Kalman Filters and Localization

December 13, 2022

Localization

Common Sensors

- GPS: Uses time-of-flight to several satellites to estimate x/y/z position
- Gyroscope: Electromechanical device for determining the direction of gravity
- Accelerometer: Measures the angular acceleration
- Magnetometer: Uses a magnet to determine magnetic North
- IMU: Integrates gyroscope, accelerometer, magnetometer to determine location.

The actual IMU and GPS algorithms are outside the scope of this presentation.

Kalman Filter

Many techniques exist for filtering the data. The provided MATLAB code uses the standard kalman filter.
$\bar{u}_k = u_k - \delta u_k + w_k$
where u_k is a signal, w_k is an additive noise matrix, and δu_k is a slowly varying measurement bias:
$\delta u_k = \delta u_{k-1} + w_k^*$
and w_k^* is an additive noise matrix with a specific covariance matrix, derived from the data. Each datapoint is then determined by another iterative function: $u_{k+1} = f(u_k)$

$$u_k = u_{k-1} - \delta(\delta u_{k-2} + w_k^*) + w_k$$

Our gyroscope has a known error of .01 degrees latitude per second, showing a cumulative growth in the next slide along the y and z directions.

Task 1: Error Growth

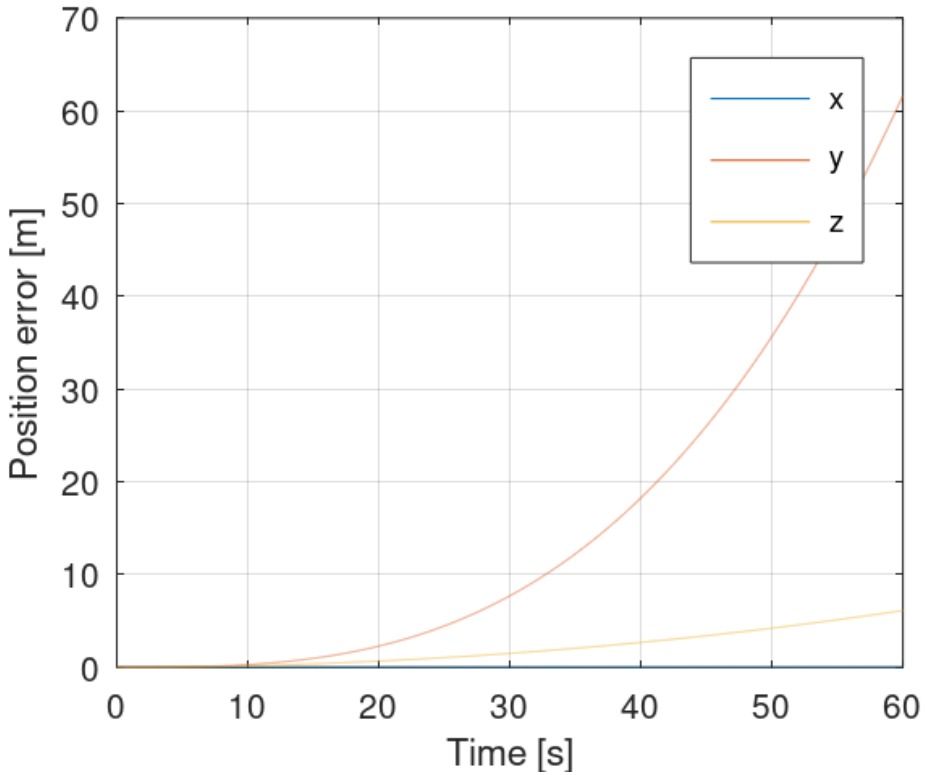


Figure: Error Growth over time for unaided IMU.

We can see that, as expected, the error rate grows over time without bound.

