# PresTrack

## Functional Specifications for the Plantar Foot Pressure Analysis System by PresTrack

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## Glossary

| | |
|---|---|
| A/D | Analog/Digital |
| FSR | Force Sensing Resistor |
| GUI | Graphical User Interface |
| LED | Light Emitting Diode |
| MCU | Microcontroller Unit |
| MUX | Multiplexer |
| PC | Personal Computer |
| PFPAS | Plantar Foot Pressure Analysis System |
| RM | Measuring Resistor |
| SD | Storage Device |
| Subtalar joint | |
| I2C | Inter-Integrated Circuit |

# Abstract

Having the ability to wake up every day without a clenching pain in your feet should be given to each and every person. However, this is not a living reality for those suffering with plantar fasciitis. The plantar fascia aids in stabilizing the foot by absorbing the energy imposed on the heel with each heel strike, but can become the source of great pain with this characteristic inflammatory disease. Generally characterized as "inferior heel pain", its causes are difficult to infer due to its" multifactorial nature." [1] A published study for converging on risk factors for plantar fasciitis found that obesity and prolonged strain on the feet due to body weight were one of the leading causes for this condition. [2]

PresTrack is making steady progress towards establishing a cost-effective Plantar Foot Pressure Analysis System that will enable potential at-risk patients to be evaluated for mechanical indicators of Plantar Fasciitis. Following the functional specification document, we have made strong effort to design our product to fit the functionality. During this phase, we have took human factors and design principles into consideration by keeping the generic consumer in mind, making our product intuitive to use.

This document entails all fundamental mechanical, electrical and software engineering aspects that are a part of the Plantar Foot Pressure Analysis System. Upon completion of production, this product will be available to researchers in laboratories, and then can be developed further for manufacturing to all consumers.

# 1 Introduction

## 1.1 Scope

The design specification documents presents an in-depth view into the Plantar Foot Pressure Analysis System. This document complements the functional specification, and we have made an effort to ensure that the design meets all the functional requirements of our project. The design process has also taken comfort and safety into significant consideration, along with ensuring accurate representation of data. We have detailed the design parameters for our final demonstration product, as well as included some aspects of design that could be added post-demonstration for enabling manufacturing of the product.

## 1.2 Intended Audience

This design specification documented by the executive board of PresTrack. It is intended to be used by the engineering team to develop the product to ensure it meets the functional specification requirement. This document will also be used as a reference for components and assembly of the final product. In terms of future work, production engineers can use this document as a resource for ensuring the product can be modified for manufacturing.

## 1.3 Background

Plantar Fasciitis is a condition of the foot characterized by intense pain and discomfort surrounding the heel of the foot, in addition to decreased quality of life, as this discomfort prevents the sufferer to enjoy day to day activities. As treatment for this condition can cause much emotional, physical, and economical stress, addressing key risk factors for plantar fasciitis would aid in the treatment, but more effectively the early risk assessment and prevention of plantar fasciitis.

This Plantar Foot Pressure Analysis System is a system that quantifies the kinematics of the foot during walking. Although risks factors due to foot kinematics are limitless, this system has focussed on six foot features kinematics:

- Frequency of pronation
- Rate of pronation
- Angle of flexion
- Distribution of pressures on the bottom of the foot
- Impact force of the heel during walking
- Pattern of toe off

These measurements of foot mechanics will utilize Force Sensitive Resistors (to measure the pattern of toe off, heel impact force, and distribution of pressures), accelerometers (to measures the angle of flexion), and a gyroscope (to measure the frequency and rate of pronation).

The measurement device includes green, yellow, and red LEDs as feedback mechanisms to let the user know when system calibration, data collections, or system error is taking place. The user will also be able to control the measurement device using a switch that will connect the microcontroller to power, as well as begin the data measurement procedure.

The Plantar Foot Pressure Analysis System includes the following features:

- Portable
- Data logging for a continuous hour
- Compatible computer program to analyze and display findings in an easy to understand format

# 2 System Overview

## 2.1 System Design

The figure below portrays the concept arts of the device. Without heavily relying on specifics of technicalities, this image allows both technical and non-technical personnel to get the general overview of our final model of the system. The figure depicts the main hardware components which include the sensor embedded insole, the enclosed data collection device, as well as the gyroscope and accelerometers.

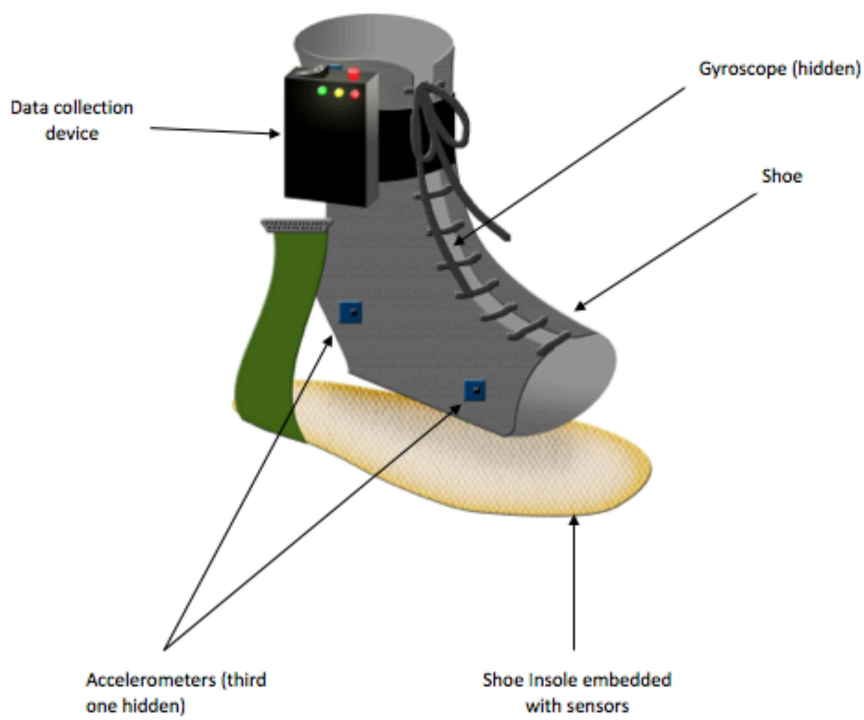



*Figure 1: Device Concept Art*

## 2.2 System Overview

This section provides a high level overview of the entire design. Design details specific to each part will be discussed in detail in their respective sections of the functional specification.

