Sensitivity of Tri-Axial Accelerometers within Mobile Consumer Electronic Devices: A Pilot Study

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Abstract

Tri-Axial accelerometers built into mobile devices allow for the measurement of motion characteristics by measuring the instantaneous acceleration of an object, compared to gravity at any given time. The objective of this study was to establish a protocol for a large scale study to determine the sensitivity of acceleration values. Five devices were used to collect instantaneous accelerations recorded by the SWAY Software in a steady state. Repeated measures were recorded in both screen-up and screen-down positions with the device laying flat and angled to 60-degrees. In the flat position, screen-up and screen-down mean accelerations were -1.0074g (±0.0202g) and 0.9966g (±0.0189g) respectively with a sensitivity of 0.0165g (±0.0086g). In the 60-degree position, screen-up and screen-down mean accelerations were -0.5094g (±0.0198g) and 0.4929g (±0.0207g) respectively with a sensitivity of 0.0190g (±0.0065g). These devices demonstrated consistent sensitivity values across multiple devices as demonstrated by low coefficients of variability.

Key Words: Accelerometry, Accelerometer, Bioengineering, Wireless Accelerometer, Wireless Sensors, Signal Processing, Communication

1. Background

Technological advancements in electronics and mobile computing have provided accessible quantitative methods of assessing patient's health. Accelerometers built into mobile devices allow users to measure static and dynamic motion characteristics. Micro Electro-Mechanical Systems (MEMS) accelerometers measures the instantaneous acceleration of an object, compared to gravity at any given time, in a free-fall reference frame. MEMS accelerometers typically incorporate three measurement axis's that quantify acceleration independently, but are housed in the same device, which are termed tri-axial or tri-axis accelerometers[3]. Accelerometers combine an accurate variability of movement measure with a non-invasive, portable method of measurement[1]. Postural sway evaluation using accelerometers has been validated against clinical balance assessment tests in multiple populations[2]. Recent literature supports the accuracy of iPod and iPhone devices to monitor quantified balance parameters with a sufficient level of consistency[4-7]. However, continued research is needed to assess the sensitivity and consistency of accelerometry housed in mobile consumer electronic devices.

Sensitivity measures for the ST Microelectronics MEMS LIS331DL Accelerometer are reported in the Technical Specifications Manual[8]. However, these values are determined through manufacturer testing completed prior to the components being shipped to mobile consumer electronic device manufacturers for installation in various devices, such as smartphones and other mobile multimedia devices. Thus, there is a need to assess the sensitivity of the accelerometers after being placed in devices such as smartphones. Sensitivity describes the gain of the sensor and tolerance levels define sensitivity range over a large population of sensors. Sensitivity measurements following mounting inside the smartphone have not been published and the effect of software applications built to report instantaneous acceleration from the MEMS LIS331DL motion sensor are unknown. The objective of this study was to establish a protocol for a large scale study to determine the sensitivity of acceleration values across multiple mobile consumer electronic devices using the SWAY Software.

2. Methods

Five mobile consumer electronic devices (Apple iPod Touch, 4^{th} Generation, iOS 5.1.0) were used to collect instantaneous accelerations recorded by the SWAY Software (v.1.0.0.1 4/30/2012, Capacity Sports LLC, Tulsa, USA) in a steady state.

The device was placed on a level surface with the z-axis in a -1g recording position, which corresponded to the screen facing toward the ceiling (Figure 1). The surface was leveled using a precision level which was accurate to 0.001 degrees. Instantaneous accelerations were recorded at 10 Hz for a 10 second period to determine the amount of variation in steady state recordings. A second test was immediately performed with the same protocol, but the z-axis was faced in the +1g position or screen pointed toward the ground. This protocol was repeated three times on each of the five devices.

Following the testing with the device lying on a level surface, acceleration data were also collected from the device while placed on a surface angled at 60 degrees, which was determined using a sine plate. Similar to the testing protocol for the device on a flat surface, data were collected from the device with the screen facing toward the ceiling (Figure 2), followed by collection of data from the device with the screen facing toward the ground. This testing protocol was repeated three times for each of the five devices tested.

The data collected was stored locally on the device and exported to the SWAY server until it could be downloaded for analysis. Sensitivity was determined by comparing the mean instantaneous acceleration across the 10-second recording in the -1g z-axis position to the corresponding mean instantaneous acceleration of the 10-second recording in the +1g z-axis position. Sensitivity was specifically calculated by subtracting the larger mean output value from the smaller mean output value and dividing the result by 2.0, as specified in the ST Microelectronics Technical Specifications Manual[8].

