EKF based Localization of ePolaris ATV
Tabish Badar, MSc thesis

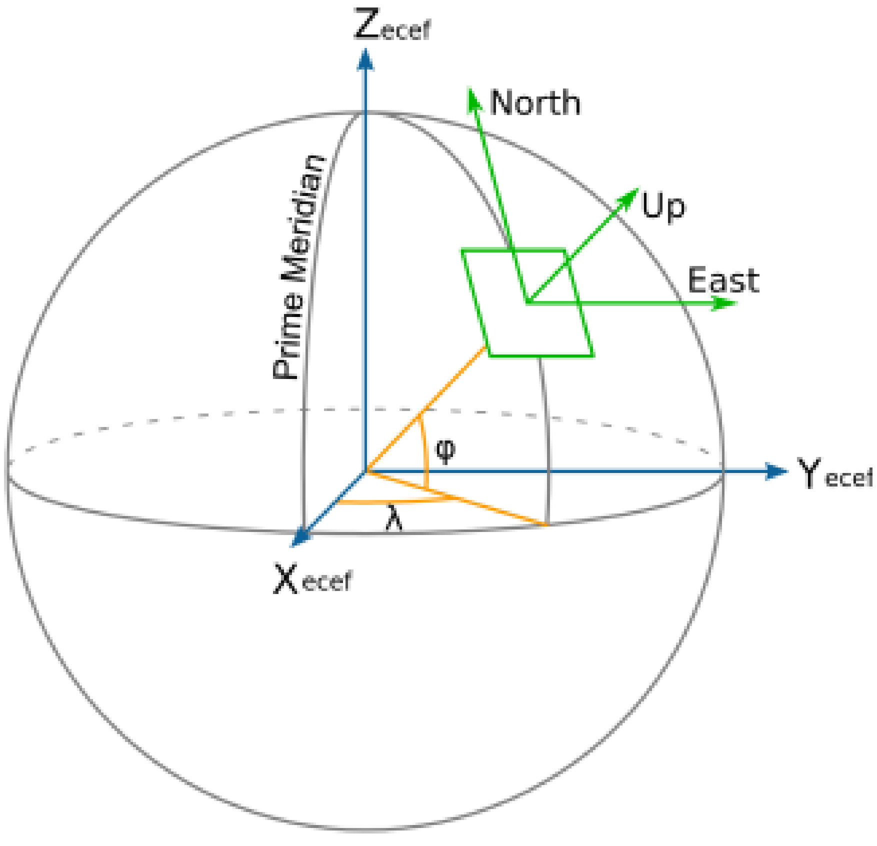
- ePolaris. Conventions.
- Kinematic model of ePolaris, Odometry.
- Different EKF -implemention of Sensor Fusion with Odometry
- Reference from Novatel SPAN with most accurate correction signals

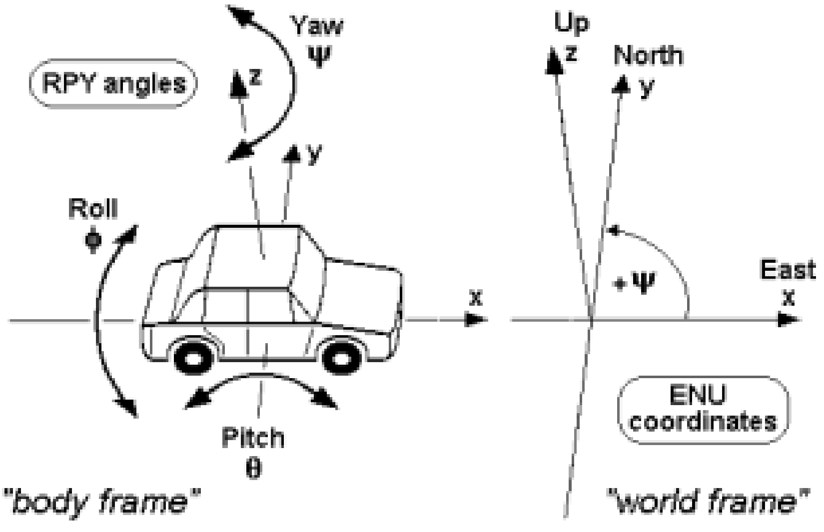
ePolaris

- Odometry
  - Wheel encoder data and steering angle measurements
- Novatel SPAN-IGM-S1
  - Synchronous Position, Attitude, and Navigation (SPAN), tightly coupled of
  - The absolute accuracy of GNSS positioning
  - The stability of the Inertial Measurement Unit (IMU)
- (The Velodyne HDL-32E LiDAR
- Basler Ace Series Camera + omnidirectional lens, 360◦ range of the surrounding area.)