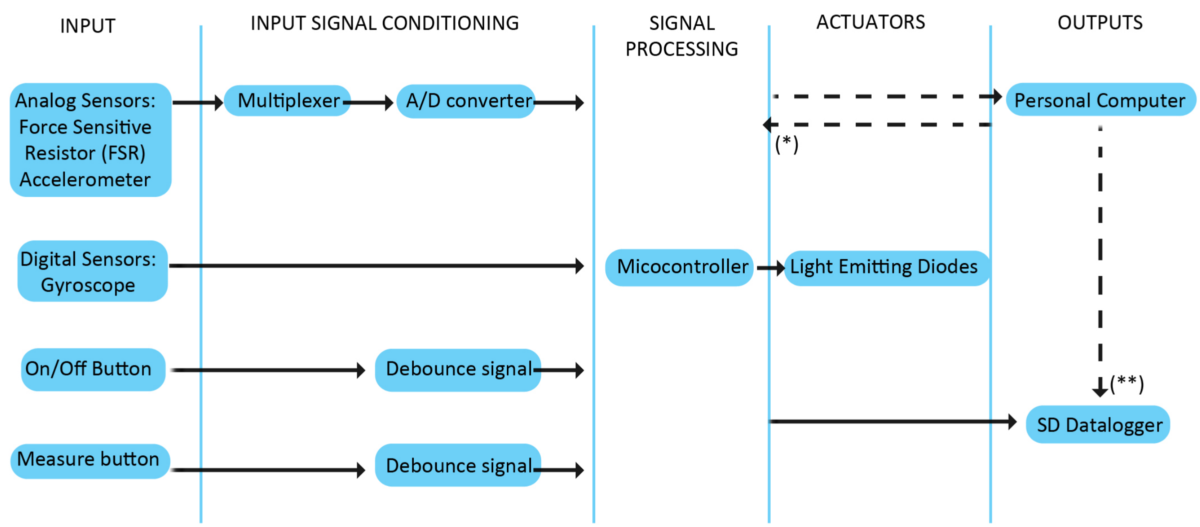



*Figure 2: High Level System Overview*

- *- indicates that the Personal Computer does not interface with the microcontroller during data collection;*
- *** - indicates that the personal computer accesses the SD Datalogger indirectly via the mircontroller.*

System inputs include buttons that turn the device on, and also begin data collection and analog and digital sensors. The gyroscope and accelerometer sensors are on breakout boards with built in circuitry to intrinsically mange any filtration necessary. Analog input will be relayed via an analog multiplexer, and conditioned through an A/D converter on the micro controller for further processing and data logging.

LED feedback is driven directly from the microcontroller, and is the only actuator in this device.

Signal processing takes place in the microcontroller where data is then logged onto an SD card device.

# 3 Sensors

## 3.1 Force Resistive Sensor (FSR)

The force sensitive resistor (FSR) is fundamentally a variable resistor that changes resistance when a pressure is applied over it. We will be using the FSR 402 manufactured by Interlink as our sensor for pressure in this project.

### 3.1.1 Material and Fabrication

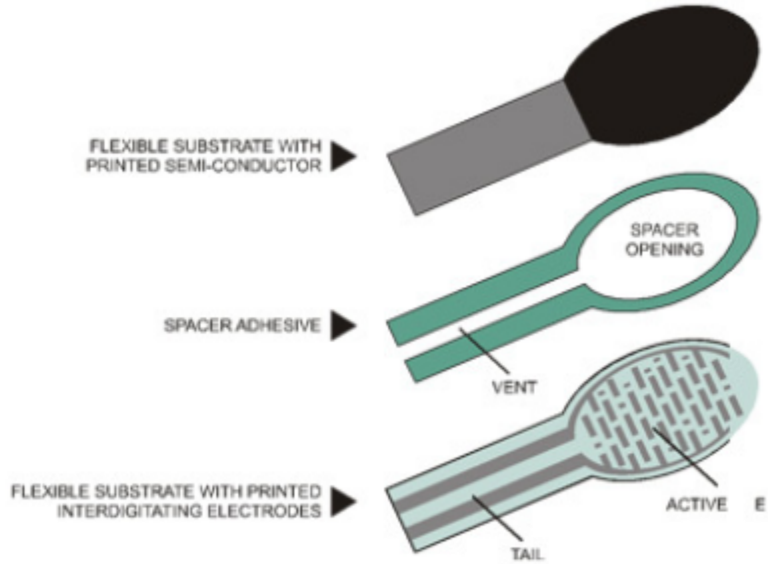



*Figure 3: The Material Layers in an FSR [3]*

The FSR is manufactured into three material layers as shown in the figure above. For this project, we did not tamper with this fabrication and/or modify the semiconductor properties, as this was a variable resistor and we used this sensor in its factory manufactured condition.

