GNSS puck data collection and analysis report –

OBJECTIVE -

The following report consists of analysis done on two data collection modes –

A. Stationary – Where the GPS puck is held fixed at one position so that the position readings it records should be ideally constant w.r.t time.
B. Walking straight for around 100 meters – Where the GPS puck is carried while walking straight for a recorded distance.

All the analysis is done using Matplotlib library. The Jupyter notebook file is attached in the lab files.

ANALYSIS –

A. Stationary –

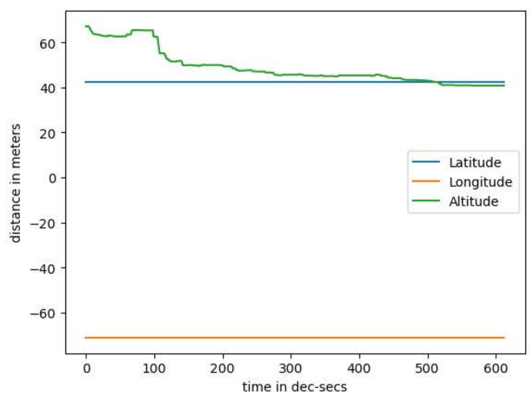

Fig.1 – Lat, Long, Alt w.r.t time

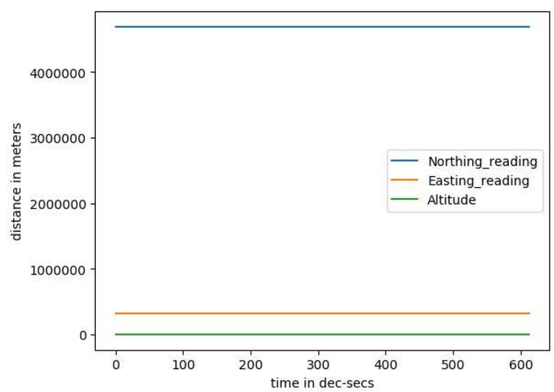

Fig.2 – Northing, Easting, Alt w.r.t time

From the plots, it is evident that the readings are not fluctuating with time. Although we can see that these lines are fairly straight, when it comes to zooming in to minor scales, we'll still see some variations in the readings. To observe these variations let's statistically summarize our data –

	Latitude	Longitude	UTM_northing	UTM_easting	Altitude
mean	42.314325	-71.104829	4.686822e+06	326539.841507	48.775367
skew	-0.345438	-0.448219	-1.125093e-01	-0.265974	1.168010
std	0.000010	0.000014	1.163705e+00	1.115699	7.661526
max	42.314339	-71.104805	4.686824e+06	326541.906250	67.099998
min	42.314301	-71.104858	4.686819e+06	326537.750000	40.799999

Fig.3 – Statistical summary

From the statistical data we can compute the skew(kurtosis) first and then determine the correct error estimate for our measured values. Since, all skew values for our parameters lie in the range(-1.5,1.5) we can consider our error for all parameters as normally distributed. Hence we can take the error estimate parameter as the standard deviation from mean.

From *fig.3* =>

Error in terms of std. deviation –

a. Northing reading – 1.164 m
b. Easting reading – 1.116 m
c. Altitude – 7.661 m

Since we are treating these errors as normal distribution curves, we can have bounds in terms of confidence intervals. These bounds can help us estimate where the position (Northing, Easting, Altitude) of our puck is with confidence probablity.

Hence, with our dataset, we can say that the readings which we'll receive from the puck will have the accuracy to be in the 1st deviation range with 68%; 2 deviations => 95%; 3 deviations => 99.7%.

As the error for altitude is high we can see how it behaves wrt to it's mean in the below figure –

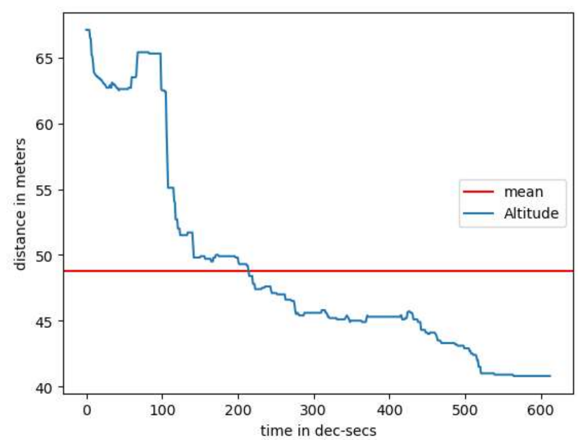

Fig.4 – Altitude/Mean w.r.t time

From the graph, we can see that altitude is decreasing suddenly after some time and stabilizes after a point. While this may be true in our experiment, we cannot say this with certainty.

B. Moving –

While plotting and estimating the GPS data when stationary was fairly simple to plot and conceive. For the moving data, we need to correlate Northing and Easting readings. To do this, we plot both, so that the result which we receive, ideally, should be a straight line as the rate of decrease/increase in the Longitude and Latitude values is constant. Hence, we plot them as below.

