Exercises, module 2 week 38

UAV attitude estimation

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3 Global Navigation Satellite Systems

In addition to GPS in USA, Europe has Galileo, Russia has GLONASS, BNSS in China and others. GPS is most commonly used around the globe and has been established the longest. Galileo was established in 2016 and will be fully deployed in 2020. The Chinese system is much more accurate compared to e.g. GPS with fewer satellites since the satellites are always located above China. The Russian system works better in the northern hemisphere.

3.1 GPS architecture

The GPS space segment consists of a constellation of satellites transmitting radio signals to the user.

The GPS control segment consists of a global network of ground facilities that track the GPS satellites, monitor their transmissions perform analyses and send commands and data to the constellation of satellites.

The GPS user segment consists of the GPS receivers that receive the GPS signals from the GPS satellites and uses the signals to calculate the users' 3 dimensional position and time.

3.2 GNSS error sources

GNSS are affected by Multipathing, where the signal from the satellite is reflected by an object before being received by the drone, causing a delay in the signal that can cause the receiver to calculate an incorrect position. Another contribute is the earths atmosphere molecules which slows down the signals. If the clock on the receiver is not precise then it can also introduce an error.

Additional errors, which are less prominent include the drift of the satellites' atomic clocks and slight deviation from the planned orbits.

3.2.1 Dilution of Precision (DOP)

DOP is a term used to specify the error on positional measurement based on navigation satellites. DOP can be expressed as the separate measurements GDOP, PDOP, HDOP, VDOP denoting Geometric, Positional, Horizontal and Vertical Dilution of Precision, respectively.

DOP is based on geometry and yield a value larger than 1. The error should be multiplied by this value to take into account the geometrical position of the satellites. 2 satellites very close to each other do not provide much information, so more scattered satellites yield a lower DOP.

3.2.2 Real Time Kinematics GNSS

RTK measures the carrier wave phase in addition to the pseudo-random noised signal. Since the carrier wave is very high frequency, this requires high quality electronics and is thus more expensive. This methods attempts to calculate the total number of full wavelengths between the satellite and the receiving system. This problem is a very difficult task and is referred to as integer ambiguity.

3.2.3 GNSS accuracy

The following four solutions exist in the GPS system:

1. Standard Positioning Service (SPS) uses 4 satellites to measure the position of the receiver. Accuracy is around 15m [1].
2. Differential GPS (DPGS) also uses stationary receivers with known locations on the ground to better estimate the error terms mentioned in section 3.2. Accuracy is around 10cm [1].
3. RTK float and fixed: Fixed is the most accurate. Accuracy is down to around 1cm [2].

Usually the GPS solution starts using SPS and stabilizes towards RTK fixed. However, the more accuracy one wants, the more expensive the solution.

4 Coordinate system

4.1 Universal Transversal Mercator (UTM) accuracy

UTM is a coordinate system where the globe is divided into section cut-outs and the coordinates are then related to the section specified by the first number.

From the given geodetic coordinates $N55.47°\ E010.33°$ the UTM coordinates are calculated to be 32 U 584078.06983e 6147898.57170n. In table 4.1 one can see the geodetic coordinates based on a 1km change in UTM coordinates and the resulting actual distance to the original geodetic coordinates.

Difference	Geodetic	Distance
1km North	$N55.48°\ E010.33$	$0.9991\ [km]$
1km East	$N55.47°\ E010.35$	$0.997\ [km]$

This difference in distance is bigger the further away from the center of the section. For long distances, one should thus use geodetic coordinates and use UTM for short distances and when located near the center of a section.

4.2 National Marine Electronics Association (NMEA) 0183 data

Figure 1a shows the altitude above the Mean Sea Level. It seems like the drone is turned on for 100s while on the ground (suggesting a bias of 15m) and then it flies for 300s before landing again.

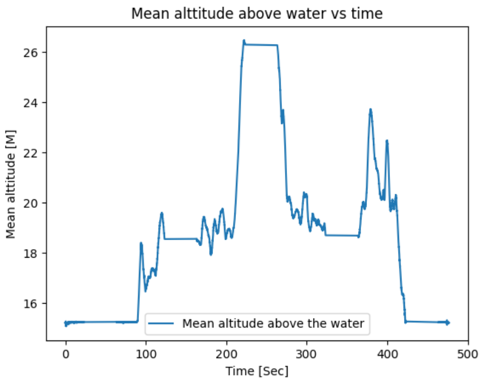
The amount of satellites in range of the drone in this period can be seen in figure 1b. It can clearly be seen how initially few satellites' signals are picked up, but the amount increases over time and stabilizes.

Figure 1d shows a track of the drone flying. To convert the GNSS data to the correct format to be plotted with the KML format equation 1 was used.

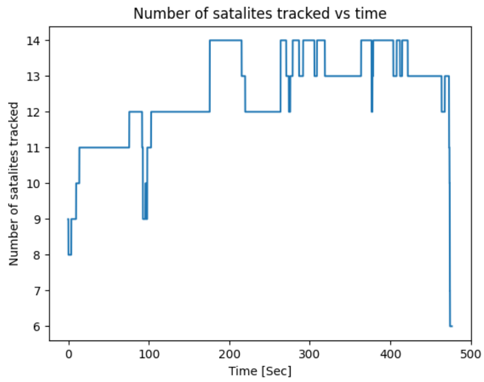
$$\begin{aligned} &\text{Data format = DDSSSS.SS} \\ &\qquad\text{Long = DD + (SSSS:SS) / 60 if N else if S = DD - (SSSS.SS) / 60} \\ &\qquad\ \ \text{Lat = DD + (SSSS.SS) / 60 if E else if W = DD + (SSSS.SS) / 60} \end{aligned} \tag{1}$$

Equation 1 was also used when making the map for the static data.

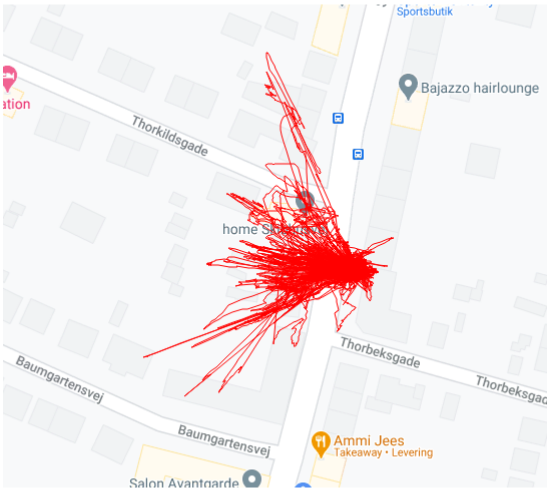
Figure 1c shows the Static GNAA accuracy over a 24H period of time, it can be seen the accuracy is not good - the biggest spread was measured to $120[m]$. This is a lot of variation an would need to be accounted for.



(a) Altitude above Mean Sea Level



(b) Number of satellites



(c) Static GNSS accuracy

(d) Moving drone track

Figure 1: NMEA data plots

References

[1] GrindGis. "Difference Between GPS and DGPS". URL: https://grindgis.com/blog/difference-between-gps-and-dgps.

[2] Novatel. "An Introduction to GNSS". URL: https://novatel.com/an-introduction-to-gnss/chapter-4-gnsserror-sources/error-sources.