### 3.1.2 Circuitry

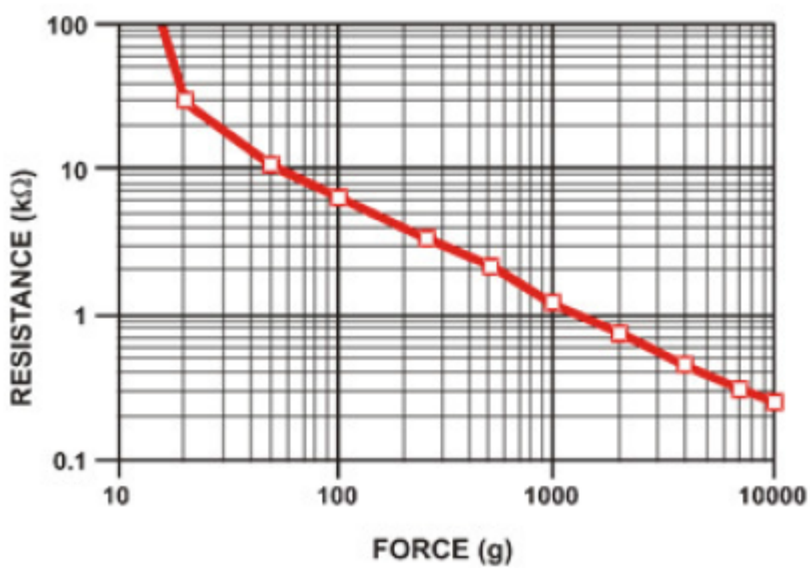
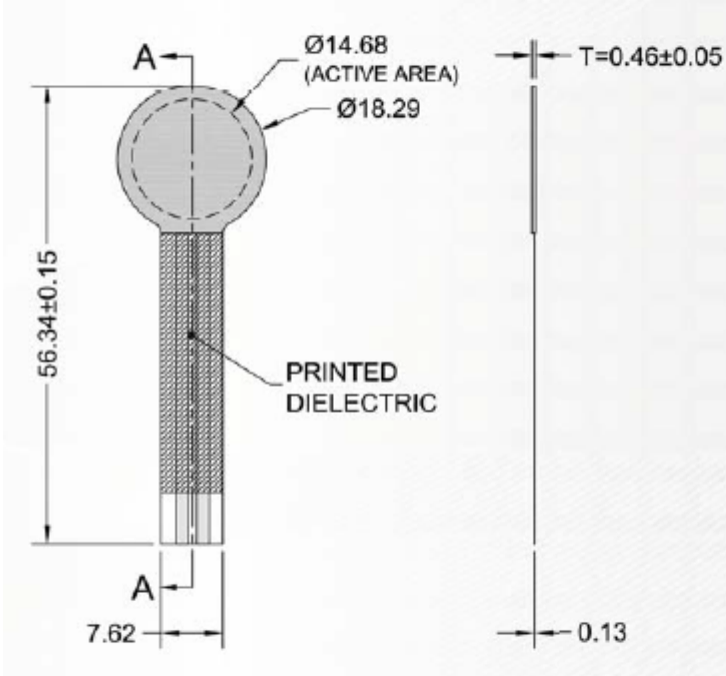



*Figure 4: Force versus resistance relationship plot for the FSR [3]*

Figure 4 depicts the logarithmic relation of resistance and force; as force increases, resistance decreases. We will be using a voltage divider circuit with an FSR shown in the figure below, as well as an RM which is our measuring resistor of 10 kΩ. The RM can be changed depending on the maximum amount of sensitivity required from the FSR, and for our system's application a value of 10 kΩ was selected after testing various other resistors. Since the Arduino board operates between 3-5 V ranges, we chose to supply a V+ of 5V.



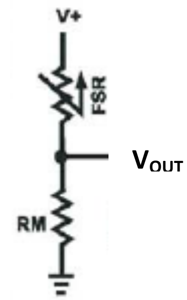




*Figure 5: Schematic of the voltage divider circuit (left) and the FSR's mechanical design (right) [4]*

With the voltage divider circuit depicted above (left) implemented, we used the following equation to compute the output:

$$V_{OUT} = \frac{R_M V^+}{(R_M + R_{FSR})}$$

*Equation 1- Output Voltage of an FSR in a voltage divider circuit*

This equation was then used in the Arduino coding for the FSR sensor so that the output data would give us the $V_{OUT}$ directly without having to do this processing through an external source such as MATLAB or Microsoft Excel. In order to accommodate any noise that is also accompanied with the data measurements, we will set threshold limits for pressure ranges within measurements, and regard any intermediate values as noise and discard them. In addition to this, we will filter out the power line noise and it's harmonics in PresTrack's MATLAB GUI Program.

### 3.1.3 Justification of Design Approach

The FSR were the main sensors to be used in our system. That being said, we needed a decent active area of sensing, and also needed to be careful about the amount of FSRs we used and their corresponding placement on the foot, as we were limited by the analog pins on our Arduino board. With this being a bit of a challenge in the earlier phases of the project, we decided to use seven FSRs as depicted below.

*Figure 6: Placement of ten FSRs on the shoe insole*

We then used a multiplexer to get the output from each FSR. A more detailed description of the MUX is given in the Hardware Design section in this document. For future improvements to this part, PresTrack plans to research into using smaller pressure sensors so that an even better resolution can be achieved.

## 3.2 Accelerometer

We'll be using the ADXL335 Triple axis accelerometer, placed on a breakout board developed by Seeedstudio. This device measures the acceleration in 3 orthogonal directions (x,y,z) and returns the measured acceleration in terms of number of g (g representing gravity which is approximately 9.81 $m/s^2$) as an equivalent voltage. The accelerometer itself is lightweight, however, as an improvement to the existing technology, we would like to eliminate this sensor and calibrate a smart phone to measure angles.

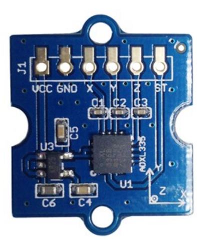



*Figure 7: Photo and circuit schematic of the SeedStudio Grove ADXL335 Breakout*

Accounting for the quadrant assignment appropriate for the calculated accelerations, the figure below demonstrates the use of 3 accelerometers (shown in red) to calculate the ankle angle (øAnkle).