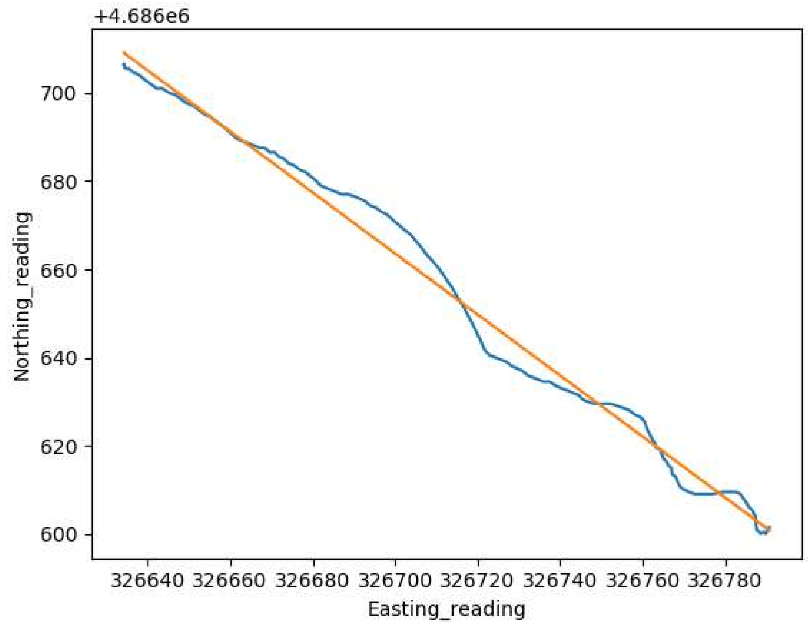

Fig.5 – Northing reading vs Easting reading

To better estimate the error, I plotted a straight line which characterizes our ideal GPS reading line (although not completely ideal, it's mean line through all the points). Below is the statistical summary for our readings.

	Latitude	Longitude	UTM_northing	UTM_easting	Altitude
max	42.313305	-71.101723	4686706.5	326790.65625	73.900002
min	42.312386	-71.103653	4686600.0	326634.21875	23.900000

Fig.6 – Statistical summary

From fig. 6, we can find the range of readings we have covered during our travel. Since our data will not be distributed normally this time, we cannot use standard methods for error estimate. To calculate the error estimate we find the root mean squared error of our data points from the straight line plotted in fig.5. which comes out as **3.545m.**

But still, this won't be the final error, this is the fluctuation error. Let's find the distance travelled by GPS and compare it with the distance travelled.

```
Northing_distance_travelled = max(gps_df_w['UTM_northing']) - min(gps_df_w['UTM_northing'])
Easting_distance_travelled = max(gps_df_w['UTM_easting']) - min(gps_df_w['UTM_easting'])
print(Northing_distance_travelled)
print(Easting_distance_travelled)
Distance_travelled_actual = 120
Distance_travelled_gps = math.sqrt(Northing_distance_travelled**2+Easting_distance_travelled**2)

#Error in gps data v/s actual data

Error = Distance_travelled_gps-Distance_travelled_actual
Error_perc = (Error/120)*100

print('Gps distance travelled %f'%Distance_travelled_gps)
print('Error in meters %f'%Error)
print('Error percentage %f'%Error_perc)
```

```
106.5
156.4375
Gps distance travelled 189.248359
Error in meters 69.248359
Error percentage 57.706966
```

Fig.7 – Calculation of distance estimate error.

From fig. 7, where I calculated the error in Jupyter. We can see the distance travelled in GPS 57.7% more than our distance travelled which is the error in GPS distance measurement for our experiment. (For calculation of this error it is assumed the distance travelled by GPS is in 2 dimensions).

Hence, our ideal line too, which we drew in fig.5, has an error estimate. So, the total error for our moving experiment will be the RMSE error and the distance estimation error.

We can look at the altitude and check the variation. Since, I walked down a hill with some slope, there is sudden decrease in altitude. *Since there is variation in stationary and moving data, we can't really compare our errors in them. But visually it can be inferred as the error is lesser in walking readings as the data shown by our puck co-relates with our experiment.*

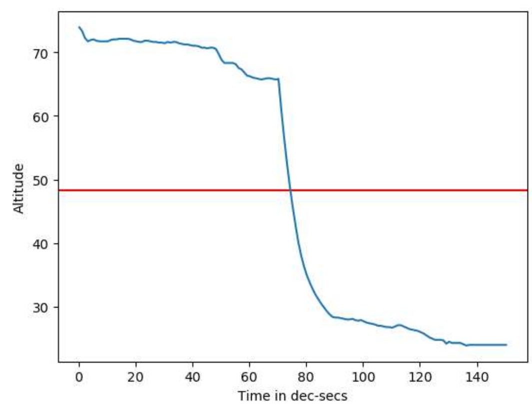

Fig.8– Altitude (in m) vs time

Source of errors for both experiments –

1. Experiment conditions – While these fluctuations may affect our readings, their impact is still evident. The climate conditions for the experiment were- 21^{o} C, Windy in a park with trees overhead. The walking readings were taken on streets hence building interference could affect the readings.
2. Human error – While ideally the puck should be stationary with 0 variance in its position, the puck might have moved a bit while measuring the readings. The laptop was too close to the puck while reading, this can induce errors because of magnetic interference.
3. Common errors –
    a. Ephemeris (Satellite position error)
    b. Multipath (Interference between the radio-waves which have travelled different paths)
    c. Atmospheric refraction.
    d. Clock errors
    e. Satellite position.