

# Integration of GPS and INS for Vehicle Navigation

(Revision: Original)

## 1 Introduction

Global Positioning System (GPS) technology has revolutionized modern navigation, providing dependable location data for a vast range of applications from smartphones to aviation. However, a significant limitation of standard GPS receivers is their reliance on a clear line-of-sight to at least four satellites in the medium Earth orbit. In dense urban environments, often referred to as "urban canyons," signals are frequently blocked or reflected by tall buildings. This results in signal outages or significant positioning errors due to multipath interference.

To overcome these challenges, Inertial Navigation System (INS) is usually integrated with GPS. The main sensor of an INS is the Inertial Measurement Units (IMUs). An IMU utilizes accelerometers and gyroscopes to provide high-frequency data on a vehicle's acceleration and angular velocity. By employing a Kalman filter, the system can fuse the absolute positioning of the GPS with the motion data from the IMU. This integration allows for "Dead Reckoning," ensuring continuous and robust navigation even when GPS signals are temporarily unavailable. This integration also calibrates the INS when the GPS is available.

## 2 Objectives

The objectives of this project are:

1. Learn the fundamentals of GNSS positioning and the mechanics of Inertial Navigation Systems (INS).
2. Select and interface hardware consisting of a GPS module and a low-cost 6-DOF IMU
3. Develop a data logging system to record latitude, longitude, and inertial raw data (acceleration and rotation rates) for post-processing.
4. Implement a sensor fusion algorithm based on the Kalman Filter (or Extended Kalman Filter) to determine the vehicle's position, velocity, and heading.
5. Analyze the "GPS Outage" scenario by simulating signal loss and evaluating how effectively the IMU maintains the vehicle's track.

6. Optimize the algorithm to minimize the drift inherent in low-cost inertial sensors over time.
7. Design a user-friendly interface to visualize the integrated real-time track compared to a raw GPS-only track.
8. Write Comprehensive User Manuals in LaTeX covering the hardware assembly and the software implementation.
9. Design a technical poster summarizing the system architecture and the performance improvements in urban simulation.

### **3 Requirements**

1. Comprehensive grasp of mathematics, specifically Linear Algebra and state-space representation required for Kalman filtering.
2. Solid foundation in software development and programming; proficiency in Matlab or Python is preferred for algorithm modeling.
3. Practical experience with embedded systems hardware, including Arduino, ESP32, or Raspberry Pi, for sensor interfacing and real-time data acquisition.
4. Advanced analytical ability and technical writing skills, with experience using LaTeX for professional documentation.