Product: Vitruvian
Team: Vee

Abstract

Our project will aim to help improve people's posture while working from home by monitoring sedentary activity and posture, notifying them via an app or by tactile feedback on a worn device.

We have made progress on the android app to accompany our hardware, building a visual, non-functional version to demonstrate intended functionality and UI. We also researched into methods for detecting sedentary activity and slouching and settled on what seem to be suitable models for both. On the hardware side we did some research into the components we'd need to put in place the models we researched and talked to Garry Ellard to establish their feasibility/availability. Finally we did some early research into potential physical designs.

1. Project plan update

Goals for first demo:

- Design Android UI - Achieved
- Create Android UI - Achieved
- Research sensor - Achieved
- Research other Components - Achieved
- Test sensor - Not Achieved
- Check Feasibility - Partly Achieved

The placement of "Test Sensor" for the first demo in our initial plan was a mistake - we realised that we did not have time to achieve this, and moved the deadline back to the 10th of February (see page 2 of our project plan) but forgot to update this everywhere. Actually testing our sensors will rely on us being able to coordinate with the technicians to get a basic device built, which was not feasible given we needed the majority of the week to plan the system out.

Feasibility checking partly relied on a physical device for testing, however we have compensated for this by reviewing existing literature.

Work organisation was handled via Trello, with tasks being assigned at our weekly meeting (Monday at 1pm), and progress being checked at a meeting held on Wednesday. The assignment of group members to tasks is roughly as follows:

- Alasdair: Research into existing literature on posture detection, planning a general structure for the detection system.
- Andrew: Research into hardware components and their availability.
- Mohamad: Research into sedentary detection algorithm and sensors.
- Vincent: Research in setting up a simulation of our device in Webots.
- Anelise: Developed the non-functional version of the Android App. Research into what technologies to use for tracking the progress.
- Morgan: Research into potential extra product features. Compilation of research data into Demo presentation.
- Jake: Designing UI for app prototype, writing slides for the video.
- Yining: Researching design.

We used one hour out of our technician budget this week. We are currently only using hardware available in Appleton, and so have not spend any of our monetary budget.

2. Technical details

Simulation We investigated and determined that webots is not a suitable environment for modeling the human body easily. Creating a simulation prototype would not have been useful, as it would not have given us meaningful insights into our full design. **Posture Detection** Having looked over the existing literature on posture detection, we identified a general method, and the hardware needed to support it, for detecting when a user is sitting or standing with poor posture.

The two indicators of poor posture that we will use are the inclination of the back, and the curve of the upper back. The inclination can be measured using an accelerometer/IMU (inertial measurement unit), and the curve can be measured either by using the difference in inclination between two accelerometer or by using a flex sensor. (Wang et al., 2015; Alsuwaidi et al., 2018)

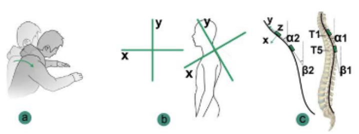


Figure 2. Angle Calculations. (a) Compensation Movement. (b) Zero Degree Calibration. (c) Calibration Model

Via (Wang et al., 2015): a and b are the angles measured by two IMUs. Y is the inclination, the average of a and b. Curve is calculated as the difference of a and b.

A consistent sticking point in the literature is the difficulty of discerning between someone slouching and someone bending over. Using both the inclination and curve was one solution (Alsuwaidi et al., 2018), and this is why we plan to use this factor together with back angle to determine if someone is slouching forward. We also use a timer system, and will only decide that the user is slouching if poor posture is retained for some period of time.

Both Wang et al and Alsuwaidi et al's work suggested the need for a calibration step. As we had already planned to have a pause feature controllable via bluetooth from an android app, we also decided to handle calibration from the app.

Other methods of posture detection that we considered were a webcam based system (an example of such an existing system can be found here (Coretech Robotics, 2014)), as well as a system relying on pressure sensors attached to a chair. We felt that both options had drawbacks compared to our chosen method, primarily in the fact that they would not work if the user left their desk.

Sedentary Detection we are going to use the same hardware we are using for posture detection. A general idea about how that can be done is by having relatively small acceleration values on 3 axis of the accelerometer used.

And by having a set of inputs within a relatively long interval of time (10 seconds for example) we can estimate a distance travelled within that time especially for Z axis which will change the most when transitioning between sitting and standing positions (look at Figure 1). Details about the algorithms we are going to experiment for this can be found in the Software subsection.