2.1 Statistical Analysis

Descriptive statistics (e.g., mean, standard deviation, coefficient of variation) were generated for the sensitivity within each device, as well as across all five devices. Additionally, the sensitivity tolerance, which is the range of sensitivities across the five devices tested, was also determined. These data were derived for the devices lying flat on the surface, as well as at the 60 degree upright angle.

3. Results

The descriptive statistics for the observed acceleration and resulting sensitivities for each of the devices is shown below in Table 1. The data in each cell (except for the sensitivity) represents the mean acceleration (and standard deviation) of the three trials. The sensitivity reported in each cell represents the mean (and standard deviation) sensitivity across the three trials.

Inspection of the acceleration data across the devices indicates the mean accelerations from each of the trials are very consistent given the extremely small standard deviations. This was observed for the devices lying flat as well as in the 60 degree upright orientation, with small coefficients of variation ranging from 1.9% to 4.2%.

For the devices in the flat orientation, the mean sensitivity was 0.0165g, resulting in a sensitivity tolerance from 0.0046g to 0.0278g. For the devices in the 60 degree upright orientation, the mean sensitivity was 0.0190g, with a sensitivity tolerance from 0.0126g to 0.0269g.

4. Conclusion

Multiple mobile consumer electronic devices were tested to quantify the sensitivity of the acceleration outputs with multiple trials. The acceleration output of the devices demonstrated a mean sensitivity of 0.0165g and 0.019g while lying flat and while in an upright 60 degree angle, respectively. Additionally, the devices demonstrated highly consistent sensitivity values across the devices, as demonstrated by the low coefficients of variability. Further studies will include various mobile consumer electronic devices utilizing different operating system software. A large scale sensitivity study will include 20 devices of each model and operating system software generation, and will be evaluated on multiple days over a period lasting no less than two weeks. This study is currently in progress.

5. References

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6. Tables And Figures

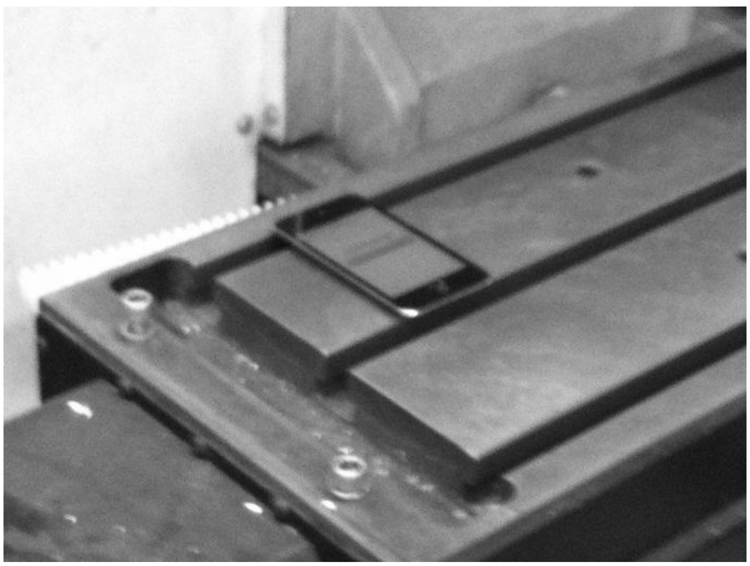

Figure 1. iPod device lying flat (screen-up) on test surface.

Figure 2. iPod device in 60-degree upright position

Table 1. Mean (SD) accelerations and sensitivity of the devices as a function of device orientation (all acceleration units are in g's).

Device Orientation	Measure	Device 1	Device 2	Device 3	Device 4	Device 5	Mean (SD)
Flat	Screen Up	-1.0210 (0.0006)	-1.0199 (0.0015)	-0.9725 (0.0004)	-1.0077 (0.0008)	-1.0160 (0.0002)	-1.0074 (0.0202)
	Screen Down	0.9855 (0.0008)	0.9801 (0.0001)	1.0280 (0.0002)	0.9985 (0.0002)	0.9907 (0.0004)	0.9966 (0.0189)
	Sensitivity	0.0178 (0.0007)	0.0199 (0.0008)	0.0278 (0.0001)	0.0046 (0.0005)	0.0127 (0.0002)	0.0165 (0.0086)
60 degrees	Screen Up	-0.5189 (0.0008)	-0.5236 (0.0005)	-0.4746 (0.0017)	-0.5154 (0.0001)	-0.5142 (0.0003)	-0.5094 (0.0198)
	Screen Down	0.4826 (0.0000)	0.4749 (0.0000)	0.5283 (0.0032)	0.4901 (0.0003)	0.4883 (0.0003)	0.4929 (0.0207)
	Sensitivity	0.0184 (0.0004)	0.0244 (0.0002)	0.0269 (0.0024)	0.0126 (0.0002)	0.0129 (0.0002)	0.0190 (0.0065)