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RMUAST Module 1 Exercise Hand-in

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1 Exercises

1.1 Global Navigation Satellite Systems

Russia's GLONASS:

19130km orbital height compared to 20180km for GPS. This means that its satellites have a period of 11 hours and 15 minutes compared to 11 hours and 58 minutes for GPS. It also has fewer operational satellites than GPS; 24 compared to 31. The listed precision is 4.5-7.4 meters compared to 5 meters for GPS. The signal encoding is FDMA compared to CDMA for GPS.

EU's Galileo and China's BeiDou:

These are not yet fully operational.

1.2 GPS architecture

The space segment is simply the operational satellites orbiting earth in a height of roughly 20,200 km. These satelites operates in a 27-slot configuration - yet they have more operational.
The control segment's purpose is to control and monitor the satelites. This segment consists of some control centers with antennas for communication to the satililtes.
The user segment is the everyday electronics such as eg. a GPS-system for your car.

1.3 GNSS error sources

Errors in GNSS position comes from variety of different sourcec. First of them is inaccuracy of receivers clock. Satellite's clocks are synchronized high precision clock, but GNSS receivers have only local and usually low cost clock. This is one of the origins of error in satellites ranges. Other errors come from the fact, that GNSS signal travels through atmosphere and is there distorted. The lower above the horizon is a satellite, the longer distace has the signal to travel through atmosphere and so the larger distorsion and final error. Other source of errors are urban areas. Because the signal is mirrored by the building, measured pseudorange results in larger distance of satellite.

1.4 Dilution of Precision (DOP)

Dilution of precision is term denoting inaccuracies in GNSS positioning originated from satellite constellation geometry and position on the horizon. The higher the value of this parameter is, the lower confidence we have about estimated position. Meaning of GDOP (Geometric Dilution Of Precision) is illustrated in figure 1 which was taken including its description(1).

DOP can be decomposed into following parts:

- HDOP - Horizontal Dillution Of Precision
- VDOP - Vertical Dilution Of Precision
- PDOP - Position Dilution Of Precision
- GDOP - Geometric Dilution Of Precision

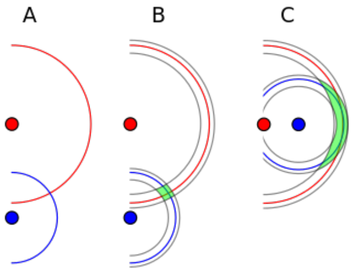


Figure 1: **GDOP** - In A someone has measured the distance to two landmarks, and plotted their point as the intersection of two circles with the measured radius. In B the measurement has some error bounds, and their true location will lie anywhere in the green area. In C the measurement error is the same, but the error on their position has grown considerably due to the arrangement of the landmarks.

1.5 GNSS accuracy

SPS - This is a system where we use 3-4 satellite to triangulate our position on earth. The satellite sends out a signal with their position and the time they were in this position. We use a term called pseudo range to describe the vector between the object on earth and each satellite - the "pseudo"-part is used since it is an approximation of the range and not the true range. Figure 2 illustrates this. Equation 1 shows how to estimate the signal received from a satellite, where b_u is the inaccuracy of the receiving ends clock, c is the speed of light and ϵ_i is an error term handling the imperfections of the real world.

$$\rho_i = |\vec{r}| * b_i * c + \epsilon_i \tag{1}$$

With this equation we end up have x,y,z and b_u as unknowns which require 4 satelite signals. If we simply look up the altitude from our x and y position then we can manage these calculations with 3 satellite signal. The accuracy of this system should be 7.8 meters 95 % of the time.

