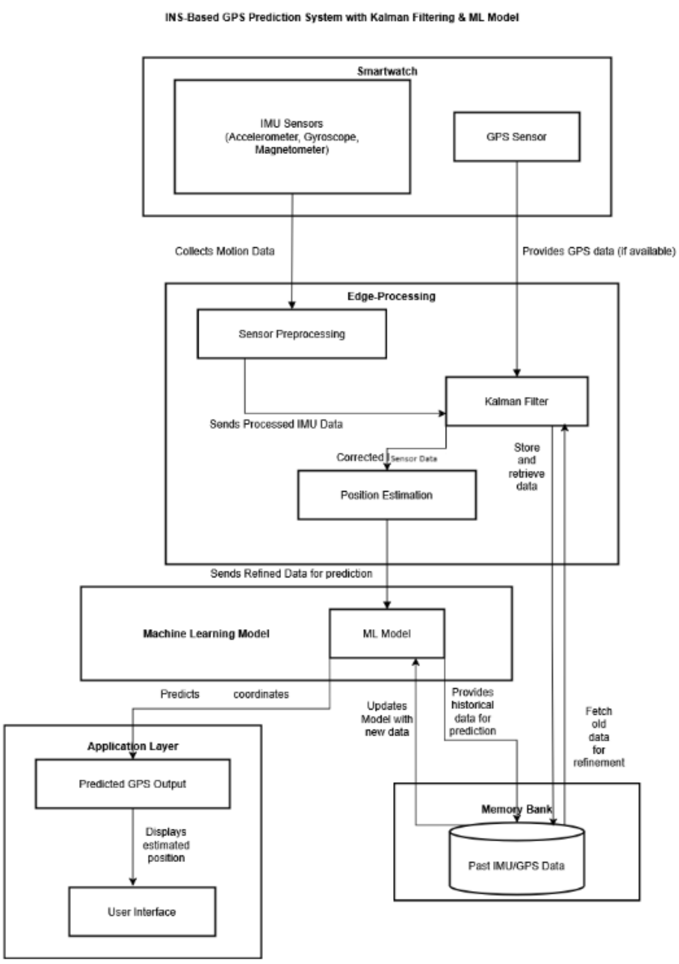
Implementing Inertial Navigation Systems in Wearable Devices using Machine Learning

Domain: IoT, Sensor Intelligence, and Machine Learning Applications

Abstract:

Wearable devices struggle to provide reliable navigation when GNSS signals degrade or disappear, causing pure inertial tracking to accumulate large drift due to noise and bias in low-cost MEMS sensors. This project addresses this problem by developing a GPS-independent inertial navigation framework that fuses Kalman-filtered sensor preprocessing with lightweight machine-learning models for accurate position estimation in GNSS-denied environments. The system first stabilizes raw accelerometer, gyroscope, and magnetometer data using a Kalman filter, producing drift-reduced motion features. Multiple deep learning baselines (LSTM, ResNet-1D, Transformer) were evaluated against proposed hybrid recurrent–ensemble architectures—GRU-SVR, GRU-XGBoost, and BiGRU-XGBoost. Experiments on smartwatch-collected IMU data show that while Transformer performs best among generic models with a drift of 403.8 m/km, hybrid methods achieve far superior accuracy. The proposed GRU-XGBoost model reduces positional drift from 162.6 m/km (GRU-SVR) to just 16.3 m/km (a tenfold improvement), achieves average distance error below 0.009 m, RMSE in the order of 10, and maintains real-time inference latency under 3 ms. These results demonstrate that combining temporal feature encoding with gradient-boosted nonlinear regression significantly enhances drift suppression while remaining efficient for on-device wearable deployment. The framework offers a practical pathway for continuous pedestrian localization, emergency responder tracking, and fitness analytics in environments where GNSS is unavailable or unreliable.

Architecture / Flow Diagram:



Supervisor:	**Team No.:** 93			
Nagalakshmi SR Assistant Professor	**Yash Sinha** PES2UG22CS675	**Tushar Swami** PES2UG22CS633	**Vedant Singh** PES2UG22CS654	**SK Hithasree** PES2UG22CS559

Publication:

Status: Paper Drafted

Yash Sinha; Tushar Swami; Vedant Singh; S. K. Hithasree; Nagalakshmi S. R. (2025).
XGBoost-Enhanced Recurrent Hybrid Models for Wearable Inertial Navigation in GNSS-Denied Environments.
Paper Drafted, 2025.