Error Bias

This error arises from the uncertainty of the accelerometer since the acceleration, a in the x, z directions is initialized as:

$$a_x = 0, a_z = -g$$

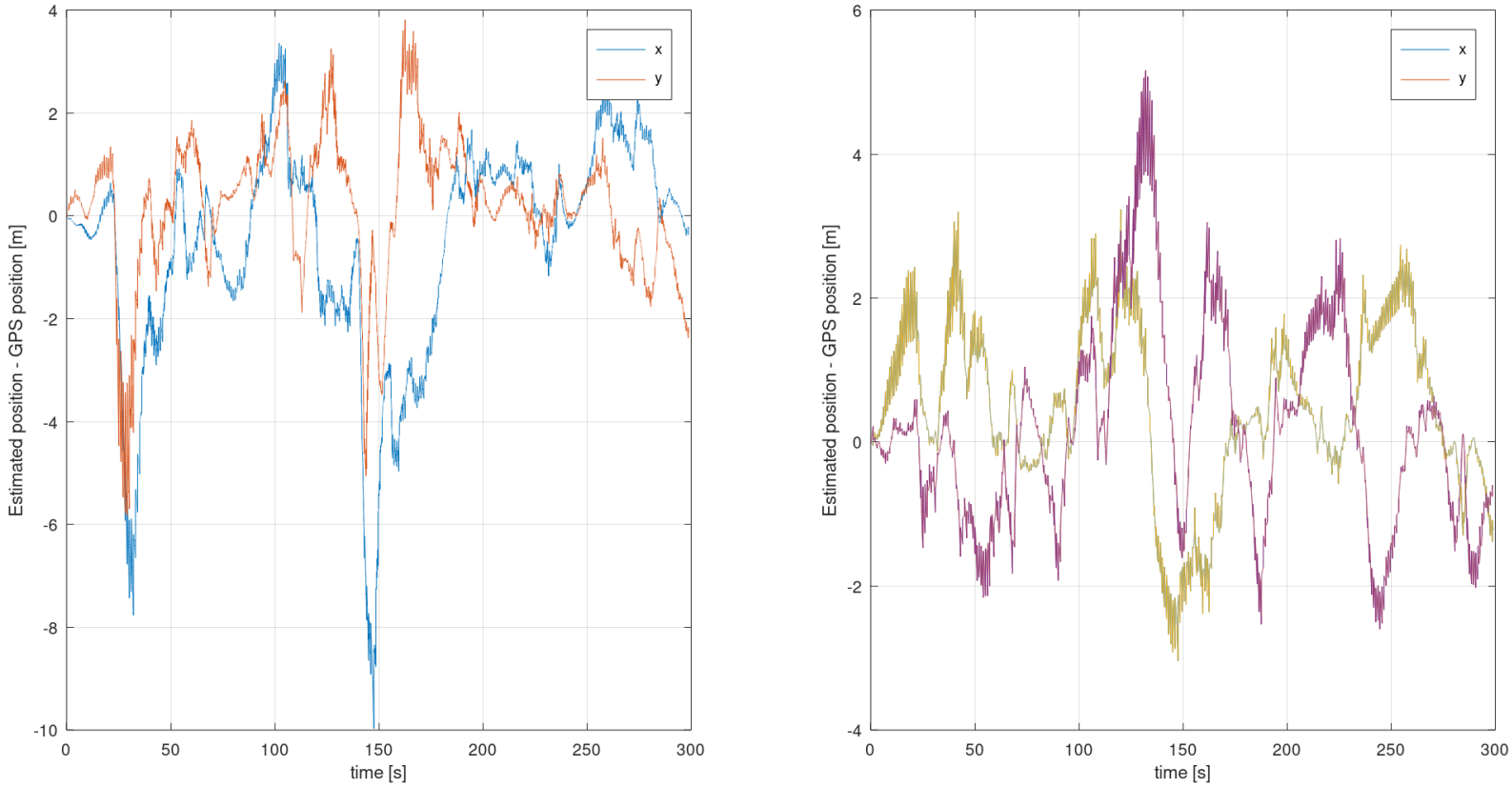
$$\delta a = \begin{bmatrix} \delta a_x \\ \delta a_z \end{bmatrix} = \begin{bmatrix} -g\delta a \\ 0 \end{bmatrix}$$

Integrating over the iterative function from the previous, we know that

$$\delta a(t) = \delta u_0 + \int_0^t err_0 \cdot dt$$

where the err_0 is the instantaneous error. There should be no signicant difference in bias between Lund and Stockholm.