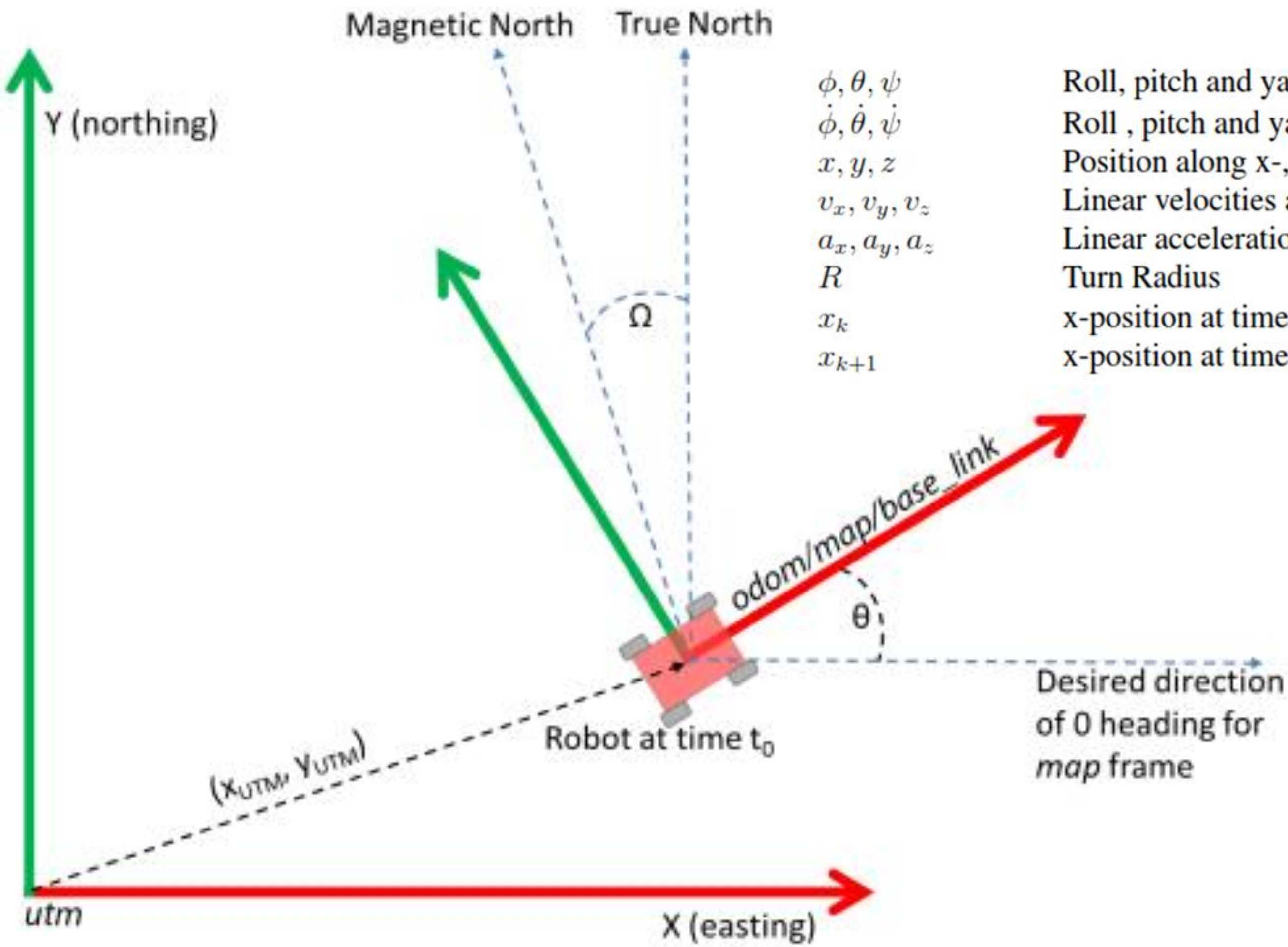
Conventions

- Earth-Centered-Earth-Fixed (ECEF) frame of reference
- East-North-Up (ENU)





Conventions



ϕ, θ, ψ	Roll, pitch and yaw angles respectively.
$\dot{\phi}, \dot{\theta}, \dot{\psi}$	Roll , pitch and yaw rates respectively.
x, y, z	Position along x-, y- and z- axis.
v_x, v_y, v_z	Linear velocities along x-, y- and z-axes respectively.
a_x, a_y, a_z	Linear acceleration along x-, y- and z-axes respectively.
R	Turn Radius
x_k	x-position at time instant k.
x_{k+1}	x-position at time instant k+1.

