DESIGN OF A BACK POSTURE CORRECTION ASSISTIVE DEVICE

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Abstract - Poor back posture is difficult to correct because it doesn't present any symptoms until it has already reached a state where it is very difficult to correct. The objective of this report is to outline the design of a back posture correction assistive device. Using commercially available microcontrollers and inertial measurement units capable of measuring acceleration and angular velocity the author was able to design a device capable of knowing its orientation in space and alert the user whenever a threshold angle was reached while staying compact and unobtrusive. The result was the successful development of a compact device that will assist users in correcting bad posture whenever in use by alerting them of a deviation in their spine. The report will cover all the design process and future work to be done to have the device be commercially viable.

***Keywords*— Accelerometer, Arduino, Bioinstrumentation, Posture**

I. Introduction

The importance of back posture is often socially and culturally emphasized for benefits like professional and trustworthy appearance and confidence, but more importantly having a good back posture is important because it can negatively affect your health [1]. Because of the increasing amount of time spent sitting down at home, the office, classrooms and transportation in the industrialised world, bad posture is an increasingly common issue that goes unnoticed until adverse health effects start developing.

Health issues developed through bad back posture often lead to expensive treatments such as chiropractors and once they become an issue they are extremely hard to correct as the bones in the spine and the muscles surrounding them develop to sustain the poor posture [2].

Prevention is important to combat the development of a poor posture, this is done by constantly maintaining the back straight and keeping the natural curvature of the spine.

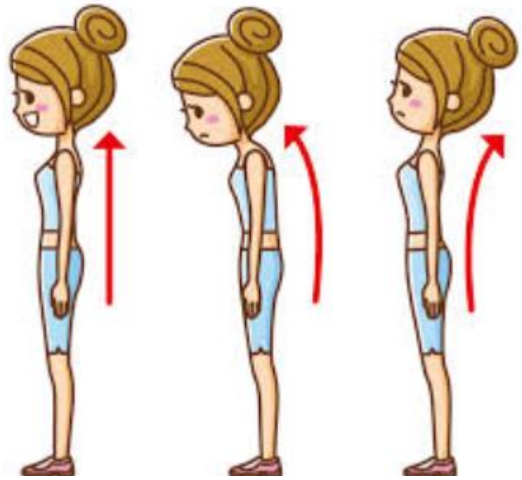
This report will outline the design of a back posture correction assistive device conceived to help users correct their poor posture by alerting them of a deviation of their back when in use. The report will outline all the design steps and specifications, provide background information and available solutions and finally describe the results obtained as well as a short summary of the future work that will need to be done in order to bring the product to a commercially viable solution as well as useful features that could be added.

II. Background of the Issue

Back posture is controlled by the tightening and releasing of the back muscles changing the orientation and positioning of our spine. As shown in Fig. 1 bad back posture is caused by repetitively positioning the spine in an orientation deviated from its natural curvature such that certain muscles weaken while others develop creating an unbalance and changing the curvature of the spine [2]. By maintaining the poor posture over a long period of time by for example sitting in a poor position at work every day, the muscles develop to keep that poor position and fixing it becomes harder.

A bad posture can have several adverse health effects. First, a bad posture can change the curvature of the spine which will translate to the spine being loaded in unnatural positions and increase the bending force on the vertebrae and the overall loading of the bones. An increase in the loading of the vertebrae can lead to the formation of an hernia and after long periods of time can cause degenerative disk disease which is a disease caused by repeated wear and tear in the vertebral disk and causes severe pain in the spine, it can only be cured through surgery and implant of a vertebral disk prostheses [3]. A change in the curvature can also affect the range of motion of the individual as the muscles will not allow for bending after certain angles and will cause severe pain [4].

Additionally, bad back posture can increase the risk of cardiovascular issues by compressing the chest area not allowing for the proper expansion of internal organs such as the lungs and the heart [4].



(a) (b) (c)

Fig 1. Change in the curvature of the spine due to bad posture, (a) good straight posture, (b) forward inclination and (c) backwards inclination [2].

Most of these adverse effects only develop after long periods of time which means they go unnoticed until symptoms show. In many cases as outlined above, the cure for the adverse consequences of bad posture can involve surgery so the best course of action is prevention. Prevention of bad back posture is complicated as it usually becomes a habit and goes unnoticed, therefore the developed device could have a big impact.