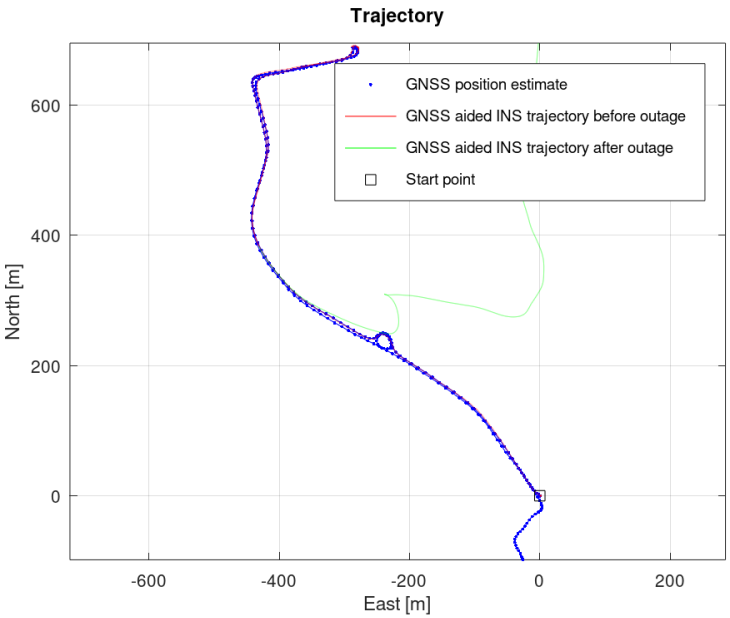
Task2 : Location



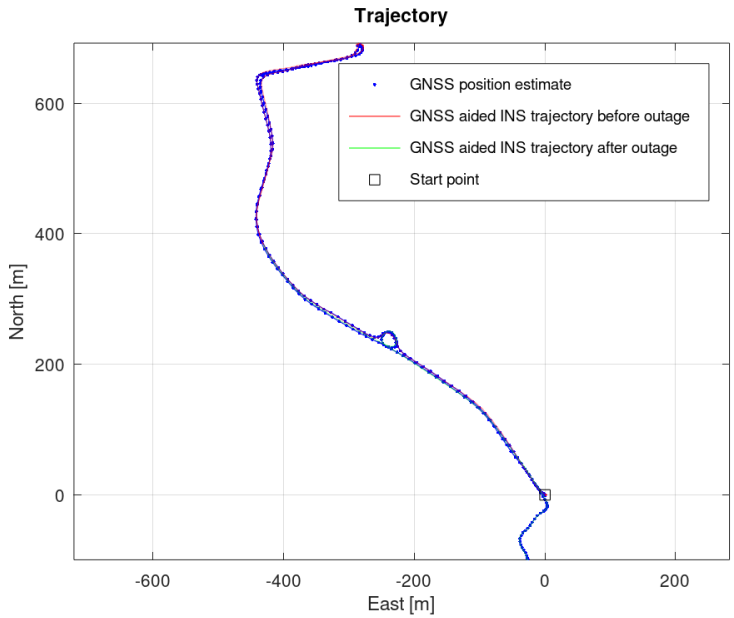
(a) With Outage RMS Error = 187.37 (b) Without Outage RMS Error = 1.86

Figure: Location over time for aided IMU. The error is too small for these plots to be of much use, even when zoomed in.