GPS Position Profile

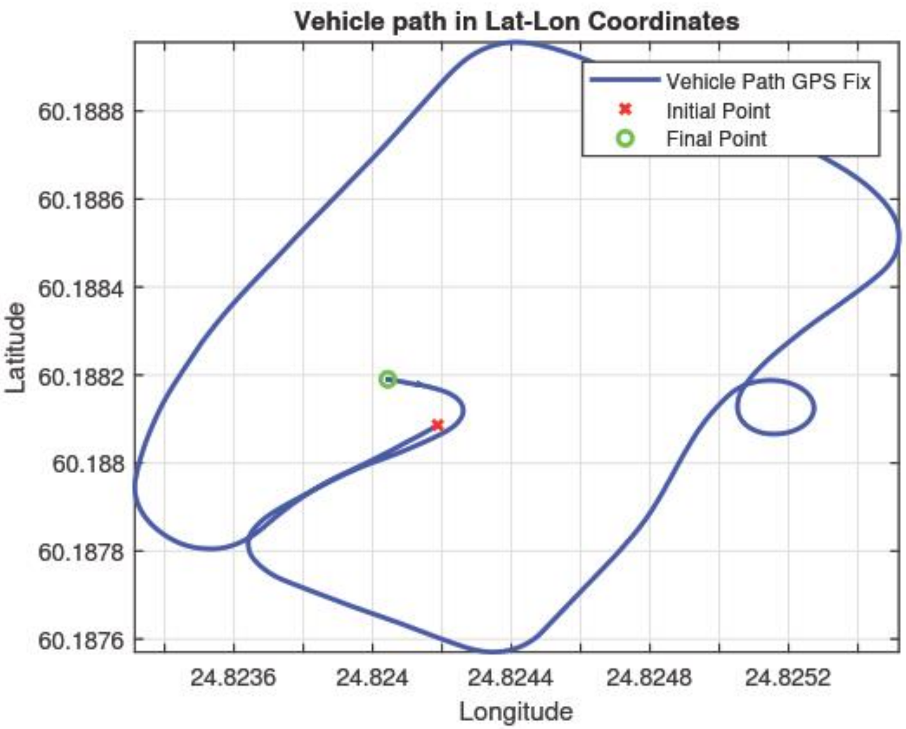


Figure: Vehicle Trajectory in Lat-Long format

Figure: Courtesy: Google Map

Available Sensors and Data Rates

- GPS Position in UTM Coordinate at 10 Hz.
- Integrated GPS Position in Latitude, Longitude and Altitude at 50 Hz.
- GPS Track over Ground Velocity and Angle at 10 Hz.
- Integrated North, East and Down Velocities at 50 Hz.
- Corrected IMU Angular Rates and Linear Accelerations at 50 Hz.
- Estimated Orientation (Roll, Pitch and Yaw Angles) at 50 Hz.
- Wheel Encoder Data and Steering Angle Measurements at 10 Hz.
- DGPS Corrections from NLS Finland in RTCM Format at 1 Hz.

Not used here

- LIDAR Data in form of Point Cloud at 20 Hz.
- 360◦ Camera Data at 10 frames per second.

Kinematic model of ePolaris, wheel odometry

Bicycle model on the basis of Ackerman steering for a four-wheeled robot, a car-like vehicles, like Polaris

