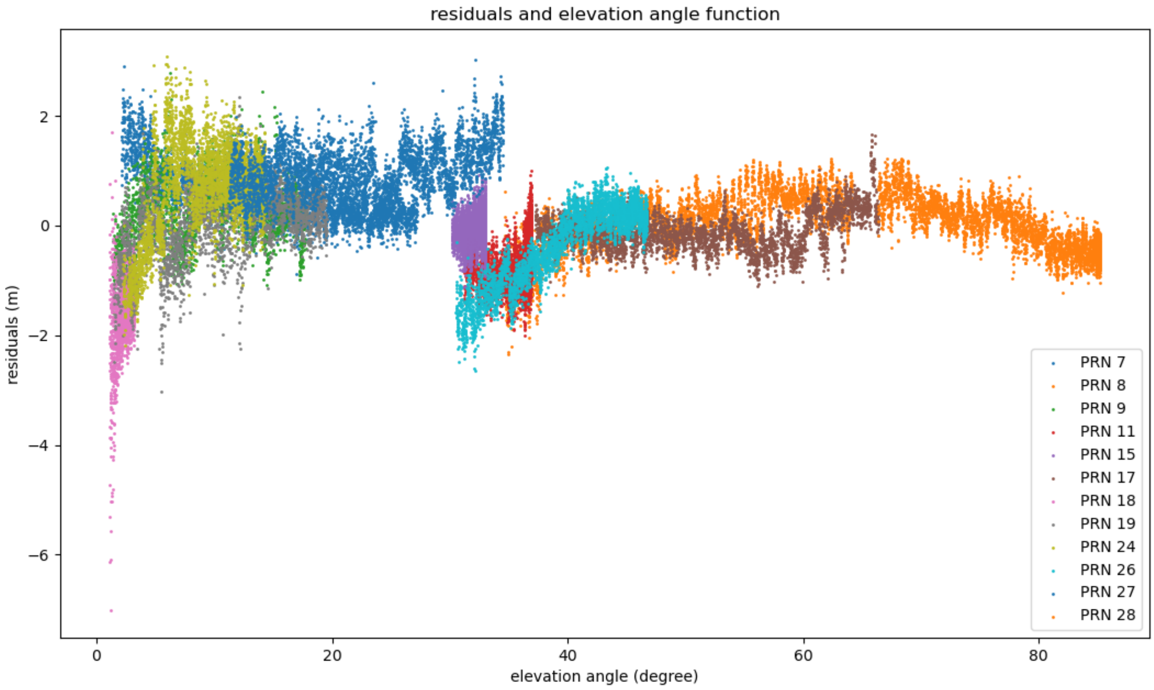
**4. Compute the residuals**
**a. Plot each satellite's residuals as a time series (one plot, with a different colour for each satellite).**

Calculate the residuals based on observation, geodetic range and clock offset. Then divide the residuals to correspond satellites.

$$\bar{r} = z - H\bar{x}$$




**b. Plot all the residuals as a function of satellite elevation angle.**




Transfer the ECEF frame into aer frame and plot elevation angle with its corresponding residuals of each satellite.

**c. Discuss the trends seen in plots 4a/4b and discuss what you see.**

Most of the residuals are in the range of -2 to 2 meters. Onlysatellite 18 has bigger residuals during the 1500 to 2000 epochs. With a lower elevation angle, the residuals have more bias and fluctuation, while higher elevation angle provide more consistent residuals with less fluctuation.

**5. From the tasks above, update your intuitive general conclusion from Lab 1 on the quality of the position estimates obtained by a user from GPS based on the number of the satellites in view, their spatial distribution in the sky as well as the quality of the pseudorange.**

From the above graphs, we can see that the quality of the position estimate in the East is acceptable, while the North error and Up error are relatively higher. Because our observations still have bias and multipath, the current solution still has room for improvement. Most satellites' residuals are in a consistent range and only a few satellites have bigger residuals, which means the solution is not good enough. And for elevation angle, satellites with higher elevation angles provide more consistent residuals which indicate better accuracy. Overall, the current quality of position estimation is not good enough and we should do further processes to improve it.