Task2 : Difference



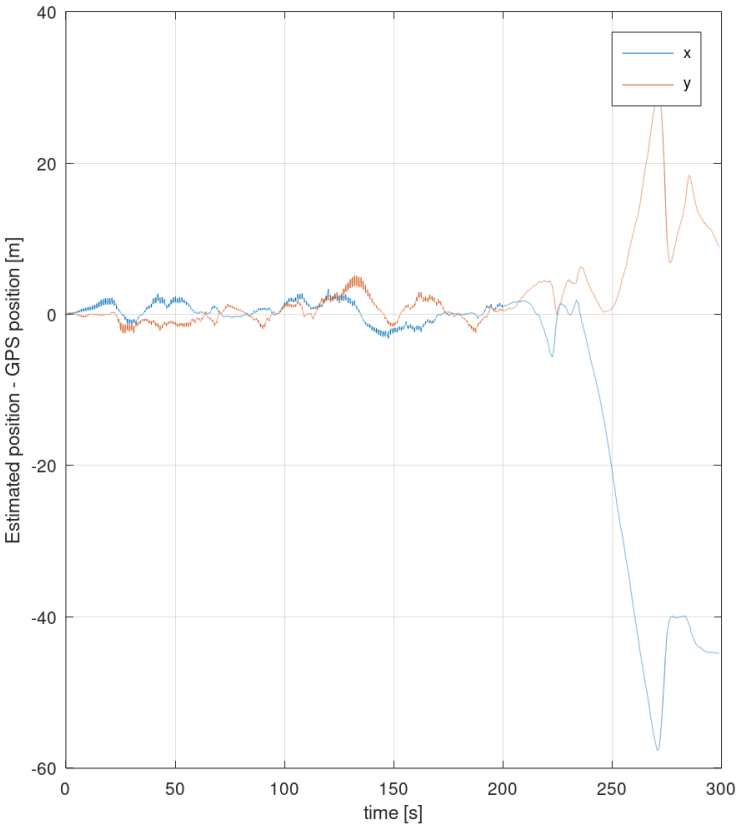
(a) With Outage RMS Error = 1.65

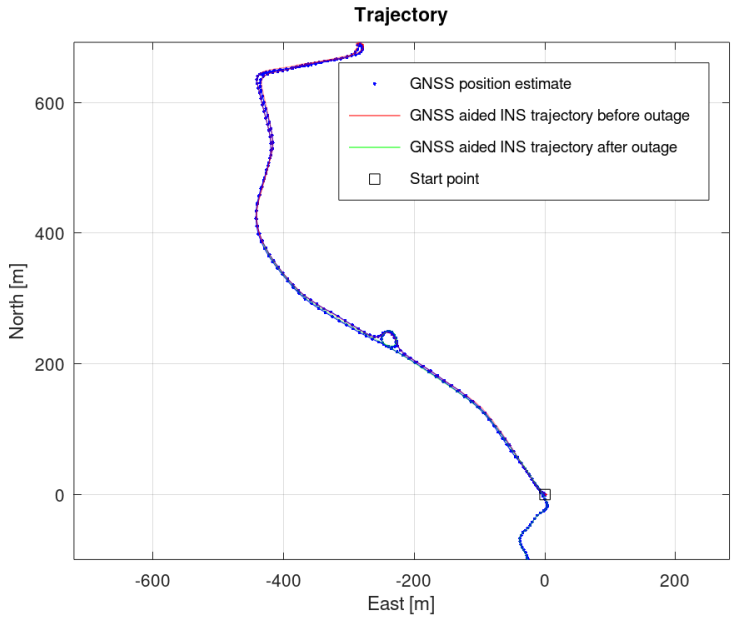


(b) Without Outage RMS Error = 1.56

Figure: Error over time for aided IMU. Using IMU + Accelerometer data.