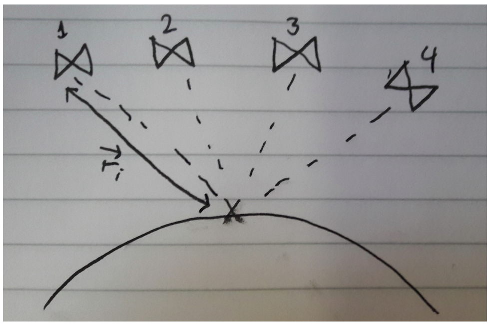


Figure 2: This is the general configuration of the SPS. We have 4 satelites in this instance, where the cross in the drawing is representing the user. $\vec{r_i}$ represents the pseudorange

DGPS - We start out by having the same setup as SPS but include a fixed antenna on the surface. Since the antenna has a fixed location we can make a vector of error terms, which we can transmit to the user. The accuracy of this system should be from 1 to 5 meters (`https://www.fs.fed.us/t-d/pubs/pdfpubs/pdf04712307/pdf04712307dpi300.pdf`).

RTK - Our transmissions from the satelite include a carrier signal where the length of the period is 19 cm and then there is the PRN (pseudo random noise) code, which has a period length of 300 m. Then the idea is to measure the phase between these two signals.This technique has two states and can thereby either be floating or fixed. Floating simply means that you only measure the relative phase and do not know the number of periods for the carrier signal between you and the satellite. Fixed simply means that you know the number of periods for the carrier signal between you and the satellite. The number of periods is used to give a better estimate of the pseudo range and is also known as the integer ambiguity. The RTK technique can give around 1-2 cm of accuracy.

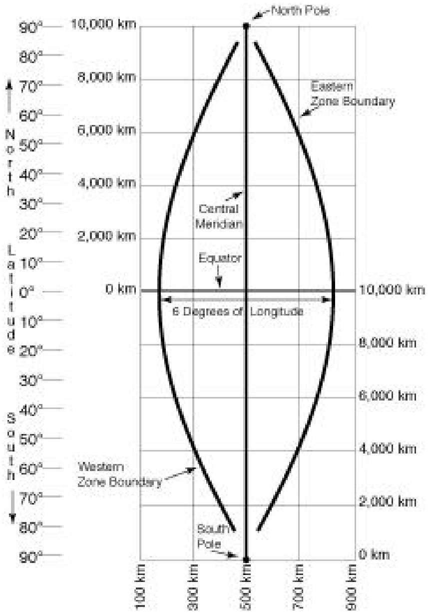


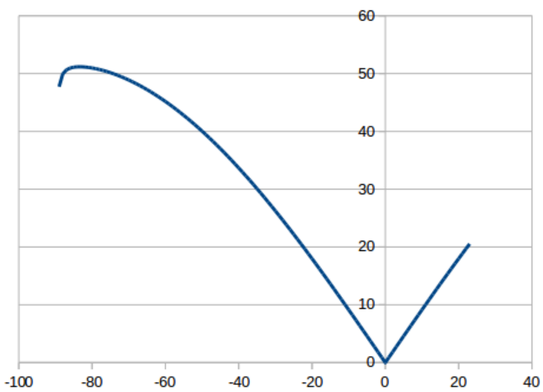
Figure 3: Distortion within a UTM zone.

2 Coordinate systems

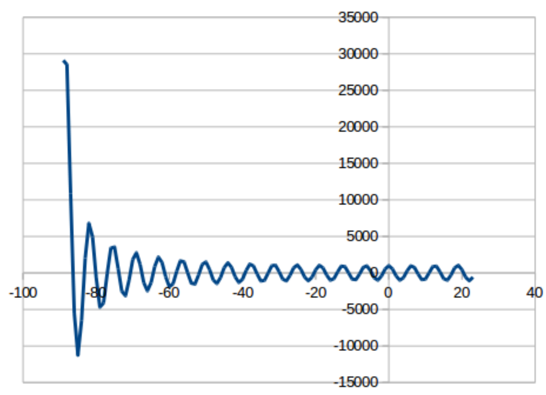
2.1 Universal Transversal Mercator (UTM) accuracy

We tried adding 1km to the northing and easting parts of the UTM format before converting back to geodetic and found that the error was very significant for locations far from the zone origin. This is shown in figure 3.

