CUED - Engineering Tripos Part IIB 2021-2022 **Module Coursework**

Module	4B25	Title of report	Coursework 5 Report

Date submitted: 14/01/22

Assessment for this module is ☒ 100% / ☐ 25% coursework of which this assignment forms 35 %

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Feedback to the student

☐ **See also comments in the text**

		Very good	**Good**	Needs improvmt
CONTENT	**Completeness, quantity of content:** Has the report covered all aspects of the lab? Has the analysis been carried out thoroughly?			
	Correctness, quality of content Is the data correct? Is the analysis of the data correct? Are the conclusions correct?			
	Depth of understanding, quality of discussion Does the report show a good technical understanding? Have all the relevant conclusions been drawn?			
	Comments:			
PRESENTATION	**Attention to detail, typesetting and typographical errors** Is the report free of typographical errors? Are the figures/tables/references presented professionally?			
	Comments:			

Marker: Date:

4B25 - Coursework 5 Report

1. Problem Solved

The project focused on implementing a pedometer (or step-counter), to record and display the number of steps taken by a person while carrying the device. It can also estimate the calories burned while exercising with the device, by editing the parameters corresponding to the user's approximate height and weight. In addition, it can also compute whether the user is walking or running by measuring whether the number of steps in each time period exceeds an empirical threshold. The display can be chosen from 3 different variants to show calorie consumption, distance travelled or current speed estimates.

2. Stakeholders

The problem addressed by this project concerns any person who is interested in tracking their daily motion and is especially important for fitness enthusiasts as well as people with underlying health issues. The number of steps taken can be used as a measure of cardiovascular exercise, allowing users to quantify how active they are day-to-day and relative to baseline health figures. The estimate for the number of calories burnt can be used as a proxy to meet health institution recommended daily exercise goals, as well as personalised routines suggested by trainers or dieticians.

3. Current State of the Art[1]

Following the advent of MEMS IMUs, there has been a large increase in popularity of embedded pedometer systems, and there is a broad spectrum of products available to consumers ranging in accuracy and price point. The use of MEMS inertial sensors permits more accurate detection of steps and fewer false positives. The software technology used to interpret the output of the inertial sensor and "make sense of accurate steps" varies widely. The problem is compounded by the fact that in modern day-to-day life, such step-counters are expected to count accurately on locations where users frequently carry their devices.

- **Fitbit**:
The Fitbit is an always-on electronic pedometer, that in addition to counting steps also displays distance travelled, altitude climbed, calories burned, current intensity, and time of day. It also purports to measure the length and quality of a user's sleep. Based on activity, users are awarded badges for daily step and climbing targets. Most Fitbit devices estimate distance travelled based on steps counted, the intensity of the steps and the user's profile data (specifically gender and height. Higher-end Fitbit models include additional features such as heart rate monitoring and GPS tracking.

- **Apple watch**:
The Apple Watch extended step-counting capability to Apple's first wearable device using the accelerometer and gyroscope integrated in the Apple SIP (System in package). The Apple Watch works in parallel with a connected iPhone to improve accuracy of the user's step count

- **Smartphones**:
Since most smartphones are enhanced with an integrated accelerometer it is possible to introduce pedometer functionality to these devices. This option was successfully realized by several smartphone application developers, enabling users to track the number of steps taken as well as distance travelled (GPS also), and calories used.

4. My Approach

Figures 1 and 2 show a schematic and photograph of my pedometer device implementation, respectively.

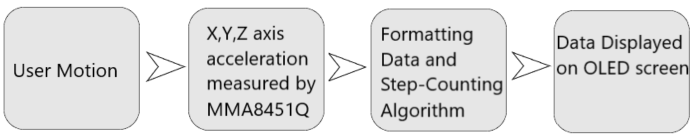

Figure 1: Pedometer operation flowchart

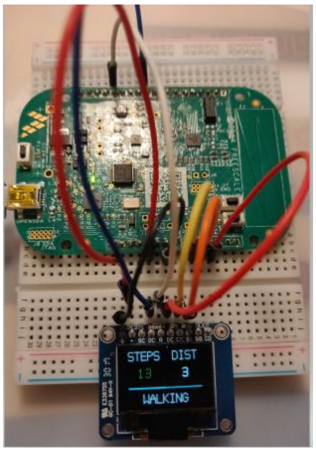

Figure 2: Photo of pedometer

The embedded system comprises the following hardware items:

- MMA8451Q IMU
- Kinetis KL03 microcontroller
- SSD1331 OLED Display
- Breadboard + Jumper wires

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[1] The material in this section has been adapted from https://en.wikipedia.org/wiki/Pedometer

The step counting algorithm has the following steps:

- Read x, y, z axis accelerations from IMU sensor (at 50Hz) and store in data buffers. Buffers hold 3s of data
- Low pass filter the data for maximal activity axis with an FIR filter
- Differentiate
- Check there haven't been any steps in the last buffer period
- Count the steps using derivative and spread of data points
- Keep track of steps in buffer based on entering and leaving steps

The calorie consumption, distance and speed estimates follow empirical equations found through experimentation[2].

