Lab 2 - Global Navigation Satellite Systems
Introduction to Drone Technology

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1 Global Navigation Satellite Systems

1.1 GPS architecture

The term GNSS (Global navigation satellite system) is the general description of position, navigation and timing of any satellite constellation on either a global or regional level. While the GPS is the American version of GNSS other known versions are:

- Galileo (Europe)
- Beidou (The People's Republic of China)
- QZSS (Japan)
- IRNSS (India)
- GLONASS (Russia)

The typical GPS accuracy is $\pm 15m$

GPS Space segment
A constellation of satellites transmitting radio signals to the users.

Control segment
Several ground facilities that can track the GPS satellites, monitor their transmissions, perform analyses, and send commands and data to the constellations on a global scale.

User segment
The GPS receiver equipment, which is capable of receiving signals from the GPS satellites and use the transmitted data to calculate the 3-dimensional position and time of the user. Receivers could be phones and ATM's.

1.2 GNSS error sources

Most dominant error sources of GNSS:

Multipath: Signal reflections off of structures such as buildings. (± 1 m)
Geometry: When positioning of the satellites aren't widely spread out (± 2.5m)
Atmosphere: Change of the speed of propagation of a GPS signal due to atmospheric conditions (Mostly the atmosphere refracting the satellite signals) (± 0.5 m- ± 5 m)

1.3 Dilution of Precision (DOP)

The DOP's are defined with an unitless scalar confidence value. The sources used in this exercise: [1], [2] & [3].

GDOP
Known as Geometric Dilution of precision and describes the error caused by the relative position of the GPS satellites.

PDOP
Known as Position Dilution of precision and describes how many satellites are spread evenly throughout the sky.

HDOP
Known as Horizontal Dilution of precision and describes horizontal (Latitude and Longitude) position value.

VDOP
Known as Vertical Dilution of precision and describes vertical (Altitude) position value.

1.4 Real Time Kinematics GNSS

RTK
(Real time Kinematics) is the way of trying to search for and correct common errors in GNSS. By using the measurement of the phase of a signal's carrier wave combined with the information content of the signal to give real-time corrections with accuracy within centimetres [4].

The **Integer Ambiguity** is the number of whole cycles on the path from the satellite to the receiver. The carrier-phase measurements are ambiguous by a constant integer amount, because the true initial cycle count is unknown.

1.5 GNSS accuracy

SPS (Standard Positioning Service)
Calculations of the GPS position measurements that are based only on the C/A code of the signal. The distance estimations are considered pseudo-range measurements (± 3 m-10 m)

DGPS (Differential GPS)
An enhancement to the GPS, where accuracy is improved by using an additional ground fixed reference station and comparing the difference between these signals to correct the general signal (± 10 cm-40 cm)

RTK Float
This algorithm aims to identify the probable location using statistical methods, but never attempts to solve the integer ambiguity problem, as it only tries to identify the most probable position within a circle drawn around the current estimated position (± 20 cm-40 cm)

RTK Fixed
This algorithm aims to solve the integer ambiguity problem and is only being used, when it has done so. The rest of the time RTK float is used. (± 1 cm-2cm)

2 Coordinate systems

2.1 Universal Transversal Mercator (UTM) accuracy

Reference point: $N55.47°$ $E010.33°$. The first value is latitude and the latter longitude. Latitude is from 0 to 90 degrees and longitude from 0 to 180. To easily distinguish the two latitude is denoted with two digits and longitude with three. To compare the results with different groups, it is important to use the same reference point. The error is not uniform throughout the UTM "slices", and being in the same general area will result in the same error being applied.

The reference point was converted to UTM and two new points was generated by adding 1000 meters to east and north respectively, and converting back into latitude and longitude. The Great Circle formula was then used to calculate the actual distance between these points, implemented with the following code:

```
distance_radians = 2 * asin(sqrt((sin((lat1 - lat2) / 2))**2 + cos(lat1) * cos(lat2)
* (sin((lon1 - lon2) / 2))**2))
radius_earth_km = 1.852 * (180 * 60 / pi)
d = radius_earth_km * distance_radians
```

Point	Coordinate	Great Circle Distance [km]	Error [%]
Reference	$N55.47°$ $E010.33°$	-	-
1 km East	$N55.46982716°$ $E010.34581377°$	0.99624960	-0.37504049
1 km North	$N55.47898330°$ $E010.33030256°$	0.99840561	-0.15943895

There is a difference in the error between moving east and north, where moving north is more accurate. Moving north means moving along a longitude, which by definition is a great circle.