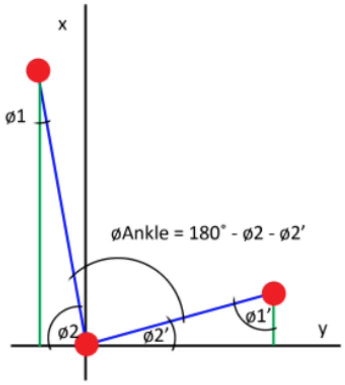



*Figure 8: Relationship between 3 accelerometers to determine ankle angle*

### 3.2.1 Circuitry

The ADXL335 is an analog device, where the x, y, and z components need only be read by the A/D converter of our microcontroller. The analog outputs have already been conditioned with 1 µF capacitors that are built into the design of the breakout board, enabling a 50 Hz bandwidth of filtering. As per the device specifications, the Gnd and Vcc will be connected to the Gnd and 3 V of outputs of our microcontroller respectively.

### 3.2.2 Justification for design approach

This device was chosen for its small size (4x4x1.45mm), its low power consumption (350 µA at 3 V), it's high sensitivity (approximately .3 mV/g), as well as its shock survival rate (10,000 g shock survival). In addition, the combined sensor and breakout unit was chosen for ease of integration into our design for proof of concept.

Using these three of these sensors, strategically placed on the lateral side of the ankle, will enable us to calculate the ankle angle. Using the following relationship:

*Equation 2 Calculation of X-Axis acceleration*

$$AccelerationX = (V_X - V_{Xzero})/Sensitivity$$

*Equation 3 Calculation of Y-Axis Acceleration*

$$AccelerationY = (V_Y - V_{Yzero})/Sensitivity$$

*Equation 4 Calculation of Z-Axis Equation*

$$AccelerationZ = (V_Z - V_{Zzero})/Sensitivty$$

The 3 equations above depict the acceleration in X, Y, and Z directions. $V_X$, $V_Y$, and $V_Z$ are the voltages that represent the change in direction, and final the $V_{Xzero}$, $V_{Yzero}$, $V_{Zzero}$ are the calibrated zero voltages with reference to the starting position of the foot; all calculations of angle will be made with respect to this calibrated zero voltage.

We can then move on to calculating angles in degrees for x and y planes as follows:

*Equation 5: Angle Calculation of Y*

$$\theta_1 = \tan^{-1}\left(\frac{AccelerationX}{\sqrt{AccelerationY^2}}\right) * \left(\frac{180}{\pi}\right)$$

*Equation 6: Angle Calculation of X*

$$\theta_2 = \tan^{-1}\left(\frac{AccelerationY}{\sqrt{AccelerationX^2}}\right) * \left(\frac{180}{\pi}\right)$$

## 3.3 Gyroscope

We'll be using the ITG3200 triple axis gyroscope, placed on a breakout board developed by Sparkfun. This device measures the angular speed about 3 orthogonal axis (x,y,z) and returns the measured angular speed in terms of degrees/second

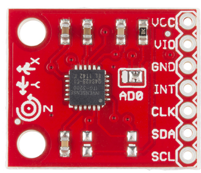



*Figure 9: Photo and circuit schematic of the SparkFun ITG3200 breakout Digital Analog sensor*

### 3.3.1 Circuitry

The ITG3200 is a digital device, communicating with our microcontroller using I2C communication. The angular speed measurements for all three axes are simultaneously transmitted along the SDA data bus, while clock cycles of the sensor are synchronized with the master microcontroller using the SCL lines. Gnd will be connected to the ground of the device, while the

### 3.3.2 Justification for use

This sensor was chosen for its low power operation (6.5 mA), its high sensitivity (14.375 LSBs per degrees/second), its small size (22.22 mm x 18.48 mm) as well as it large measurement range (+/- 2000 degrees per second). In addition, the combined sensor and breakout unit was chosen for ease of integration into our design for proof of concept. By placing the gyroscope on the medial aspect of the foot, near the subtalar joint, we'll be able to measure the speed of pronation, and keep track of the frequency of pronation as well.

# 4 Insole

## 4.1 Material

According to the functional specifications previously stated for the PFPAS, the chosen material for the final product of the shoe insole will be polyurethane foam like Sorbothane. This was chosen because literature states that it is the most comfortable material to be used for shoe insoles [5].

However, for proof of concept we are going to use shoe insoles that might not be made of this material so we can demonstrate that our idea works. We are going to use a generic shoe insole like the Dr. Scholls AirPillo to show that when placed on an insole FSRs can detect the change in pressure as required by our system [6]. The insole has a layer of soft cushioning foam which will provide comfort. It also has a grip foam which will prevent wrinkling and bunching up which could disturb the placement of the sensors, the wires and consequently the collection of data.

