Validation of Step Count Logs in Apple Health

Apple Health Step Counts and Timestamps as a Reliable Source of Forensic Data

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Abstract

Apple health data derived from iPhone movement and Apple Watch sensors is increasingly of interest in criminal investigation, addressing the actions, timing and location of suspects and victims of crime.

Step count logs are of particular interest, providing insight into, for example, whether a person of interest is walking or driving at a particular time, the correlation of step patterns between multiple persons of interest, and the interpretation of other movements which are recorded as steps.

We compare the logs recorded in the *Apple Health App* with external accelerometer readings to validate the differences between raw acceleration and final log in terms of step count and timestamp.

We have considered the acceleration and rotation characteristics which constitute a robust step identification to create a controlled step test rig with which we have gathered data to analyse metrics such as lag times between actual movement and log in the application.

Introduction

The potential of health data, in particular Apple Health data, is being explored for its use in digital forensics. Edwards [1] explored the file systems within iOS to demonstrate which databases can be utilised for modelling pattern of life. Zandwijk et al [2] explored the validity of using step counts as digital evidence. Their experiments consisted of comparing step counts from the Apple Health app using human subjects with a variety of experimental parameters.

In this work, we found supporting evidence as per [2] above, with a focus on the timestamps in isolation. We utilised an electrical-mechanical test rig to simulate the arm swings of a user, instead of using human subjects.

The method is one similar to Espinosa et al [3]. In Espinosa's paper, they compare the health data from the Apple Health app with the raw accelerometer data measured from SensorLog.

We also compared the Apple Health logs with acceleration data from a 3rd-party external Axivity AX3 accelerometer with the goal of assessing the Apple step counts in terms of acceleration.

Experimental Setup

This test rig simulates a pendulum and the arm swings of a user. It is constructed using a stepper motor, controlled by an Arduino microcontroller which allows us to configure the test parameters including forward and backwards angles, speed, duration and delays. With speed and duration, we can set the number of "steps", is one back and forth rotation.

Experimental Setup contd.

In this rig, an Apple Watch Series 3 and Accelerometer were placed in the same location. The benefit of using an external accelerometer over SensorLog is that we can calibrate the timestamps and verify the Apple timestamps to appropriately calculate lag time.

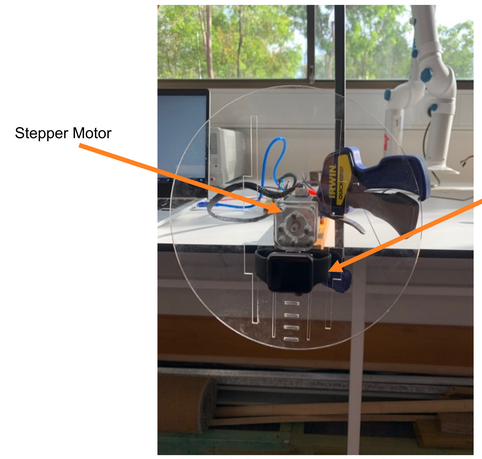

Figure 1: Experimental Step Count Rig.

For the experiments, the test parameters were set to perform swings of +- 45 degrees at a rate of 2 steps/second. There are three sets of results displayed in this poster (Result Sets 1, 2 and 3 below).

Results

Figure 2 (Result Set 1) below shows the overview for one of the repeated experiments. Blue is Apple data and Red is accelerometer data.

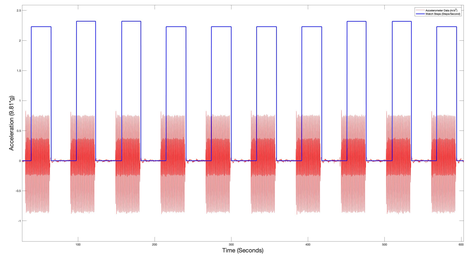

Figure 2: Result Set 1 – 10 sets of 60 steps.

We repeated this experiment 10 times to obtain a representative number of data points to determine the lag time between actual activity and log time. We applied a 20th-order bandpass IIR filter with lower 3-db frequency 0.1Hz and higher 3-db frequency 3Hz with a sample rate 100Hz.

Results contd.

The results for the first interval of figure 2 are shown in figure 3 and figure 4.