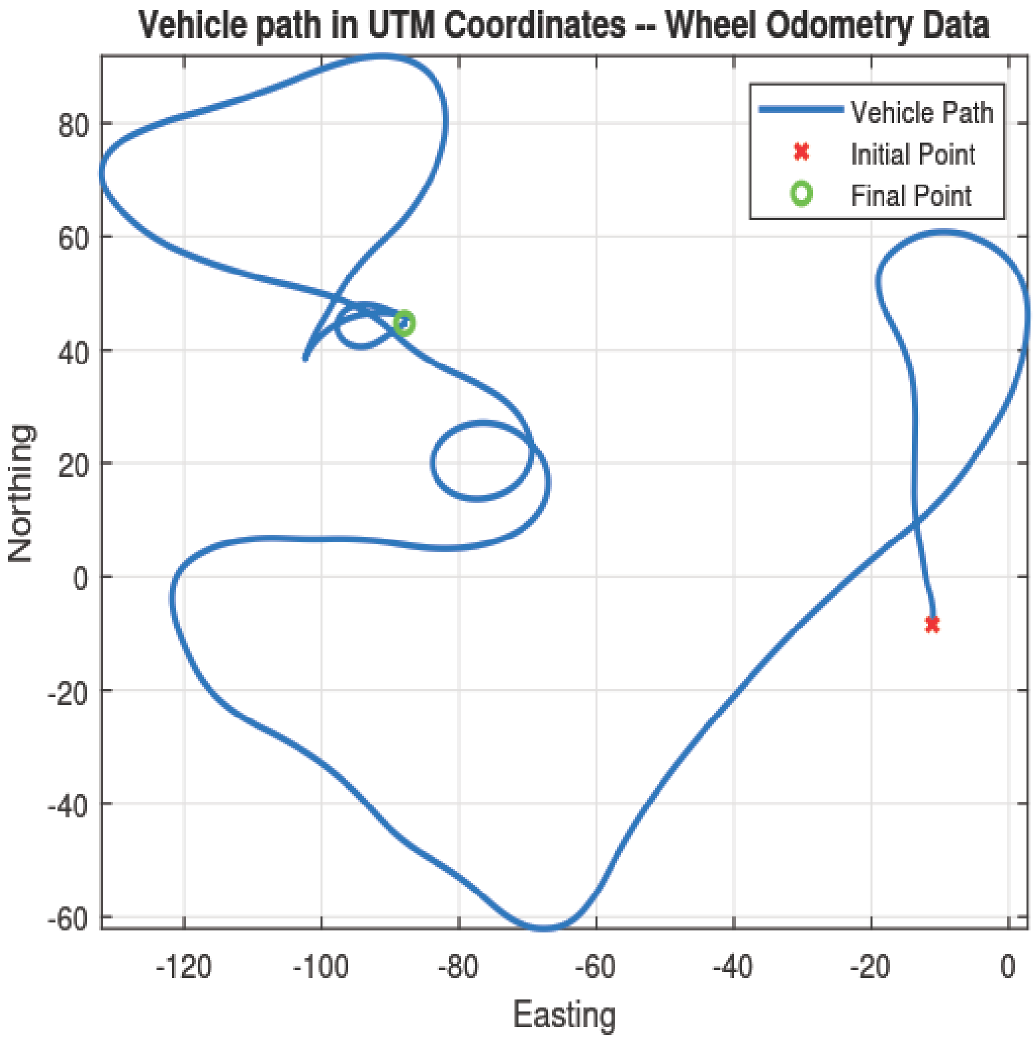
$$\begin{aligned} x_{k+1} &= x_k + v \times \delta t \times \cos(\psi_k + \phi_k/2) \\ y_{k+1} &= y_k + v \times \delta t \times \sin(\psi_k + \phi_k/2) \\ \psi_{k+1} &= \psi_k + \tan(\phi_k) \times v \times (\delta t/L), \end{aligned}$$

- In pure dead reckoning or wheel odometry, the readings of encoders on the wheels, as well as the steering angle, are utilized to update the position and orientation of the robot over time.
- Position error accumulates quicky, particularly error in heading or yaw is fatal for the position error.
- Corresponds just predictions with the dynamic, here kinematic, model