## 4.2 Fabrication for allowing sensor embedding

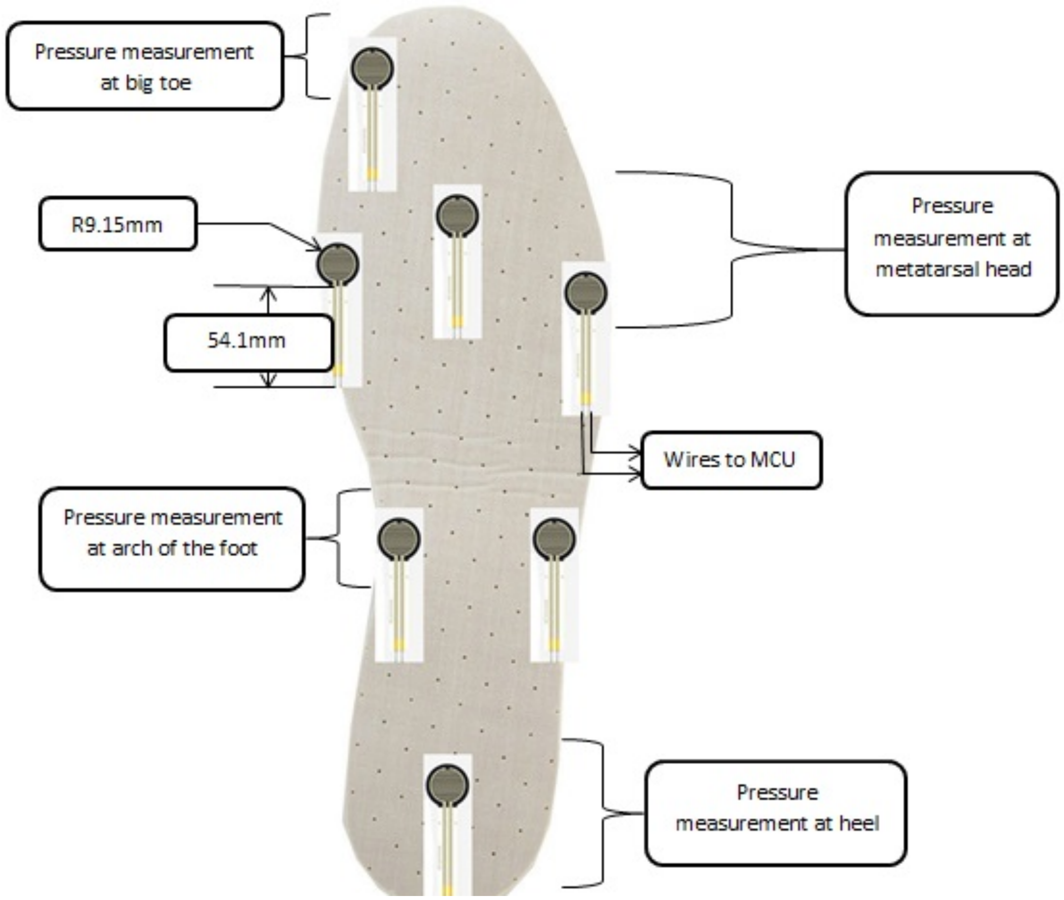



*Figure 10: Diagram of the shoe insole with the sensors integrated*

The top layer of the shoe insole will be made of fabric, this is necessary for sensor embedding. The FSRs will be sewn into the fabric so as to fix it to the insole and reduce the amount of shifting. Another alternative would be to glue the sensors onto the fabric; this reduces the possibility of tampering with the active area of the sensors through poking holes into the sensor. These sensors will then be covered by a thin film of silicon rubber in order to reduce the amount of dust and moisture on the sensors, so as to avoid altered results and potential electric shock. Shu *et al* stated that silicon rubber is ideal because it is soft and will thus provide comfort [7]. Silicon rubber is also very sensitive and will thus not affect the pressure readings and the resolution.

For proof of concept the FSRs will be sewn onto the fabric on the insole so as to secure them and minimize any shifting. Unlike in the final product, these FSRs will be exposed. There will be no risk of electric shock due to moisture because the wearer will not use the PFPAS for an extended period and the wearer will be advised to wear thin cotton socks which will absorb any form of moisture. The cotton socks like the silicon rubber should not affect the sensitivity of the FSRs. The insole also has cooling vents which keep the feet dry and comfortable [6]. In order to keep dust from settling on the insole, it shall be placed in a bag (Ziplock) whenever it is not in use.

## 4.3 Durability

An important characteristic of the sole is durability in terms of the number of cycles that the shoe insert will withstand. Unlike its counterparts, literature shows that this type of foam is superior in a number of things as well as durability [7]

For proof of concept, we will also use a durable insole so as to withstand the various pressures it will face during the testing phase and will last long enough demonstration phases of the project.  The Dr. Scholls AirPillo is durable; it has an approximate lifetime of 6 months [6]

# 5 Hardware Design

## 5.1 Microcontroller Platform (ARDUINO UNO)

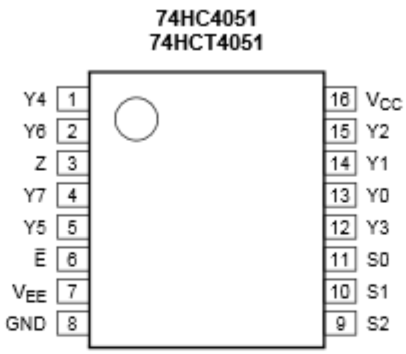
2.1 inches

2.7 inches

*Figure 11: Schematic of the Arduino Uno R3 board [8]*

The Planter Foot Pressure Analysis system will incorporate an Arduino Uno R3 with an ATmega328 microcontroller shown in the figure above. PresTrack chose Arduino as our primary processing platform because of its fit into our product's portability – at a weight of less than 30 grams, this board was the ideal choice for a wearable medical diagnostic device. In addition to this feature, its open-source coding platform and integrated development environment made Arduino an appealing choice for the engineers at PresTrack. The board will be powered via a 9V battery, which is in the range of the operational voltages of the Arduino Uno. [8]

## 5.2 Multiplexer




| Symbol | Pin | Description |
|---|---|---|
| $\overline{E}$ | 6 | enable input (active LOW) |
| $V_{EE}$ | 7 | supply voltage |
| GND | 8 | ground supply voltage |
| S0, S1, S2 | 11, 10, 9 | select input |
| Y0, Y1, Y2, Y3, Y4, Y5, Y6, Y7 | 13, 14, 15, 12, 1, 5, 2, 4 | independent input or output |
| Z | 3 | common output or input |
| $V_{CC}$ | 16 | supply voltage |

*Figure 12: Schematic Diagram of the 74HC4051 MUX (left) and its corresponding pin assignments [9]*

Initially, PresTrack did not have a MUX included as a design component. However, the limitation in the number of analog input pins on the Arduino UNO necessitates the use of this MUX. This 16 channel 74HC4051 MUX connects the FSR sensors and then the select lines are used to choose an output from each FSR sensor. This inclusion allowed us to use only one analog input pin on the Arduino. A more detailed description of how the MUX was interfaced with the Arduino UNO is present in the section below.

