Sensorfusion IMU/GNSS

Porting and validation of a Kalman filter on an embedded system in C

Graduate

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Introduction: Inertial navigation systems are employed when continuous and autonomous determination of position and orientation is required, independent of external infrastructure or environmental conditions. However, due to deterministic and stochastic measurement errors as well as accumulated numerical computation errors, such systems are subject to drift, so that position and orientation can only be maintained with sufficient accuracy over limited periods of time without external correction. Global Navigation Satellite Systems (GNSS), on the other hand, provide absolute position data with global coverage, but with comparatively high dispersion and susceptibility to signal loss or interference.
By means of sensor fusion, the complementary advantages of both approaches can be combined, enabling robust and precise navigation even under challenging operational conditions.

Objective: Specifically, the work involves porting and validating a closed-loop ESSKF (Error Space State Kalman Filter) from MATLAB to C on an STM32H7 microcontroller, developing a non-blocking GNSS driver for I²C communication, and CANopen integration. In addition, the entire system with strapdown navigation, sensor data processing, interrupts and serviceroutines was fully implemented.

Result: Validation was performed using simulated noisy sensor data, which was processed via CANopen on the STM32H7 and compared with the MATLAB reference and the target values. On a complex simulation path (Figure 2,3), the RMS error of the sensor fusion on the embedded system was 0.95 m compared to 0.89 m in MATLAB. The deviation of 0.06 m between the embedded system and the MATLAB reference is within the expected tolerance and confirms the correct porting. A real-time test with real sensor data (10 Hz GNSS, 60 Hz navigation output via CANopen PDOs) showed stable path reconstruction. The observed 20cm step size between successive 60Hz position indicates a sub-meter output resolution and supports the system's suitability for use (Figure 1)

Figure 1: Navigation solution on test ride in car
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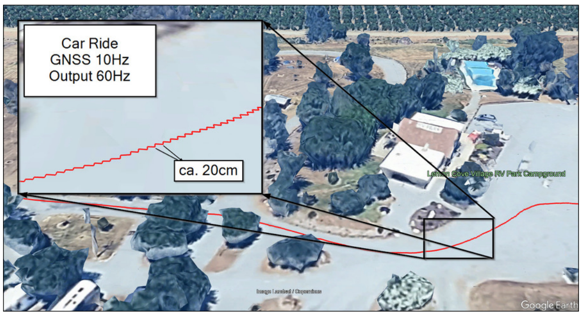

Figure 2: Logarithmic error over time of the navigation solution
Own presentment

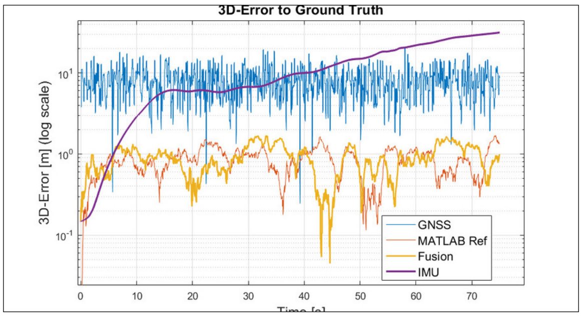

Figure 3: 3D trajectories of the navigation solution
Own presentment