IMPLEMENTING INERTIAL NAVIGATION SYSTEM IN WEARABLE DEVICES USING MACHINE LEARNING

Department of Computer Science and Engineering
PES University, EC Campus, Bangalore, 560100

PROBLEM STATEMENT

Wearable devices fail to provide reliable navigation when GPS signals are weak or unavailable. Consumer-grade IMU sensors drift quickly, causing large errors. A lightweight, real-time solution is required to maintain accurate position tracking in GNSS-denied environments.

DOMAIN IoT, Sensor Intelligence & Machine Learning Applications

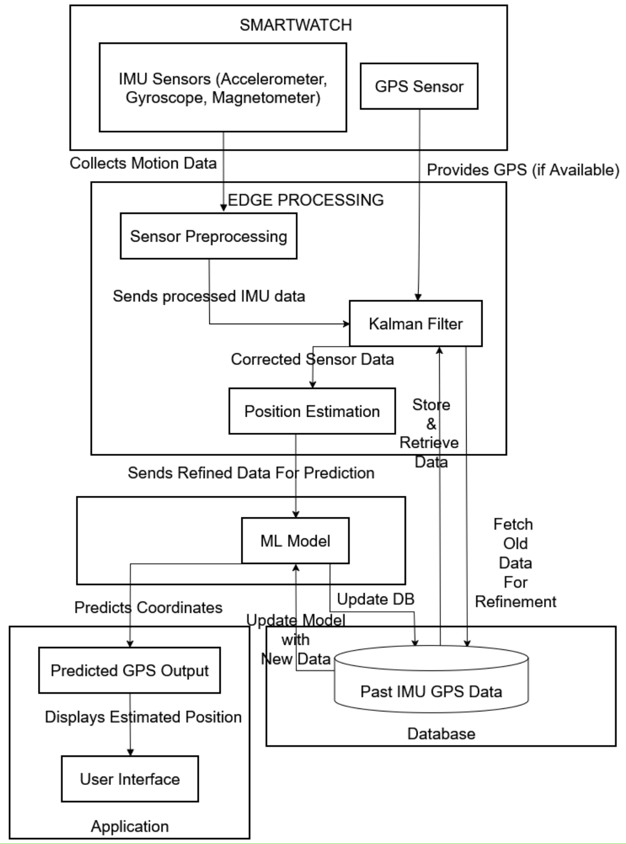
BACKGROUND

Wearable devices depend on GPS for accurate navigation, but performance drops sharply when signals weaken indoors or in obstructed environments. In such cases, devices rely on inertial sensors, which accumulate drift quickly due to noise and bias. This challenge has led to hybrid approaches that combine sensor fusion and machine learning to achieve stable, accurate tracking in GNSS-denied conditions.

PROJECT DESCRIPTION

This project presents a hybrid inertial navigation framework for wearable devices operating without reliable GPS. The system integrates Kalman Filter–based sensor fusion with GRU-XGBoost machine learning models to correct drift and estimate GPS-equivalent coordinates in real time. Smartwatch IMU data is preprocessed, filtered, and modeled to capture motion dynamics, enabling accurate, lightweight, and energy-efficient navigation suitable for GNSS-denied environments.

SYSTEM ARCHITECTURE



PROJECT OUTCOME

The project delivers a working hybrid inertial navigation system capable of predicting GPS-equivalent coordinates during GNSS outages. Using Kalman Filtering and GRU-XGBoost models, the system reduces positional drift by nearly 90–95%, achieving values as low as 16 m/km compared to baseline drift of 400m/km. It also maintains extremely low error metrics (RMSE in the 10^{-5} range) with real-time inference under 3 ms. These results confirm the system's reliability, efficiency, and suitability for wearable navigation.

MENTOR

Prof. Nagalakshmi SR
Assistant Professor

TEAM ID : 93 TEAM MEMBERS

PES2UG22CS675
Yash Sinha

PES2UG22CS633
Tushar Swami

PES2UG22CS654
Vedant Singh

PES2UG22CS559
SK Hithasree

RESULTS AND DISCUSSION

The hybrid navigation system showed major improvements over baseline models, reducing drift from hundreds of meters per kilometer to about 16 m/km. GRU-XGBoost delivered the lowest error, with RMSE in the 10^{-5} range and inference under 3 ms. These results confirm that combining Kalman Filtering with lightweight ML greatly improves stability and accuracy for wearable navigation in GNSS-denied environments. Compared to conventional deep learning models, the proposed hybrid DL models consistently demonstrated superior robustness during extended trajectories and diverse real-world motion conditions across multiple users.

CONCLUSION AND FUTURE WORK

The hybrid navigation system effectively reduces drift and improves accuracy during GPS loss, proving suitable for wearable deployment. Future work includes integrating additional sensors, enhancing model adaptability for different users, optimizing on-device performance, and expanding datasets to improve robustness across diverse environments and movement conditions.

REFERENCES

- M. Nguyen et al., "GNSS-Denied Pedestrian Navigation Using ML," IEEE INERTIAL, 2024.
- B. Or & I. Klein, "Adaptive Step Size for Velocity-Aided INS," IEEE Access, 2022.
- S. Yang et al., "Robust Wearable HMI Navigation via DL," IEEE Sensors J., 2020.
- S. Saha et al., "TinyOdom: Efficient Neural Inertial Navigation," IMWUT, 2022.
- B. Zeinali et al., "IMUNet for IMU Navigation," IEEE TIM, 2024.
- B. Menna et al., "GPS-Aided Strapdown INS," RPIC, 2017.
- G. Zhao et al., "System-Level Calibration for SINS," IEEE Sensors J., 2022.
- S. Wang et al., "Hybrid Calibration for SINS," IEEE Access, 2019.