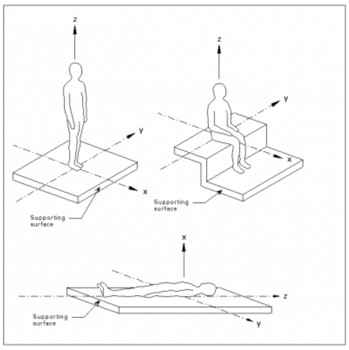
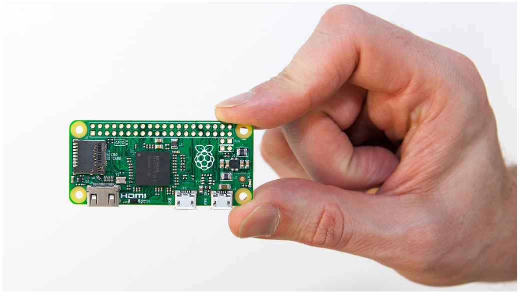


Figure 1. Human body projected on 3 axis (image source)

2.1. Hardware

Between the hardware feasibility meeting and our separate meeting with Garry, we established an initial plan for what hardware we will use. We will start with what is readily available and then refine it as we move forward.

Processor: Raspberry Pi 0 W



Raspberry Pi devices have a variety of resources available online and also can be programmed in python, making them ideal for our purposes. The Raspberry Pi 0 is smaller and more lightweight than alternatives, making it more suitable for attaching to a person as we intend, and we are unlikely to need the additional computing power of a larger model. The W models come with built-in wireless LAN and bluetooth capabilities to enable it to communicate with the app. In the short-term, however, Garry has advised us to use one of the Raspberry Pi 3's available in Appleton, which are already setup for remote access and thus quicker to start testing on.

Primary Sensors: Accelerometers (MPU-9250)

Our current intention is to rely heavily on a pair of accelerometers to measure the angle of a person's back. Using the average of two should help filter out noise, and also aid in accounting for some parts of the back being bent while others aren't. They will also serve a purpose in detecting sedentary activity when an individual has been sitting or lying for too long.

Our meeting with Garry pointed us towards the MPU-9250 available at Appleton. This 3-axis accelerometer (which also contains a gyroscope) has been used for body tracking projects at the university in the past. It is relatively lightweight and low power usage, so ideal for our application. It is however recommended for a 5V Vcc, which may be higher than the 3V Vcc for the raspberry pi 0, so further testing is required and alternatives should be kept in mind.

This article contains two different modules which are easy to connect to a raspberry pi. The GY-521 MPU-6050 contains both an accelerometer and a gyroscope for two different methods of measuring angles. The BerryGPS-IMUv4 contains both of these and a sleuth of other sensors, though at a much higher price point. This article lists another accelerometer, the ADXL345, which is more lightweight, being just a 3-axis accelerometer with low power usage.

Other Sensors: Flex sensors, gyroscopes etc.

Some of our research has indicated there may also be some practical use for flex sensors or even gyroscopes and other sensors in detecting back angle. We intend to run some basic tests with other kinds of sensors available at Appleton in order to ascertain their usefulness in terms of our system. The aim being to ensure our system is as accurate as possible while still remaining within a reasonable price range. The MPU-9250 at Appleton already incorporates a gyroscope, and Garry has informed us they have access to some pressure sensors which could be used as a stand-in for early testing of flex sensors if need be.

Power Supply: Lightweight Battery

Raspberry Pi 0 W uses a micro USB port for power, and thus a wide range of battery technologies could be adapted for use in our system. For earlier testing and prototypes since we will be using the larger standard raspberry pi 3 our power supply can be static. As we progress through the hardware design and slowly downsize our prototype, the hope is to improve the power supply too. The lab at Appleton has access to some mobile power banks, although these are relatively heavy they are easy to use and will be useful for early testing. Eventually we aim to move to some more lightweight solution for the final prototype, such as a Lithium ion or LiPo battery, depending on what can be sourced through Garry and still provide for our needs.

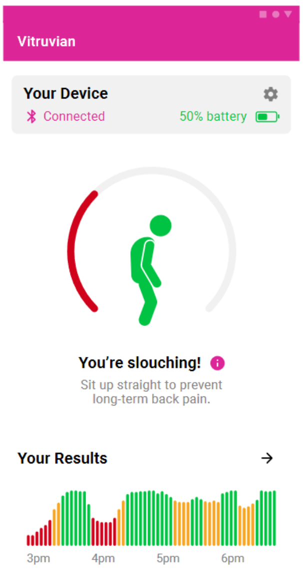
Tactile Feedback: Buzzer

This hardware element is not as critical at this point, as the collection of data and it's analysis are a priority. However eventually if the system is to provide tactile feedback for poor posture/sedentary activity, a component will be required for this. Garry has informed us that Appleton has a number of buzzers which may be suitable for our purpose. However if they are not, then our research has assured us that alternatives are available should we require them.

2.2. User interface

A visual, non-functional, version of the Android Application has been built to demonstrate the intended features and user interface. Our repository is available on Github. It was developed in Android Studio and the charts illustrated will be built using the MPAndroidChart and GraphLib open-source libraries.

We have included a video showing navigation through the app in our demo video.