III. Available Solutions

Because this is a very common issue with a big market, there are commercially available solutions that tackle it already. We will cover the two most successful ones and use them to determine a good price range for our design as well as specify some of the characteristics.

A. Mechanical Compression Jacket

The simplest and cheapest device is a compression jacket, it uses elastic fabric in order to force the compression of the back muscles and so straighten the posture of the user [5]. As can be seen from Fig. 2 below, the jacket is very obtrusive as it wraps around the entire torso of the user and forces a proper stance instead of allowing the user to correct it by themselves.

A standard compressive jacket is priced around $30 CAD by the online retailer Amazon [6].

Fig 2. Standard compression jacket [5].

B. LumoBack by Lumo Body Tech

LumoBack is a more complicated and expensive alternative to a simple compression jacket. It is a Kickstarter funded product that senses the inclination of the device and alerts the user whenever a bad back posture is reached. As shown in Fig. 3, the device is designed as an elastic band belt that attaches at the lower back in order to be unobtrusive and has a companion mobile application that gives the user feedback and tracks progress.

The LumoBack is priced at $150 USD being approximately five times more expensive than a simple compression jacket.

Fig 3. LumoBack device and companion app

As we can see there is a large price variability between the two presented solutions. Our device will need to be priced between a simple compression jacket and the LumoBack in order to be economically viable and as close as possible to the price of a compression jacket in order to be competitive. Taking these conditions into consideration the author decided on a price range between $40 CAD and $60 CAD. Additionally, the device needs to be unobtrusive like the LumoBack and have similar performance.

IV. Design of the Device

The following sections of the report will look at every element of the design and fully describe the functionality of the device.

A. *Materials*

The designed device can be fundamentally broken down into its components, there are a total of four main components that build the functionality: the microcontroller, the sensor, the actuator and the power source.

The microcontroller is the unit that processes all the data from the sensor and also controls the actuator. The microcontroller chosen for this project is the Adafruit Trinket 3.3V [7]. The Trinket is a microcontroller that is based on the Arduino infrastructure and can be programmed using the Arduino IDE which makes it easily programmable. Additionally, it only measures 27mm by 15mm which makes it highly desirable for a compact project and costs $8.89 CAD therefore being inexpensive. All of these characteristics make the Trinket ideal for our project.

The sensor is the components that translates a physical value into a digital signal. In our case the physical value that we want is the acceleration and angular velocity of our device which will allow us to determine its position in space, therefore the sensor chosen is the SparkFun MPU9250 inertial measurement unit (IMU) [8]. This device will be further explained in following sections but it is capable of measuring the acceleration and angular velocity like we require, it is very compact with a footprint of only 20mm by 10mm and costs $18.99 CAD meeting all our requirements.

The actuator is the device responsible for alerting the user. The author decided that because the device will be attached to the user a vibrating actuator would be the most appropriate. A vibrating motor is able to silently alert the user without affecting the surroundings like speakers or lights would. A simple vibrating motor with a cost of $4.99 CAD was chosen for being inexpensive and able to run with the 3.3V that the microcontroller provides [9].

Finally, the power source of the device was chosen to be a Lithium Polymer (LiPo) battery. LiPo battery technology has developed greatly over the past decade and today power most of our smartphones, they are very reliable and can go through many cycles without loss of performance [10]. Because of the size constraint and the small power consumption of the other components a 400mAh LiPo battery was chosen costing $6.99 CAD [11].

The table below summarizes the components with their price and adds the total cost of the materials for the proposed device. We can see that the total cost comes to approximately $40 CAD which sits right in the lower end of the previously proposed price range.

TABLE I. Price of the proposed device's components

Component	**Price**
	CAD
Adafruit Trinket	8.89
SparkFun MPU9250	18.99
Vibration motor	4.99
LiPo battery	6.99
Total	39.86

B. *Adafruit Trinket*

As mentioned previously the microcontroller chosen for this project is the Adafruit Trinket 3.3V. The Trinket is a microcontroller based on the Atmel ATtiny85 processor and is fully programmable with the Arduino IDE [7]. The ability to program the device with the Arduino IDE makes it easily programmable as the author already had experience with the software. As shown in Fig. 4 the Trinket has 5 input/output pins as well as including SCL and SDA pins to be able to communicate with the MPU9250 IMU.