## 5.3 General Circuitry

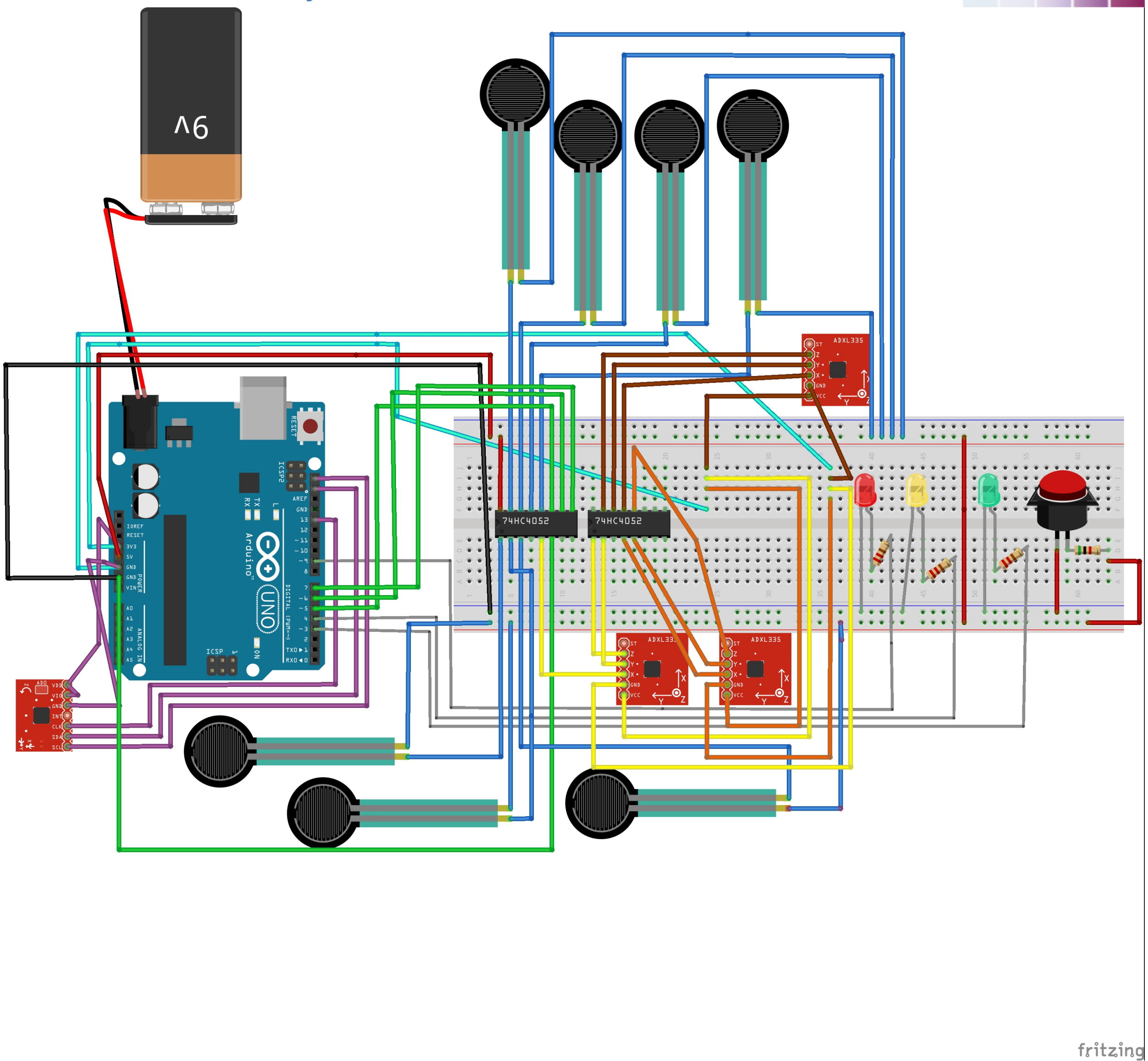



*Figure 13: Full Scale view of the wiring of the system*

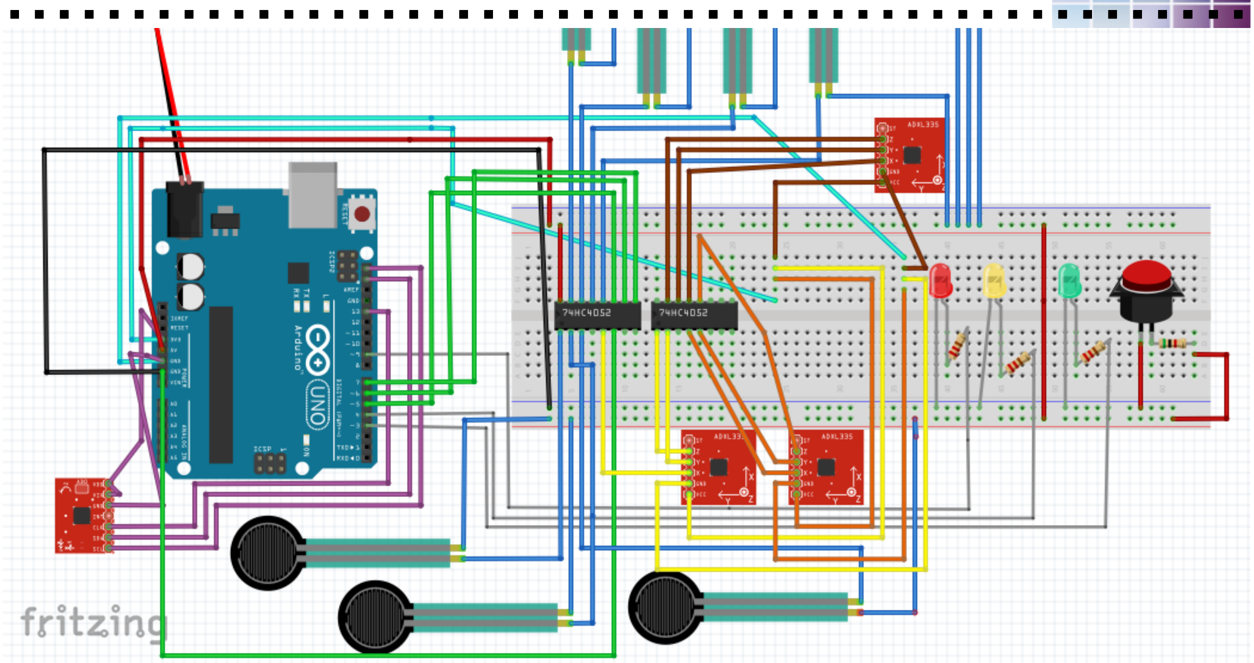



*Figure 14: Zoomed in view of the wiring of the system*

In general outlook of the hardware, our system consists of an Arduino UNO board, force sensitive resistors, accelerometers, gyroscope, and multiplexers. Along with passive components such as resistors and actuators such as LEDs. Figure 13 depicts the full view of our wiring. Please note that the nine volt battery will have a connector attached to it in the final model; this connector clip is not included in the diagram due to limitation of the parts library in the Fritzing software. Figure 14 allows for a more zoomed in display of the wiring so as to assist PresTrack's engineers, as well as future project workers when seeking details of the hardware of the system.

## 5.4 Push Button

*Figure 15: Push Button for controlling data collection from the device [10]*

For our device, the user will be able to control the beginning of data collection by pressing the push button shown on the image above (right). The schematic of the push button's connection is depicted below.

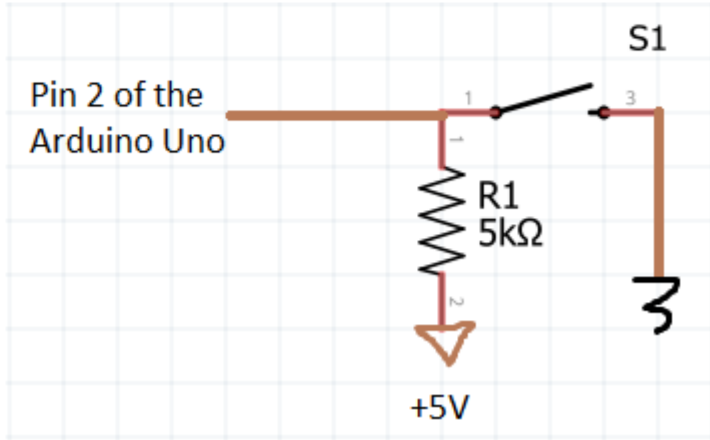



*Figure 16: Schematic of the push button acting as a switch and its connection to the Arduino Uno R3*

## 5.5 Data Logger

We will be mounting a data logger shield on top of our Arduino board which will collect the sensor data from the FSR, gyroscope and the accelerometer via the multiplexer and then store it on an SD card. This SD card can then be inserted into any laptop or PC (via an SD card reader) to further analyze the data in MATLAB.

