# GNSS VS. INS BEHAVIOR AND POSITION DATA PROCESSING

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**Abstract**

**Both systems (GNSS and inertial sensors) are very good support by localization. The GNSS is quite good localization method when it works. Between two sentences of GNSS signal the position could be very precise interpolated by INS (in the range of seconds). The INS could be also used to estimate special behavior on roads (driving thru road-gaps, roundabout, rising or sinking of the road, 90deg. turn, acceleration and breaking, vibration or hit to obstacle etc.) Localization using INS based on low cost MEMS accelerometer is above the range of minutes impossible due to rising error caused by integration.**

## 1 Inertial navigation system

Is a sensor system based on three perpendicular accelerometers and three perpendicular gyroscopes. Modern MEMS accelerometers even with 14 bit resolution and 500Hz sampling rate are not able to deliver reliable position information because after tenth of seconds the integration error overcomes the position itself (1) and (2). More accurate accelerometers for example (pendulum integrating gyroscope accelerometer - PIGA) are used only in space technology and ICBM. This not means that MEMS accelerometers are completely useless. It could be utilized for example to measuring of direction of gravitation force.

MEMS gyroscope has better properties because the output is angular velocity and it needs only first degree integration. The rotation output could be utilized in range of minutes. Rotation of the Earth is not significant within MEMS-gyro accuracy. More accurate devices are optical gyroscopes (ring laser gyroscope RLG or fiber optic gyroscope FOG) these gyroscopes are quite expensive devices (thousands of € for one axis). Optical gyroscopes are very accurate in range of days and the rotation of the Earth is very significant and could be measured with these devices.

$$v = v_0 + \int_{t=0}^{T} a\,dt \tag{1}$$

$$s = s_0 + \int_{t=0}^{T} v\,dt \tag{2}$$

Implementation to MATLAB could be utilized by following script (trapezoidal numerical integration):

```
sample_time = 1/sample_frequency;
%+-1,7g 14 bit      = 0.0004672 g LSB 0.0045816669 m/s-2 LSB
%+-150°/s 14 bit    = 0.03663 °/s LSB 0.000639314105 rad LSB
%len = length(Xacc);
%adis16354
len=17000;
velocity(3,len)=0;
for i = 2:len
velocity(1,i)=(((Xacc(i)+Xacc(i-1))/2)*0.0045816669*sample_time)+velocity(1,i-1);
velocity(2,i)=(((Yacc(i)+Yacc(i-1))/2)*0.0045816669*sample_time)+velocity(2,i-1);
velocity(3,i)=(((Zacc(i)+Zacc(i-1))/2)*0.0045816669*sample_time)+velocity(3,i-1);
end

angle(3,len)=0;
```

```
for i = 2:len
angle(1,i)=(((Xgyr(i)+Xgyr(i-1))/2)*0.000639314105*sample_time)+angle(1,i-1);
angle(2,i)=(((Ygyr(i)+Ygyr(i-1))/2)*0.000639314105*sample_time)+angle(2,i-1);
angle(3,i)=(((Zgyr(i)+Zgyr(i-1))/2)*0.000639314105*sample_time)+angle(3,i-1);
end

track(3,len)=0;
for i = 2:len
track(1,i)=(((velocity(1,i)+velocity(1,i-1))/2)*sample_time)+track(1,i-1);
track(2,i)=(((velocity(2,i)+velocity(2,i-1))/2)*sample_time)+track(2,i-1);
track(3,i)=(((velocity(3,i)+velocity(3,i-1))/2)*sample_time)+track(3,i-1);
end

rotated_track(2,len)=0;
for i = 2:len
rotated_track(1,i)=(track(1,i)*cos(angle(3,i)))-(track(1,i)*sin(angle(3,i)));
rotated_track(2,i)=(track(1,i)*sin(angle(3,i)))+(track(2,i)*cos(angle(3,i)));
end
```