GPS Position Profile

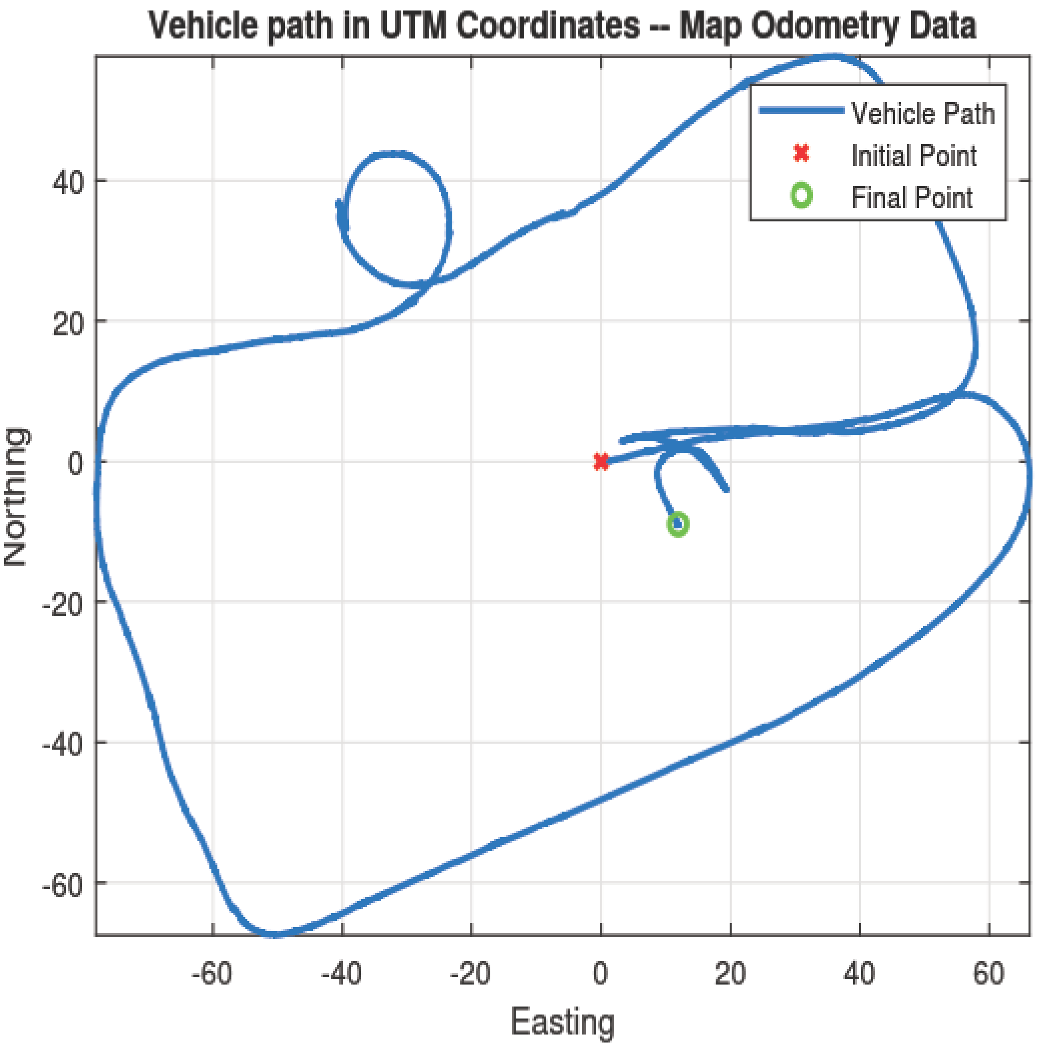
- Integrated positions from Ackermann model.
- Yaw angle from wheel steering measurements.
- Linear velocities from wheel encoders.
- Yaw rate from differentiating yaw angle.

- Does not work at all!



Odometry in Map Frame

- Positions from navsat transform package, it is creating a rotation matrix for yaw.
- EKF
- Roll and pitch angle from IMU.
- Linear velocities from wheel encoders.
- Linear velocities from GPS.
- Body rates from IMU.
- Linear accelerations from IMU.
- Works fine!