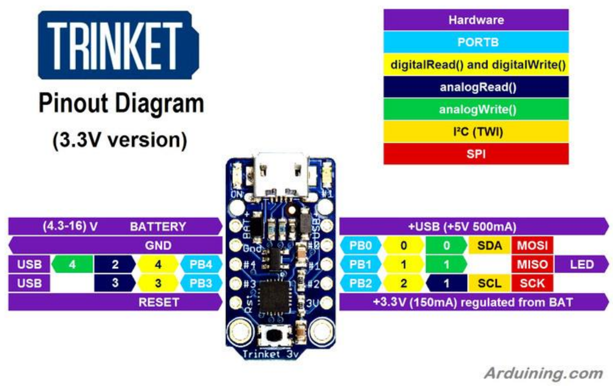


Fig 4. Pin diagram of the Adafruit Trinket

The board can be powered with an external battery which means it can work without being plugged to a computer.

Another reason for choosing the Trinket 3.3V is that it uses 3V logic instead of the 5V logic of the Arduino UNO. The 3V logic translates to a lower power consumption from the microcontroller which benefits our project reducing the size of the battery. The programming of the device will be explored in a later section of the report.

C. *SparkFun MPU9250 IMU*

The SparkFun MPU9250 IMU is a 9 degree-of-freedom inertial measurement unit capable of measuring acceleration, angular velocity and magnetic field in the x, y and z axis each [12].

The breakout board is compact and consumes little power, as per their specifications the boards largest battery consumptions comes from the magnetometer which is not used in our project. The board connects to the microcontroller using the SDA and SCL pins and uses I2C communications to transfer data.

D. I2C communication

I2C is a communication standard that allows a master device to communicate and transfer information with multiple slave devices using only two wires for each connection [13]. In our case the master is the Adafruit Trinket microcontroller and the slave is the MPU9250 IMU.

I2C communication makes our project possible by reducing the number of pins needed for communication between the sensor and the microcontroller to two. The objective of this report is not to explain I2C communications in detail, but a short description of it will prove useful in understanding how the controller and sensor communicate and how the software explained later works.

Essentially the way it works is as follows: the master starts the communications with the slave and requests information from a specific register, for example the register where the acceleration in the x-axis is saved. Then, the sensor accepts the requests and sends the data to the master, the master finally closes the communication and proceeds with the program.

E. Circuit Diagram

All the components described in the previous sections were connected according to the circuit diagram in Fig. 5. For ease of prototyping the circuit was build on a breadboard and not soldered directly. The final product will be soldered together in order to reduce the size.

The LiPo battery is modeled as a cell battery in the diagram and is connected to the mutual ground and the power line of the breadboard.

The sensor has 4 pins: the ground pin is connected to the mutual ground, the VCC pin is connected to the 3V pin of the microcontroller to provide power to run the chip and the SDA and SCL pins are connected to the corresponding SDA and SCL pins of the microcontroller for communication.

The microcontroller is modeled as the ATtiny85 processor and has a power pin connected to the power line of the breadboard as a power source, the SDA and SCL pins are connected to the sensor as described above, and the vibrating motor is connected to pin #1 used as a digital output.