Delving deeper, we decided to plot the error as a function of latitudes. Adding 1km to the easting for different latitudes results in latitude and longitude position errors shown in figures 4a and 4b. The plots are cut off at 23 degrees' latitude but this is not important as they are symmetric around 0 degrees. For all of these plots the longitude is fixed at 0 degrees. From these plots we see, as expected, that the distortion becomes greater the further we go from the zone origin, both in terms of latitude and longitude. Figures 5a and 5b show errors after adding 1km to the northing for the same latitudes. Note that in this case the latitude position error is minimized (closest to 1km) at -45 (and 45) degrees. The longitude position error shows a similar behaviour however far less aggressive.

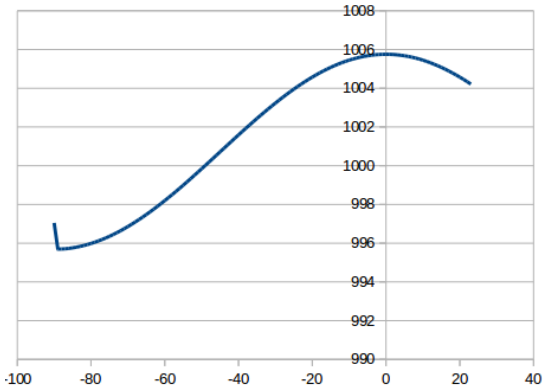


(a) Latitude position error(y-axis) versus latitude (x-axis).

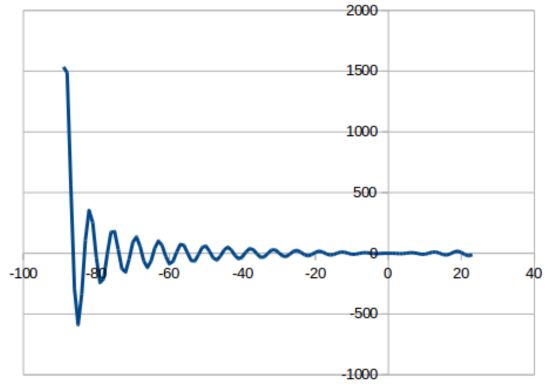


(b) Longitude position error(y-axis) versus latitude(x-axis).

Figure 4: Distortion after adding 1km to easting at a longitude of 0 degrees.



(a) Latitude position error(y-axis) versus latitude(x-axis).



(b) Longitude position error(y-axis) versus latitude(x-axis).

Figure 5: Distortion after adding 1km to northing at a longitude of 0 degrees.

2.2 National Marine Electronics Association (NMEA) 0183 data

Figure 6 shows the plots of the Mean Sea Level with respect to time, while 8 shows the plotted drone-track. Figure 7 shows the GNSS accuracy plotted versus time.

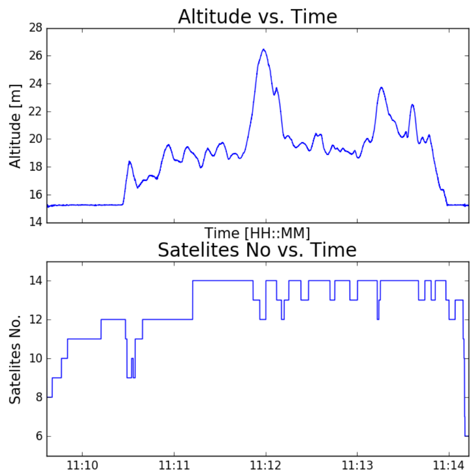


Figure 6: Plot of parsed NMEA fields

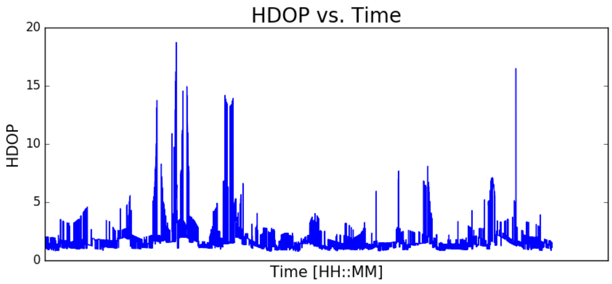


Figure 7: Static GNSS accuracy

Figure 8: Plot of drone track in Google Earth

References

[1] Gdop picture. https://en.wikipedia.org/wiki/Dilution_of_precision_(navigation).