A Quick Method for Calibrating Accelerometers

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Introduction

Accelerometers are usually very linear devices, which makes it easy to calibrate their output by carefully aligning their axis of sensitivity with and against the direction of gravity. Alignment within a few degrees of vertical is usually sufficient for accuracies of 0.1% and better. The method presented here does not require any alignment with gravity.

Calibration is performed by reading the output from an accelerometer at *equally* spaced angular positions around a nearly horizontal axis. The axis of sensitivity is in a vertical plane (within a few degrees). Equations are given here for 3-point (0,120 and 240 degrees) and 4-point (0, 90, 180 and 270 degrees) calibrations. It is not necessary to know the actual alignment of the axis of sensitivity of the accelerometers with respect to the angles of calibration.

Mechanical Explanation

Figure 1 sketches a typical setup that might be used on profilers like TurbMAP. The instrument is laid horizontal within a few degrees and this position can be checked with a standard carpenter's level. The instrument rests on V-blocks so that it can be easily rotated around its horizontal axis. A circular calibration disk with three or four equally spaced holes is bolted to the rear end cap. A holding jig with a single hole is fixed to the table supporting the instrument. A pin pushed through the holding jig and, one by one, through each of the holes in the calibration disk. The accelerometer is read at each angular position.

Mathematical Analysis

4-Point Calibration

Let the reading in position #1 be given by

$$N_1 = ag\sin\theta + b \tag{1a}$$

where *a* is the sensitivity of the accelerometer and its electronics in terms of output *N* per *g* (~9.81 m/s^2) of acceleration, *b* is the offset of the electronics and the bias of the accelerometer (usually a small value), and θ is the unknown angle between the axis of the accelerometer and gravity (the local vertical). The purpose of the calibration is to determine *a* and *b* so that the output *N* can be expressed in terms of *g* or m/s^2 of acceleration. The readings in positions 2, 3 and 4 are:

$$\begin{aligned} N_2 &= ag\sin\left(\theta+\frac{\pi}{2}\right)+b \\ N_3 &= ag\sin(\theta+\pi)+b \\ N_4 &= ag\sin\left(\theta-\frac{\pi}{2}\right)+b \end{aligned} \qquad \text{(1 b-d)}$$

It is possible to solve equations 1a-d without knowing θ. From symmetry and trigonometry, we have

$$\sin(\theta+\pi) = -\sin\theta$$

$$\sin\left(\theta+\frac{\pi}{2}\right) = -\sin\left(\theta-\frac{\pi}{2}\right) = \cos\theta$$

Thus, (2 a-b)

$$b = \frac{1}{4}\{N_1+N_2+N_3+N_4\}$$

$$ag = \frac{1}{2}\sqrt{(N_1-N_3)^2+(N_2-N_4)^2}$$

3-Point Calibration

It is also possible to calibrate the accelerometers within only 3 equally spaced readings taken 120 degrees apart. The three readings are:

$$N_1 = ag\sin\theta + b$$

$$N_2 = ag\sin\left(\theta + \frac{2\pi}{3}\right) + b = ag\cos\left(\theta + \frac{\pi}{6}\right) + b \qquad (3\text{ a-c})$$

$$N_3 = ag\sin\left(\theta - \frac{2\pi}{3}\right) + b = ag\cos\left(\theta - \frac{\pi}{6}\right) + b$$

The 3-point solution is

$$b = \frac{1}{3}\{N_1 + N_2 + N_3\}$$

$$ag = \frac{2}{3}\sqrt{{N_1}^2 + {N_2}^2 + {N_3}^2 - (N_1N_2 + N_1N_3 + N_2N_3)} \qquad (4\text{ a-b})$$