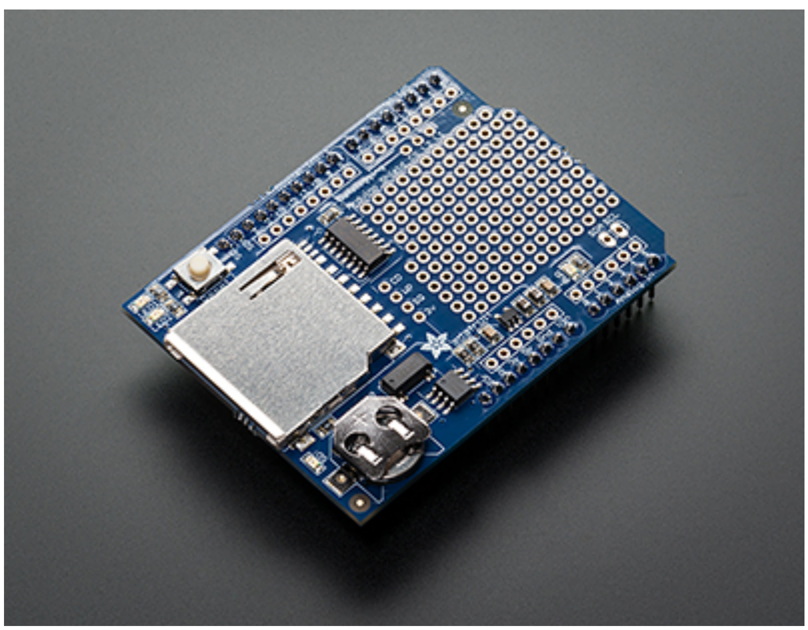


*Figure 17: An SD card Data Logger Shield for Arduino Uno to collect sensor data [11]*

## 5.6 Battery

The battery will be the primary source of power for the PFPAS. It will power the Microcontroller unit (MCU), the gyroscope, the datalogger and SD card, the 8 to 1 MUX and the three accelerometers. We chose to use an alkaline manganese dioxide battery, specifically the Duracell MN1604 9V (6RL61) D battery because it is affordable and it will provide us with adequate power for our system.

| Properties of the Duracell MN1604 | Value/Range |
|---|---|
| **Nominal Voltage** | 9V |
| **Operating Voltage** | 9.6 -4.8 V |
| **Impedance** | 1700 MΩ @ 1kHz |
| **Typical Weight** | 45g |
| **Typical Volume** | 22.8cm$^3$ |
| **Storage Temperature Range** | -20°C to 35°C |
| **Operating Temperature Range** | -20°C to 54°C |

*Table 1: Table showing the specifications of the battery [12]*

The recommended input voltage for the MCU is any voltage between 7V to 12V [13] and this will provide the required voltage for all the individual components of the PFPAS. The MCU has 3.3V and 5V pins that will be used to power the PFPAS components. The gyroscope operates between 2.1V and 3 .6V [14], the data logger and SD card operate at 3.3V [15] and consequently these will be connected to the 3.3V pin. The MUX will be connected to the 5V pin as it's and the optimum operating voltage is 5.0 V [16].