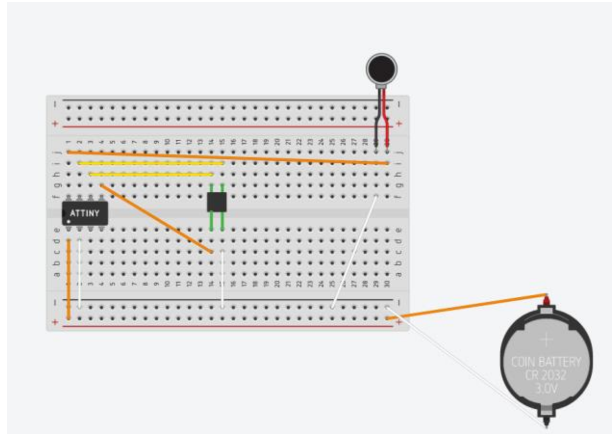


Fig 5. Proposed circuit diagram

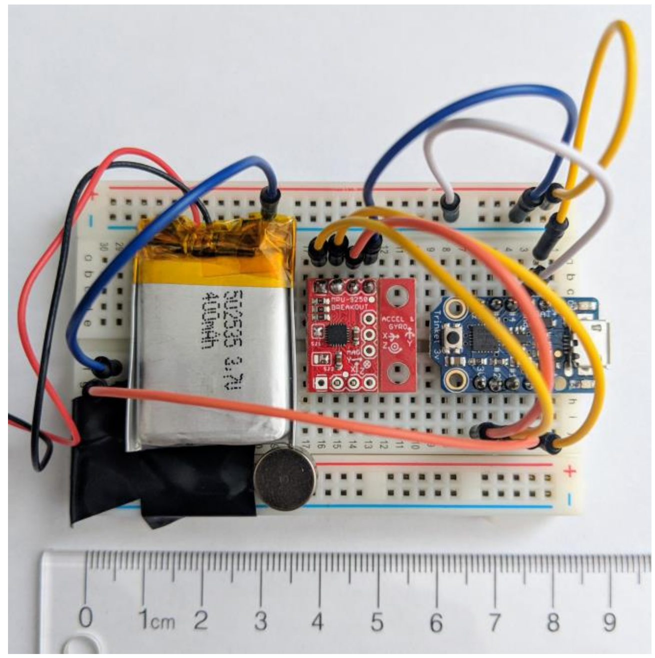


Fig 6. Actual component wiring following the circuit diagram with a ruler for scale

F. Software

The software for this device was programmed using the Arduino IDE with the help of a couple open-source libraries. Libraries are a collection of functions that we can import into our code in order to increase its functionality [14].

For this project, the author used the TinyWireM library by Adafruit [15]. This library provided all the functionality to communicate using the I2C protocol such as send and receive methods. The MPU9250 by Asuki Kono library was also used [16]. The later library provides methods for obtaining values in standard units from the sensor and a variety of computations with those values like yaw, pitch and roll for example. By combining the two libraries we can communicate with the sensor and obtain the necessary data.

A screenshot of the code is provided in the Appendix; in summary the code works as follows:

(a) Initialize the I2C connection and the IMU
(b) Calibrate the sensor and find the current position, set this as the balance position.
(c) Check the current position repeatedly and compare it to the balance position, if deviated enough from the balance position activate the vibration motor.

As we can observe, the software allows for the device to be worn in a variety of orientations as it calibrates itself at the very beginning of the program. Additionally, the acceptable deviation from the balance position can be easily modified to change the sensibility of the device.

V. Results

The design process outlined above allowed for the successful development of the intended device. The device is capable of calibrating itself by finding its current orientation and alerting the user whenever the deviation from the balance position overcame a certain threshold.

The device is intended to work as follows: it is attached ideally to the back of a shirt collar and turned on, it will undergo a short calibration process that is programmed to take approximately two seconds alerting the user with a quick double vibration once it is done. After this, once the user deviates from the balance position enough the device starts vibrating in short one second pulses to alert the user and stops once the user goes back to the balance position.

The two figures below show the final prototype and the device alerting the user that of an inclination exceeding the threshold. An LED was used as an alert instead of the vibrating motor for clarity.