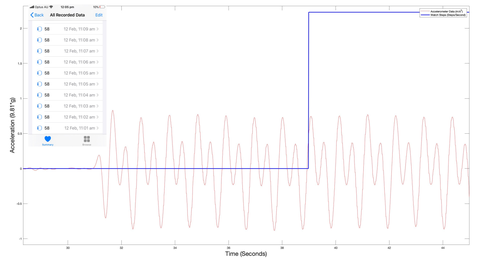

Figure 3: Lag for the start of the activity interval

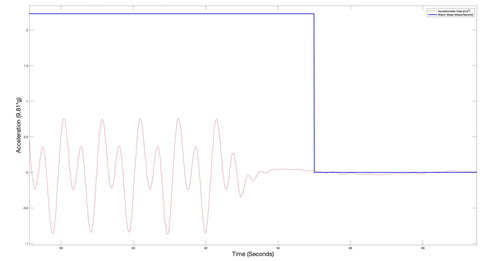

Figure 4: Lag at the end of the activity interval

The results for the 10 sets of intervals are displayed in table 1 below.

	Axivity		Apple Health					
Interval	Step Start	Step End	Log Start	Log End	Step Count	Start Lag	End Lag	Step Rate (Steps/sec)
1	31.0s	63.0s	39s	65s	58	8.0s	2.0s	2.23
2	89.8s	121.8s	98s	123s	58	8.2s	1.2s	2.32
3	148.7s	180.7s	157s	182s	58	8.3s	1.3s	2.32
4	207.5s	239.6s	215s	241s	58	7.5s	1.4s	2.23
5	266.4s	298.4s	274s	300s	58	7.6s	1.6s	2.23
6	325.3s	357.3s	333s	359s	58	7.7s	1.7s	2.23
7	384.1s	416.2s	392s	418s	58	7.9s	1.8s	2.23
8	443.0s	475.1s	451s	476s	58	8.0s	0.9s	2.32
9	501.9s	533.9s	510s	535s	58	8.1s	1.1s	2.32
10	560.8s	592.8s	568s	594s	58	7.2s	1.2s	2.23
Mean lag						7.85s	1.42s	
Standard deviation						0.34s	0.35s	
Measurement error						±1.12s	±1.12s	
Combined error						±1.17s	±1.17s	

Table 1: Test results for lag time at 2 steps/second

We found that for a step rate of 2 steps/second, the typical lag start time is between 7-8 seconds (15-16 steps). The typical lag end time is between 1-2 seconds. The average start lag is 7.85 seconds and the average end lag is 1.42 seconds.

The step counts are accurate for these tests at a step rate of 2 steps/second.

Results contd.

The second set of results evaluated log behaviour for longer duration intervals. Figure 5 (Result Set 2) demonstrates the log for a step count activity that lasts a maximum of 600 seconds.

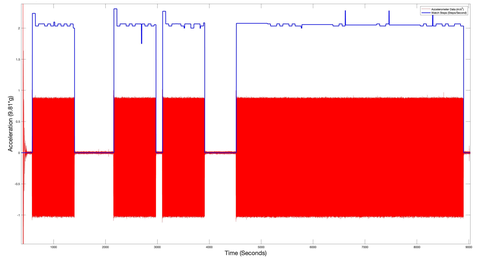

Figure 5: Result Set 2 – 600 second (10-minute) activity interval

We found that Apple Health can record up to 600 seconds of continuous step counts, which is consistent with the authors in [2].

Figure 6 (Result Set 3) below demonstrates a test where we found that separated intervals were aggregated into a 600 second interval in Apple Health. This was the same experiment as done in figure 2, but after the Watch was updated from WatchOS 5.3.1 to 6.1.2.

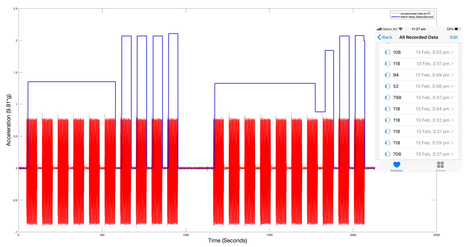

Figure 6: Result Set 3 – Aggregated step intervals

The results show that after the iOS update, Apple Health became more aggressive in aggregating its step intervals and the delay between sets was no longer enough for Apple Health to distinguish them.

Future Work

We will continue these experiments to determine future effects of OS updates on lag times, as well as extend to other devices both Apple and other brands.

References

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2. Jan Peter van Zandwijk and Abdul Boztas. The iphone health app from a forensic perspective: can steps and distances registered during walking and running be used as digital evidence? Digital Investigation, 28:S126–S133, 2019. ISSN 1742-2876. doi: https://doi.org/10.1016/j.diin.2019.01.021. URL https://www.sciencedirect.com/science/article/pii/S1742287619300313. 104
3. Hugo G Espinosa, David V Thiel, Matthew Sorell, and David Rowlands. Can we trust inertial and heart rate sensor data from an apple watch device? In Proceedings, volume 49, page 128. MDPI, 2020.