Task3 : Non- Holonomic



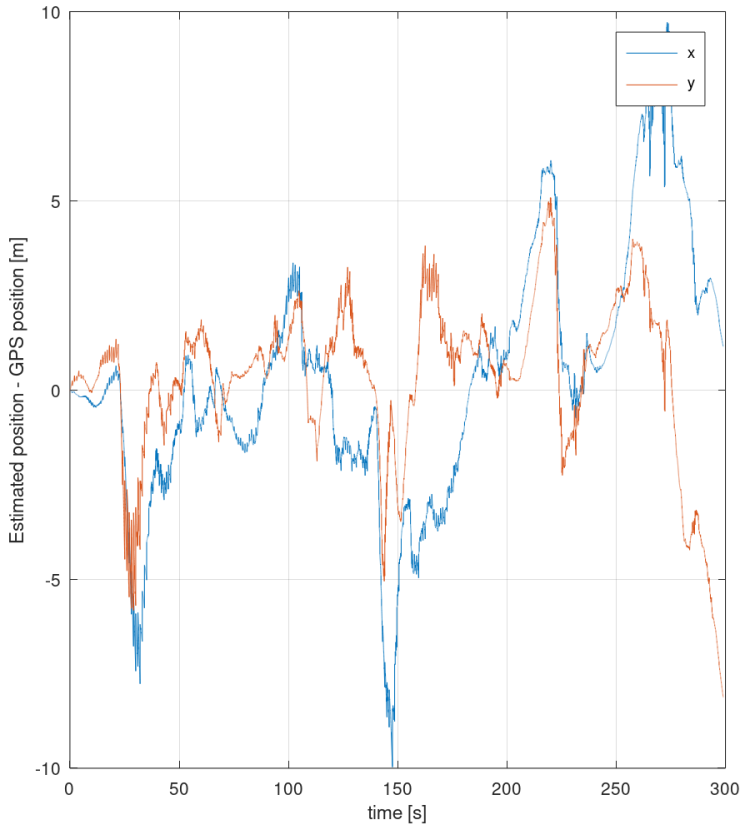


(a) X, Y Error, RMS Error = 1.56

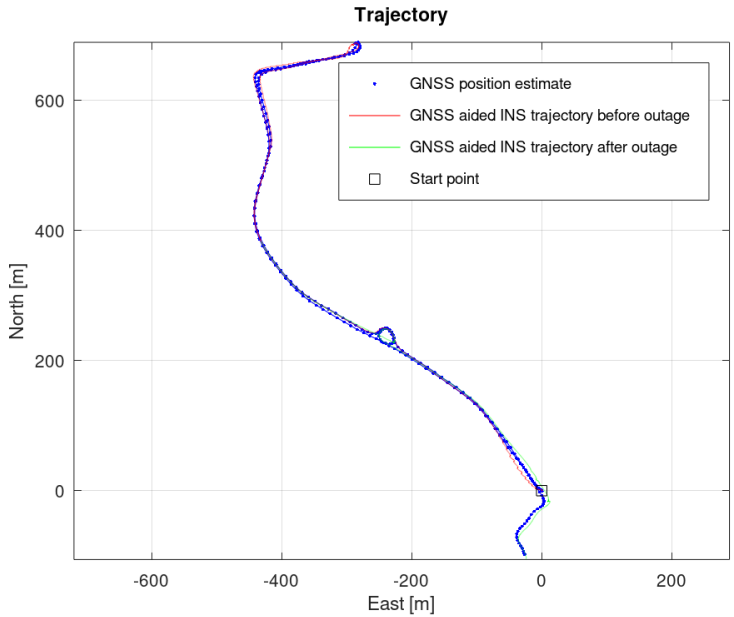
(b) Trajectory

Figure: Error over time for aided IMU. Using IMU + Accelerometer data.

Task4 : Speed data



(a) X, Y Error, RMS Error = 3.9327



(b) Trajectory

Figure: Error over time for aided IMU. Using IMU + Accelerometer data.