Odometry in Map Frame

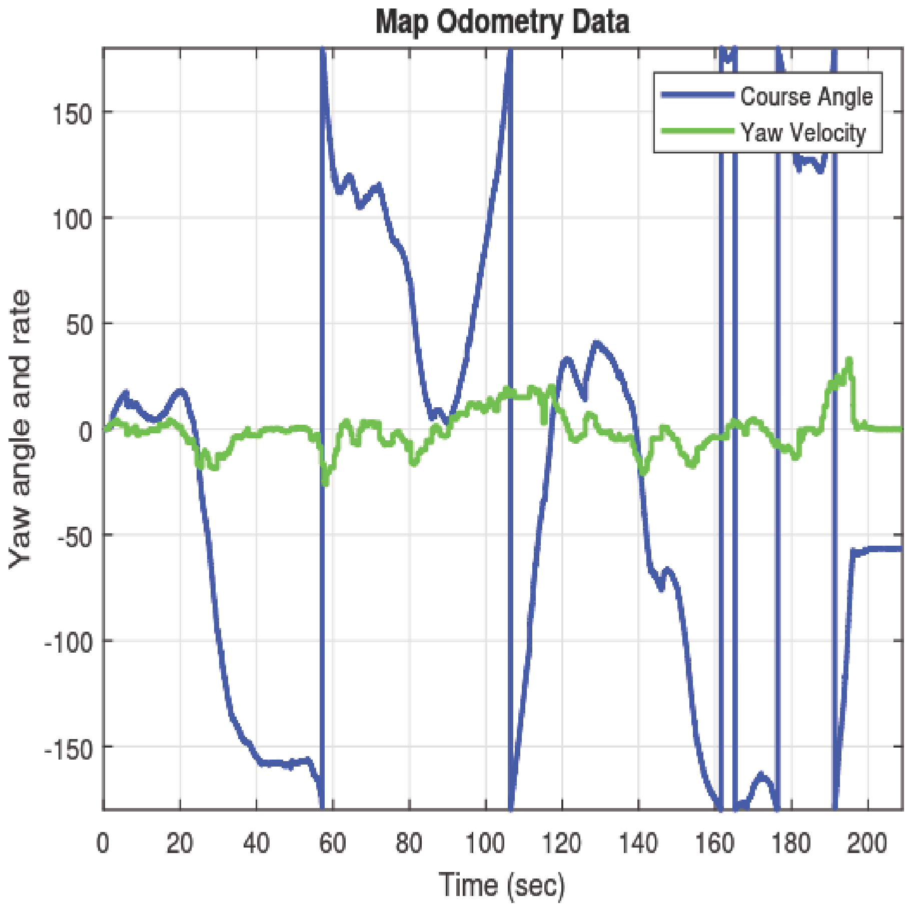


Figure: Integrated Yaw Dynamics