The output from the step counter can be used to calculate additional parameters of interest including those mentioned above along with the mode (i.e. rest, walking or running). This information is then displayed on the OLED panel for the user to see.

5. Results

To test the accuracy of my approach, I travelled 100 steps along a flat test surface while carrying the pedometer and my phone (strapped to body for higher accuracy). This experiment was repeated 5 times walking and 2 times running, keeping the walking and running paces as similar as possible. The pedometer had an average error of 9.7% while walking and 11.5% while running, whereas the smartphone had an average error of 7.3% while walking and 8.5% while running. The best pedometers are accurate to within ± 5% error, and it is not surprising that the smartphone performed better than my approach. Considering this, the performance of my pedometer is reasonably good at medium walking speeds, and the accuracy drops off at higher (running) speeds or very slow walking. Pedometer placement also has an important effect accuracy and there are several studies that analyse this in depth[3].

Figures 3 and 4 show the variation in X, Y and Z accelerations as measured by the IMU (before filtering), for walking and running motion. The peak-to-peak value is larger when running as expected. Based on the orientation of the device as worn, the maximal activity axis is the Z axis (green trace).

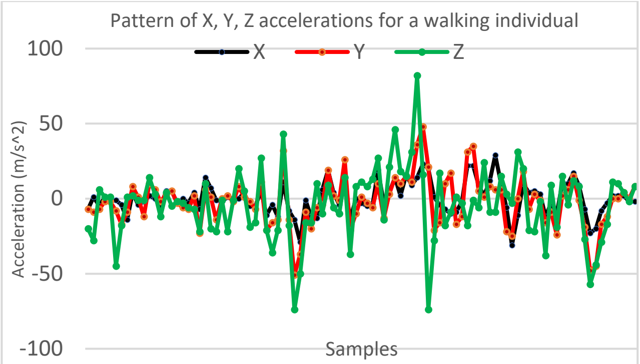

Figure 3: X, Y and Z axis acceleration measurements while user is walking

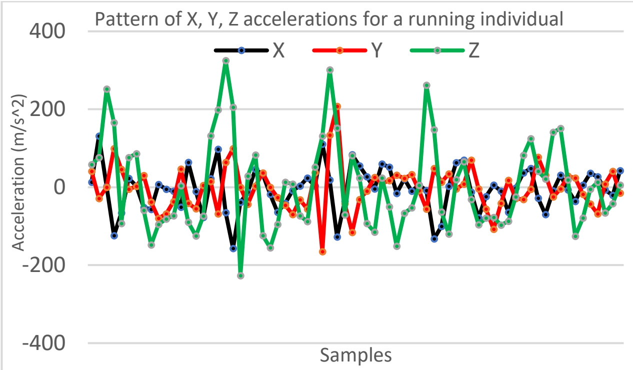

Figure 4: X, Y and Z axis acceleration measurements while user is running.

Figure 5 below shows the different interface designs for the OLED display, showing different data, and the three different modes: running (bottom left), walking (top) and rest (bottom right). Note that the screen is dimmed while at rest to lower power consumption. A green data value suggests the user's exercise goal has been met. This can be changed in the code.

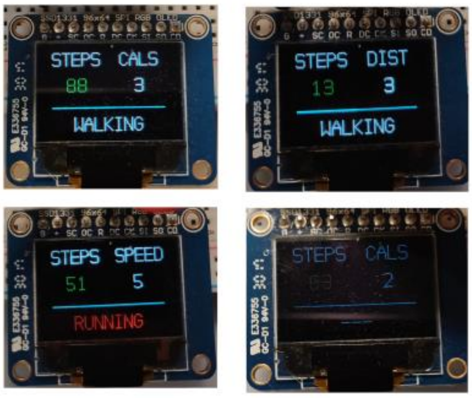

Figure 5: Different Display panel designs toggling between calorie, distance and speed measurements.

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[2] 'Full-Featured Pedometer Design Realized with 3-Axis Digital Accelerometer' - Neil Zhao

[3] Effect of walking speed and placement position interactions in determining the accuracy of various newer pedometers. Park, Lee, Wu, Tanaka