Adaptive Quadruped with Sensor Fusion for Precise Multi-Sensor Data Collection and Analysis

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Research question & Motivation

How can a low-cost, sensor-fused system improve pose estimation accuracy for mobile robots in real-world environments?

This research explores the integration of visual, inertial, and ultrasonic sensing to develop a more robust and accurate pose estimation method. The goal is to enhance perception in robotics, enabling reliable navigation, data collection and movement analysis, particularly in low-resource or unstructured environment.

Research Method

- **Visual Odometry:** PiCamera2 provides the ORB features and essential matrix to compute relative motion.
- **Ultrasonic Sensor:** HC-SR04 gives absolute Z-distance to resolve scale ambiguity in monocular camera motion.
- **IMU (BNO055):** Supplies Linear acceleration and orientation used to capture motion trends.
- **Fusion:** Fuse camera and ultrasonic data and pass to Extended Kalman Filter **(EKF)** to reduce noise and estimate pose while verifying it with IMU based motion tracking.

Findings & Progress

- The fused pose closely aligns with IMU translation across all axes.
- Z-axis accuracy and motion smoothness improved significantly with fusion filtering.
- Robustness to Noise Drift due to smoothening.
- Validated Multi-Sensor Agreement

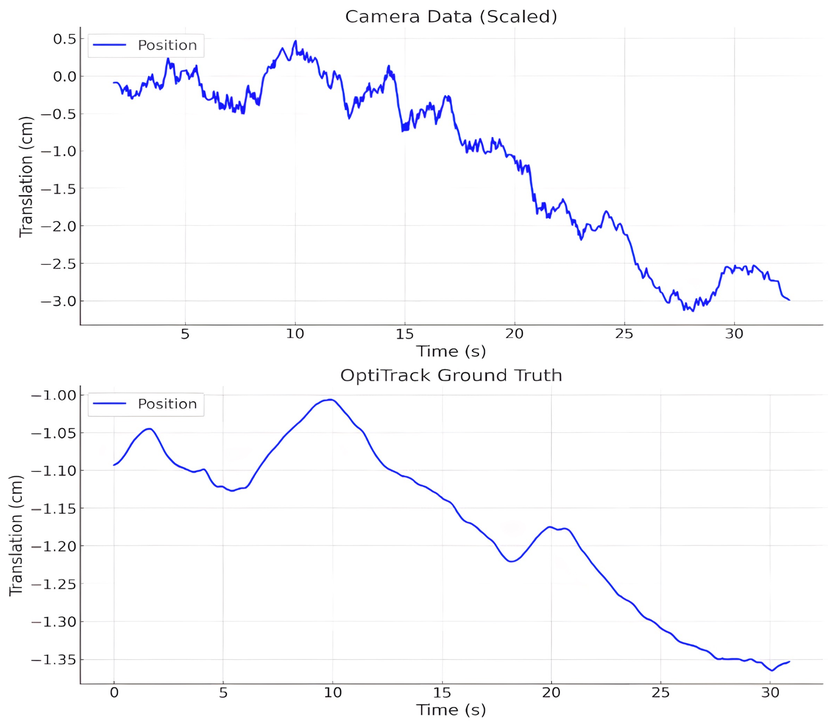
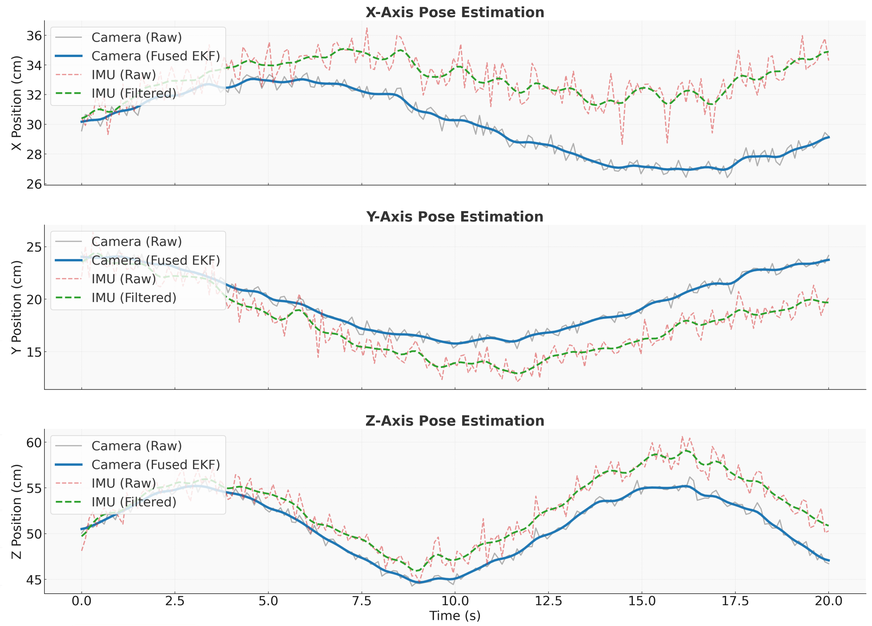


Fig. Camera Translation v/s OptiTrack

Obstacles Faced & Overcome

- **Scale Ambiguity in Vision:** This was solved using an ultrasonic sensor based real-world scaling.
- **Drift in IMU:** Mitigated with filtering and validation against fusion pose.
- **Sensor asynchrony:** Addressed with timestamped logging for clean alignment.
- **Noise:** Handled using Kalman Filter and Savitzky-Golay Smoothing.



Credits

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