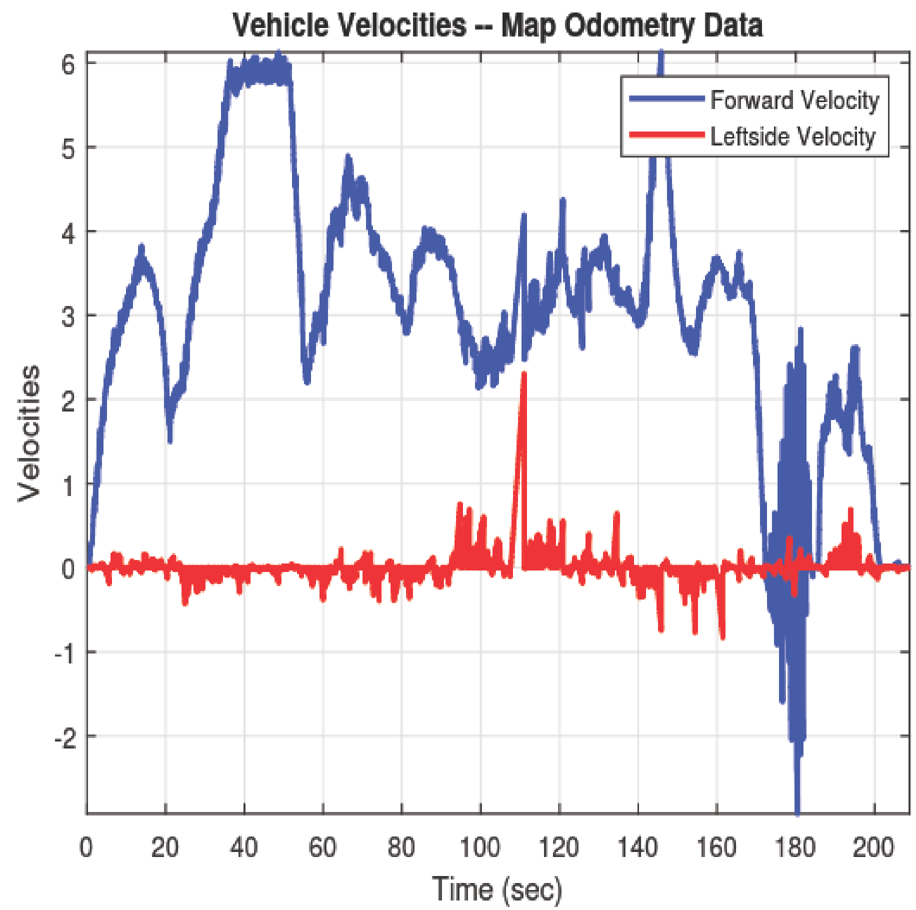
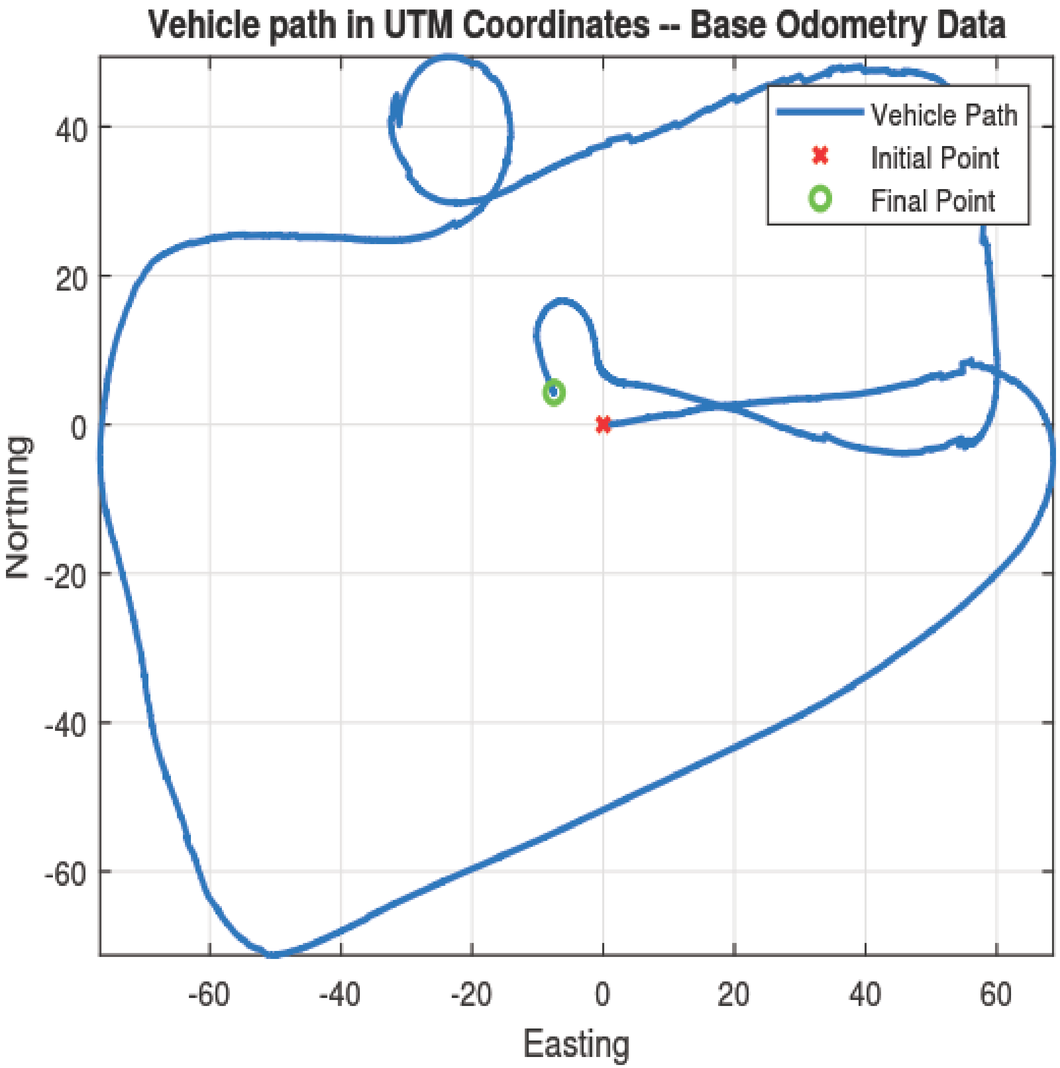


