On multi-sensor based calibration of inertial measurement units

Subject: Energy and Environment
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MEMS inertial measurement units (IMUs) are rapidly expanding in the commercial use for a large field of applications. Unfortunately, the unavoidable systematic errors delivered by MEMS-IMUs limit their direct use in vehicle accident and/or trajectory reconstruction and make calibration mandatory. In this thesis we investigate and compare two different calibration procedures for accelerometers able to increase accuracy of velocity estimates in an inertial navigation system.

Motivation

Driven by a specific application in the field of motorcycle trajectory reconstruction, we consider calibration techniques for IMUs with the aim to increase system performance in the most cost saving way. We further clarify to what extent stationary post-crash information from IMUs (used as crash-recorders) can increase the accuracy of trajectory reconstruction.

Implementation

We present and investigate two known calibration procedures under static conditions. The first one uses a pseudo measurement – the norm of the local gravity vector – as reference measurement in a Kalman filter to estimate accelerometer scale factor and bias. The second one integrates gyro measurements and uses orientation information to project the local gravity vector onto sensor axis in the body frame. A platform with a consumer grade IMU (218 µg/√Hz) and two IMUs with tactical grade performance (70 µg/√Hz) is used ($g \approx 9.81\ m/s^2$).

Results

This comparison unveils the following: in the present form the calibration methods can't properly handle consumer grade IMUs, due to their important noise level. Both procedures work well for IMUs with tactical grade performance and lower noise level. Hence, good IMUs can do better with these methods.
Admissible results in the consumer grade IMU calibration are achieved for the method using pseudo measurements, when the accelerometer is sufficiently and smoothly rotated in the earth gravity field (around at least two independent directions). The procedure using gyro measurements suffers excessively from the orientation errors coming from the fact that noisy gyro data have to be integrated. To improve this calibration, a more accurate orientation sensor is needed. This calibration method is interesting in so far, as dynamic conditions can be handled and orientation of the sensitive measurement axes can be gained.
To overcome the calibration problems with consumer grade IMUs, an implementation using geometrically constrained redundant IMUs is shortly discussed.
We also show that stationary post-crash information is not enough in order to estimate error parameters. Using the notion of observability of a dynamic system, it is seen that attitude changes are needed. However, stationary measurements are still useful in so far that we can use them to estimate relevant noise strength suitable for filter techniques initializations.

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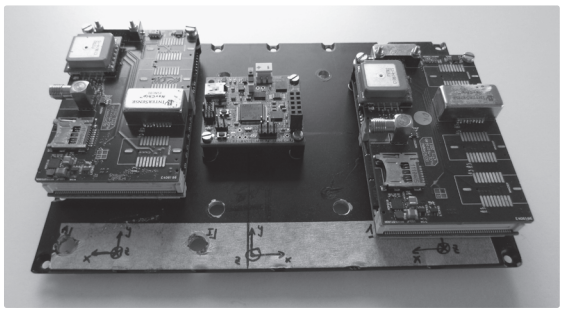
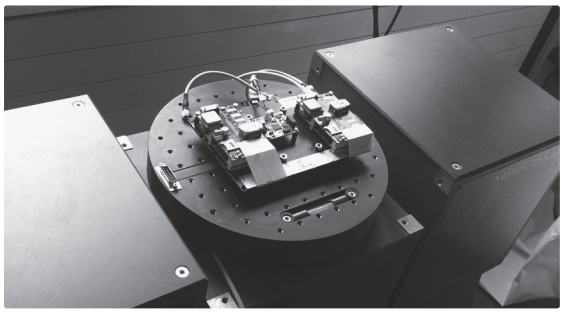


multi-sensor platform



2-axis turntable (acuitas AG)