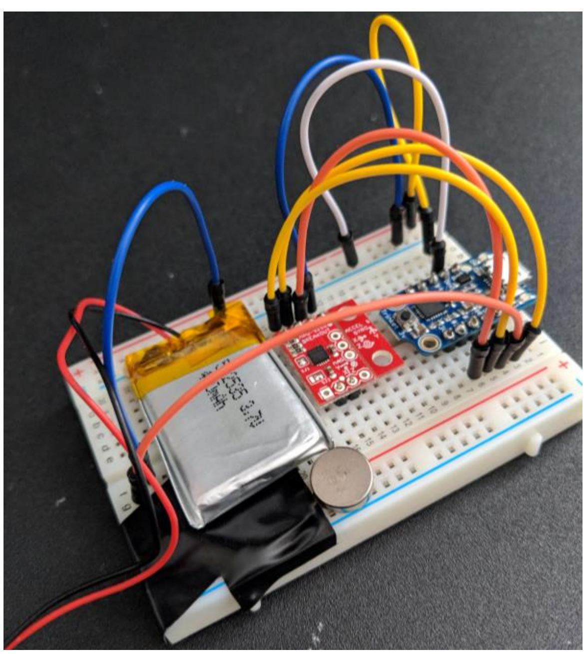


Fig 7. Final prototype of the device

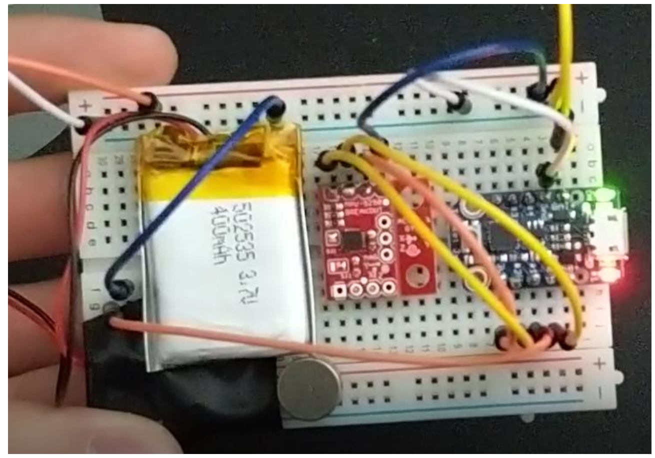


Fig 8. Device in operation, green LED shows the device is on and operating and the red LED is the alert

As can be seen by the pictures above the device is compact and has potential to be further reduced in size if the breadboard is removed and all connections are directly soldered together.

The resulting device performs as intended but has areas where improvement can be done: the sensor is slightly more sensible when placed in an horizontal position than a vertical position, therefore when placed vertically the angular deviation needed to activate the alert is higher than when placed horizontally. Further testing will need to be done to characterize the sensitivity of the sensor in different orientations but a solution is to program an extra calibration step in the code.

VI. Future Work

Although the developed device works properly and meets all the basic functionality that was intended to, it is not a fully-fledged and finished product yet. The list below contains tasks that will need to be done in order to make this a commercially viable product.

(a) Design of casing: a casing will need to be designed to protect the electronics, increase the ease of use of the device as well as provide a way to attach it to the user. The casing will ideally have a port for charging and a single power button to start and stop the device. The casing will be initially prototyped using 3D printing and then the final model can be mass produced using injection molding reducing cost.
(b) Specifications characterization: further testing will need to be done in order to determine specifications like expected battery life, recommended attachment locations and sensitivity.

(c) Add Bluetooth connection and companion mobile application: more research needs to be done to determine the viability of having a companion app. It would benefit the usability as it could log the data and track progress while providing a way to modify the sensibility but at the same time it would increase the cost of the device and decrease of use.

VII. Conclusion

To conclude, the back posture correction assistive device was developed successfully and meets all intended functionality. It correctly alerts the user whenever it is inclined past a balance position alerting him or her to correct his/her posture. The device is compact measuring only 8cm and 5cm in width with potential to be further shrunken down by removing the breadboard and soldering connections directly; therefore, meeting the size requirement. The material cost of the device is approximately $40 CAD which seats perfectly in the lower end of the required price range. Finally, there are a number of tasks to be completed in order to make the device commercially viable, these were listed and include the design of a casing, characterization of the performance specifications and implementation of a companion mobile application using Bluetooth connection.

Appendix A – Sample Code of The Back Posture Correction Assistive Device

```
#include <MPU9250_asukiaaa.h>

MPU9250 imu;
float aSet, aY;
int led = 1;

void setup() {
  pinMode(led, OUTPUT);
  TinyWireM.begin();
  imu.setWire(&TinyWireM);
  imu.beginAccel();
  aSet = 0;

  for(int i=0; i<50;i++){
  imu.accelUpdate();
  aSet += imu.accelY();
  delay(50);
  }

  aSet = aSet/50;
  digitalWrite(led, HIGH);
  delay(300);
  digitalWrite(led,LOW);
  delay(300);
  digitalWrite(led, HIGH);
  delay(300);
  digitalWrite(led,LOW);
}

void loop() {
  imu.accelUpdate();
  aY = imu.accelY();

  if((aY > aSet+0.3)||(aY < aSet-0.3)){
    digitalWrite(led, HIGH);
    delay(500);
    digitalWrite(led,LOW);
  }

  delay(500);
}
```


Acknowledgment

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