Figure: Integrated Velocity Dynamics

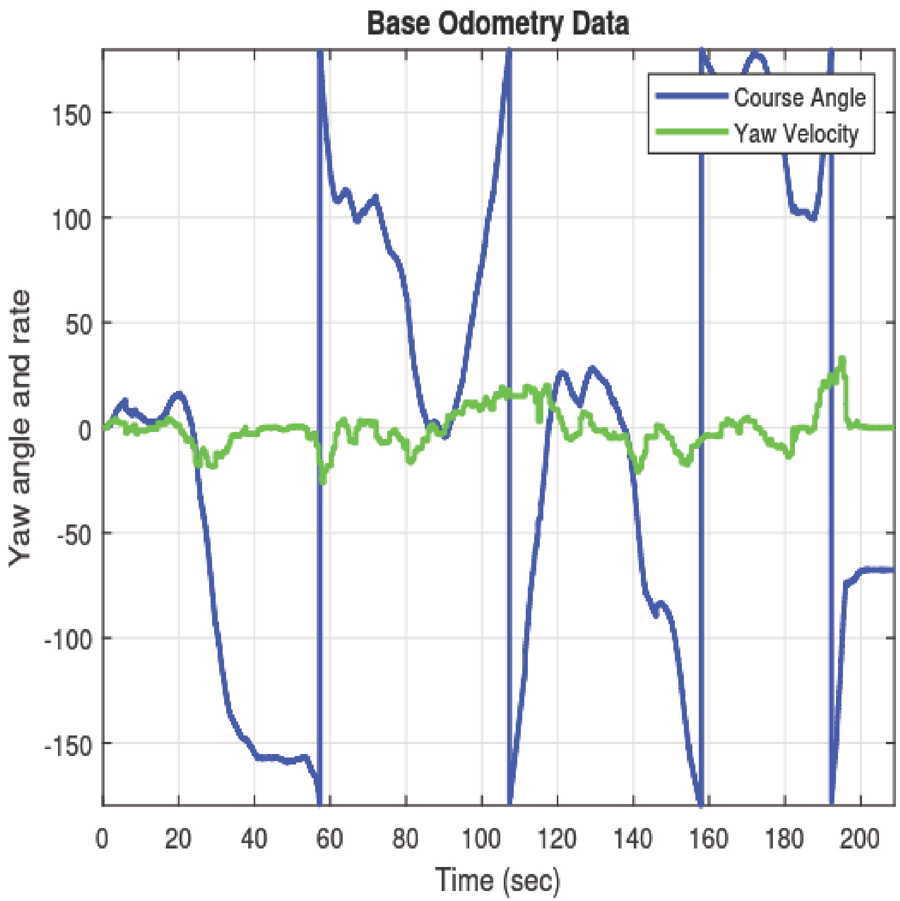
Odometry in Base-link Frame

- Integrated Positions by EKF.
- Roll and pitch angle from IMU.
- Linear velocities from wheel encoders.
- Linear velocities from GPS.
- Body rates from IMU.
- Linear accelerations from IMU

- Works!



Odometry in Base-link Frame



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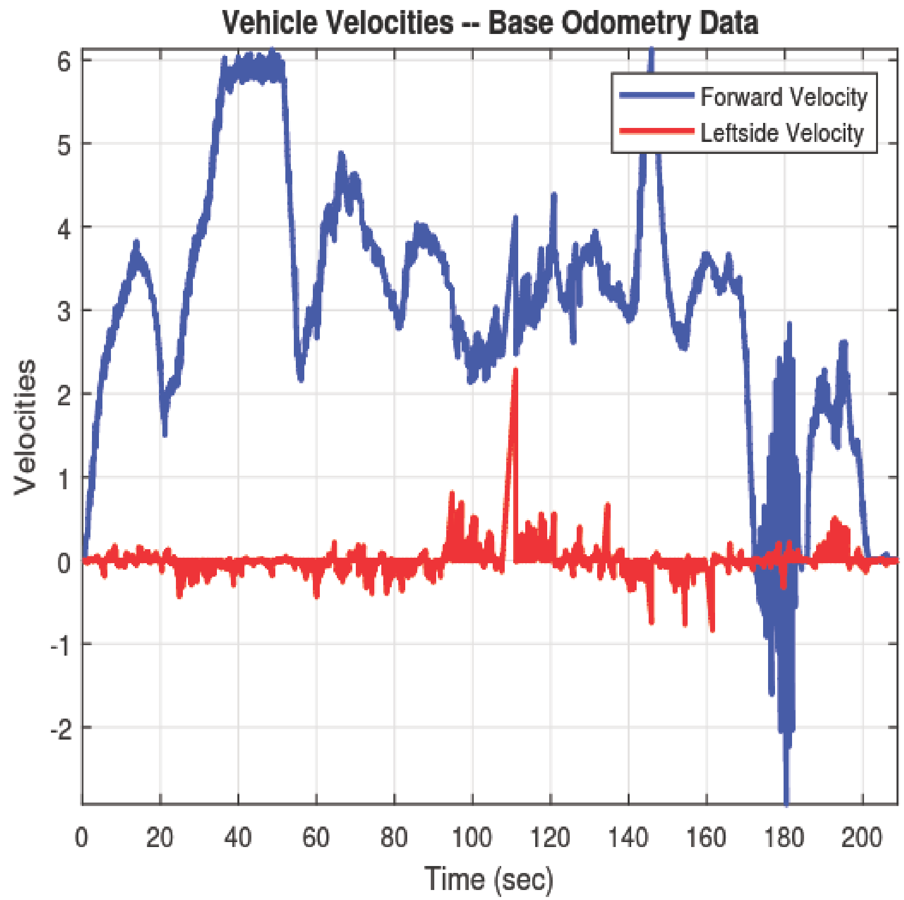

Figure: Integrated Velocity Dynamics

Positioning Comparison