2.3. Design

We considered several design ideas, settling on an undershirt-based form factor. During our meeting Garry he said that he would investigate sourcing them via the University sports department.

We plan to use a silicon-rubber-based mold to construct the housing, which will help protect the device. We will keep in mind the need to separate the CPU and battery for heat purposes.

2.4. Software

Posture detection Based on our use cases, the specific indicators of back posture that we chose based on the literature, and the hardware components that we have identified, we created the following flow chart for system state while measuring posture.

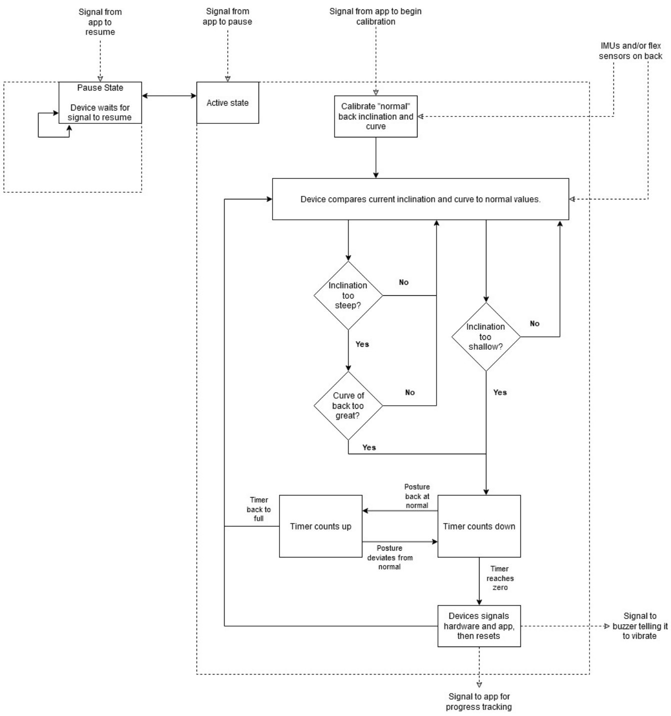


Figure 2. Posture Detection Flowchart (The dotted arrows here represent I/O operations)

Following from this, we have identified several parameters that we will have to decide upon once we have access to a first hardware prototype to perform testing on.

1. Thresholds for "Inclination too steep", "Inclination too shallow", and "Curve of back too great"

2. Length of timer

3. Rate that timer counts back up at

Sedentary Detection An optimal algorithm to detect sedentary behaviour would be a machine learning/deep learning classification algorithm, that will classify the current position of the device wearer (sitting, standing, walking..etc). And for that model to be possible we need a labelled dataset of accelerometer inputs to train it. We found a dataset which was used in (Kwapisz et al., 2011) and contains over 1 million samples of raw accelerometer inputs labelled with the following classes:

- Walking: 424,400 (38.6%)

- Jogging: 342,177 (31.2%)

- Upstairs: 122,869 (11.2%)

- Downstairs: 100,427 (9.1%)

- Sitting: 59,939 (5.5%)

- Standing: 48,395 (4.4%)

The study recorded a sample every 50ms, that's 20 samples per second. And then they transformed raw samples to intervals of 10 seconds. where they claimed that 10 seconds were enough to catch any repeated patterns in movement. They found that decision tree (J48) model had the best accuracy for detecting standing and sitting positions with percentages of 93.3% and 95.7% respectively. And those two positions are the important to develop our sedentary detection algorithm. One major concern when using the above dataset is that the study used smartphones accelerometers which was placed in the front pocket (the upper part of the thigh) while our product is intended to be placed on the middle to upper back. This may result different values on accelerometers for the same movements especially the ones that involve moving legs or thighs. another thing to consider is that this dataset is largely unbalanced and need to be pre-processed before training.

An alternative solution is to find suitable acceleration boundaries. if not crossed, the wearer is presumed in a sedentary position. We can also try to predict a transition between standing and sitting positions by monitoring increase in acceleration of the vertical axis along with how long the increase lasted.

3. Evaluation

It was not feasible for us to construct a model of the human spine and back in Webots, or to set up a sensor rig via technician commission for the first demo, and so our system could not be tested for this report. We will work with the technicians to have a basic prototype this week, and testing will begin then.

4. Budget

As mentioned above, we have not used any of our monetary budget yet, as all parts for the prototype are available in Appleton. As our design is refined we may need to spend some of our budget on specific components to better suit our needs. We utilised 1 of our 3 hours of technician time in week 3 to hold a meeting on potential hardware components. We intend to fully utilise our technician time budget for construction and testing over the rest of the project.

5. Video

https://uoe.sharepoint.com/:v:/s/SDP2021-Group-5/ESTT39xBsptEm9ktFW9D-ZYBht9iSDtOzMZ6WZwpVLJrAg?e=zRudIS

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