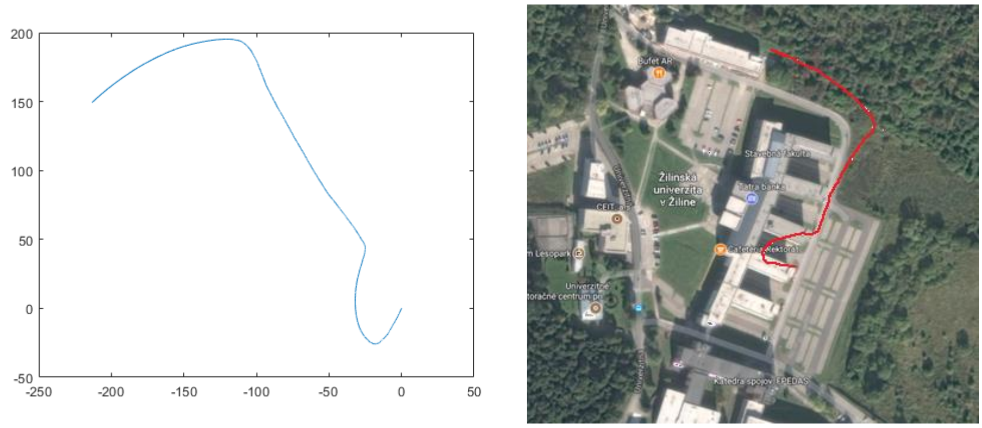

Figure 1: Track as MATLAB output (in meters) and projection in a map

On Figure 1 could be seen first 31 seconds (17000 samples) of record plotted in a map. This is very poor result but still the 90 deg. turn could be recognized.

## 2 Global navigation satellite system

Is based on satellites in space (space segment) and ground stations (control segment). The satellites are equipped with atomic clock for accurate time information. These (military) systems have non-military by-product: the localization service for all users worldwide (which could be turned off within a minute or give false data in case of war). Nowadays only two systems are working in global range (GPS from USA and GLONASS from Russia) next systems are Chinese BEIDOU and European GALILEO, whose are at this time not in global constellation.

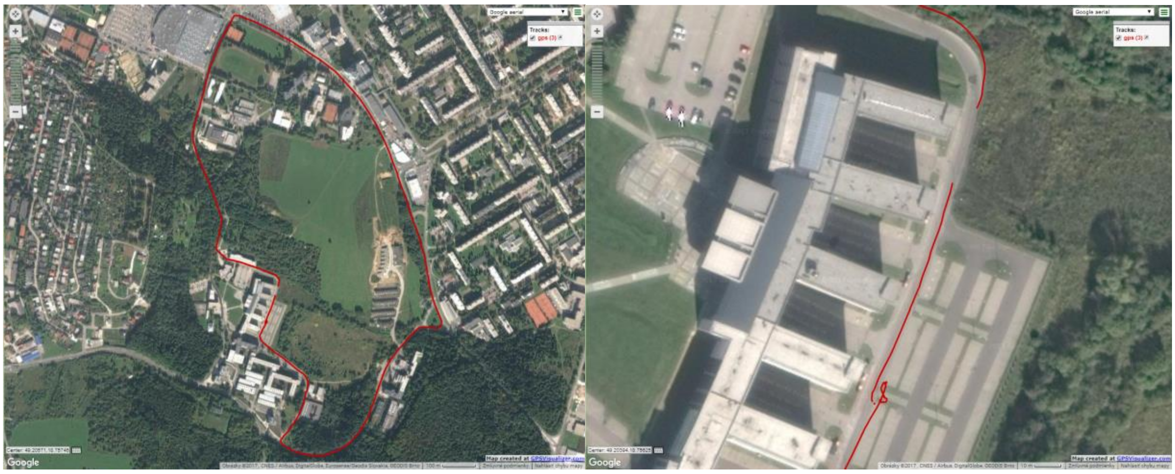
Figure 2: The test track (left) and short 6s absence of GNSS signal (right)

On our test track GPS only receiver was used. On left side of Figure 2 the GPS signal looks very accurate, by detailed observation (left) a lack of GPS signal for 6 seconds could be observed.

## 3 Comparison and conclusion

Modern positioning and navigation system are utilizing as many sources of information as possible to get reliable decision. Sometimes the sensors are utilized in bad manner. Typical mistake is utilizing MEMS accelerometer as inertial navigation sensor for long term navigation. An perfect invention by data minig from accelerometer is where accelerometer is used as detector of road gaps in combination with GNSS it delivers to server the latitude and longitude of road gap. Another article is comparing services GPS and GLONASS. The most effective and robust is the combination of these services . The accuracy of GNSS cannot be increased by combination of the services. What real increases is the availability in disturbing environment. Another approach is utilizing accelerometer to get vehicle displacement by breaking together with wheel position sensor and . New appraches by data fusion in vehicle are described in . Accelerometers and gyroscopes could be used for example for special road behavior like detection of roundabout and detection of which exit was chosen. Next way is for exaple detection of slowing hump. Also detection of curves etc. Allof these approaches could be used in road transport.

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