Laboratory calibration of a MEMS accelerometer sensor

MM Solutions AD

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Background

MEMS accelerometer and gyroscope sensors became a commodity in the mobile devices. Allowing to measure the acceleration and the rotational speed in all directions, they enable many applications to benefit from the ability to estimate the device pose and motion. In conjunction with the build-in camera, novel features can be offered to the end user like navigation, guidance in a large or small environment, detection of objects of interest, augmented reality, real terrain video games, and many others.

The specific use case for this study is to use the accelerometer sensor along with a gyroscope and a camera, for estimating and tracking the camera position and orientation in space. Since the MEMS gyroscope sensors are cheap and low quality, the production tolerances play a significant role and must be taken onto account.

Constraints

Accelerometer sensors measure the linear acceleration (or actually the force) in certain direction called axis. A combination of 3 accelerometers in a single chip with orthogonal axes is used in the mobile devices, giving the ability to calculate the device position (the camera in this case) in the 3D space. Since the device may rotate, the measurement axes change their directions in space. Thus, the camera rotation should first be calculated using the gyroscope sensor.

The gravity applies also a force, which is measured as acceleration when the device is still. This gravity acceleration adds to the true acceleration, caused by the real motion which is to me measured, so it has to be subtracted from the accelerometer data. The gravity acceleration is quite big compared to the normal motion accelerations, so knowing exactly the gravity direction and magnitude is vital for achieving useful pure motion acceleration.

There are a few other factors that affect the accuracy of the measurement, which are related to the technology used itself.

- offset
  Even in still condition, the accelerometer outputs some value, called offset, meaning some fake acceleration. It has to be known and subtracted from the data before using it for calculations.
- scale
  "Scale" means the measurement units of the accelerometer sensor – those are usually m/s^2, but the actual measurement unit may deviate proportionally around this value. Improper scale will result in scaling all the calculated camera positions, and (which is more fatal) improper cancellation of the gravity acceleration, resulting in counting a fake acceleration.
- crosstalk or non-orthogonality
  In a perfect triple accelerometer, acceleration on one of the axes should not cause any measurement on the other axes. Unfortunately this is not the case in practice. Part of the measured acceleration in the "right" axis appears in the other axes too. This effect is known as crosstalk and its maximum amount is verified and specified by the vendors in the sensor specifications. The reason for the crosstalk may be either electrical transfer in the chip or deviation from the perfect orthogonality of the sensors' axes. The most severe consequence is as in the case of improper scale, improper cancellation of the gravity acceleration.

The upper described parameters has to be defined in a mathematical model, resulting in a formulae for correction of the accelerometer data before being used in calculations for camera position estimation. Then, a calibration procedure should be defined, incorporating certain measurements and an algorithm for processing the measured data to achieve the calibration parameters of the defined mathematical model.

Another restriction is the inability to take the accelerometer sensor off the device. It is mounted in a mobile phone and may not be even visible. The calibration measurements should be captured using an application for a mobile phone for reading the accelerometer data directly on the device the accelerometer is mounted on.

The calibration procedure should not require expensive equipment and the whole calibration procedure of one accelerometer should be executable within 1 hour.

Potential Solutions

Many articles deal with the problem of mutual calibration of an accelerometer and other sensors (e.g. camera). Different approaches are investigated, including run-time calibration, i.e. refining the calibration parameters during the normal operation of the device. Those methods, however are quite computationally expensive, require long time for development and assume some initial calibration of the sensors.

A simple and quick solution for laboratory-based calibration is needed, that to be used as a first-stage calibration, followed by a run-time calibration, which should cover the temperature and aging deviations of the calibration parameters.

Aims for the study

The aim of this study is to define a suitable formulae for correction the accelerometer data and a simple and quick method for determining the parameters of this correction using a mobile phone with embedded accelerometer.

Sample data will be sent, measured from mobile phone. More data can be sent if needed. More data could be captured using any suitable mobile phone and a common application for reading and showing the accelerometer data.