2.2 National Marine Electronics Association (NMEA) 0183 data

Figure 1 shows the plots of the Altitude above Mean Sea Level and the number of satellites tracked, with respect to time during the drone flight.

Figure 2 shows the drone track during the flight. The NMEA Data represents latitude and longitude in the format DDMM.MMMMM and DDDMM.MMMMM [5]. The kml format uses the DD.DDDDD and DDD.DDDDD formats. To convert the NMEA data to the kml format, the minutes are divided by 60 and added to the degrees.

Figure 3 is the drone track for the static data, and it illustrated the inaccuracies of the GNSS data. This data is being recorded in an urban area, and is therefore more subject to noise and disturbances.

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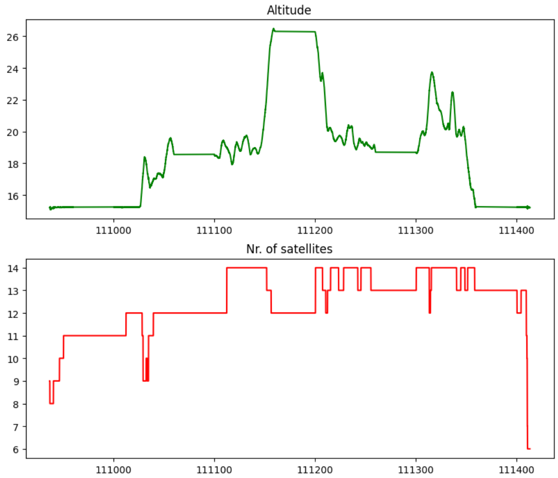
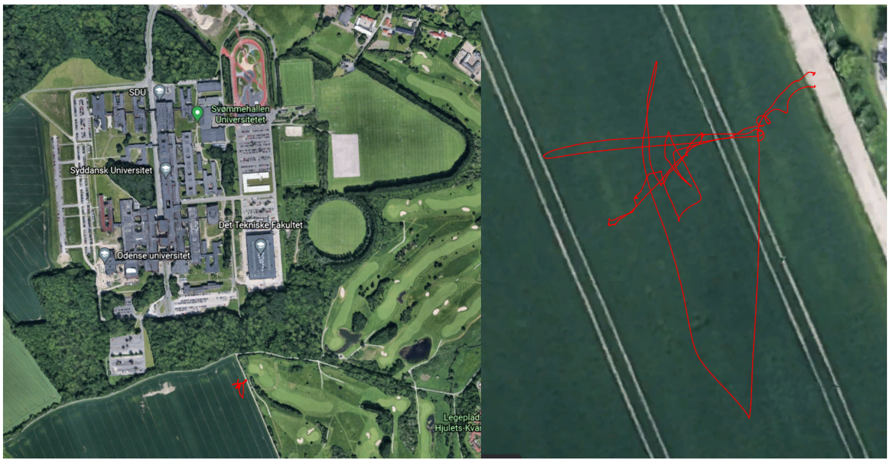


Figure 1: Plot of Altitude and number of satellites tracked with respect tot time, in the file `nmea_trimble_gnss_eduquad_flight.txt`.



(a) Drone track location

(b) Drone track zoomed

Figure 2: Plot of the drone track from afar and zoomed in.

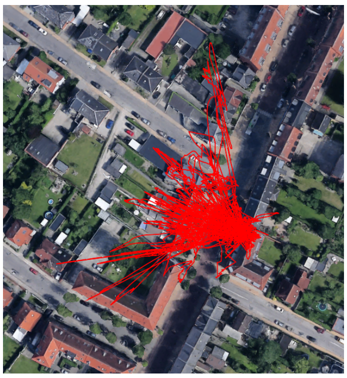


Figure 3: Drone track for the static data.

3 Bibliography

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[4] Industry Articles. What is rtk? `https://www.oxts.com/rtk/`. Online; accessed 27 September 2021.

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