The battery was also chosen because of other features like its weight, volume, storage and temperature ranges. Given that the enclosure will be attached to the ankle, it is required that the power source be light and compact and 45g and 22.8 cm$^3$ [12] are adequate. The operating temperature of the battery also provides a good range, one that covers extreme temperatures that the system could operate in. The figure below shows the typical characteristics of discharge for the chosen battery depending on the impedance in the entire system. Depending on the total impedance of our system and we can calculate the number of hours that the system will be powered. If the system is operated at minimum MCU voltage, 7.5V and has an impedance of about 1kΩ then the system can last up to 40 hours if operated at 21°C as shown in the figure below. That is more than sufficient time to run multiple tests and the logging of data.

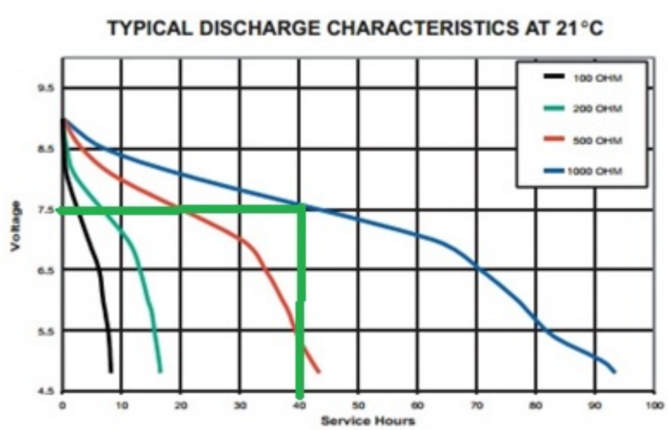



*Figure 18: Battery discharge at varying impedances [1]*

# 6 Software Design

## 6.1 Microcontroller Platform Coding

The microcontroller will be mainly responsible for collecting data from the FSRs, accelerometers, and gyroscope and processing their voltages into force, acceleration, and angular speed respectively. The figure below shows the algorithm that will be used for data collection.

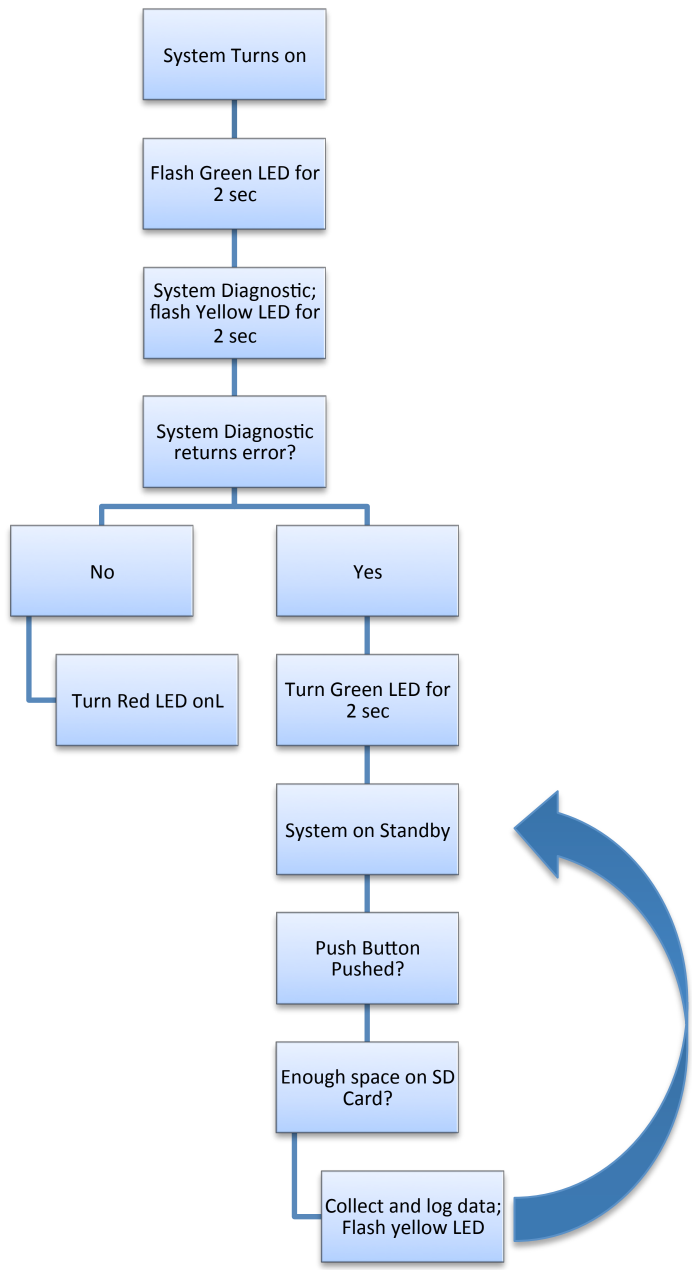



*Figure 19 Microcontroller Data Collection Algorithm*

## 6.2 Graphical User Interface (GUI)

The GUI application is designed such that it could be easily used by the physicians to analyze the collected data. It gives step by step instructions to the user and directs them throughout the process; from inserting the SD card to saving the results. It is divided into 2 main parts – Data Analysis and Results. For clarity, each dialogue box appears on a new window. An algorithm of the program can be found under Appendix B

### 6.2.1 Data Analysis

<u>Insert SD card</u>

To ensure compliance with the *User Interface* specification mentioned in the *Functional Specification for the Plantar Foot Pressure Analysis System* the GUI design is kept very intuitive and simple. The home page has a large foot icon under a magnifying glass as its background which indicates the user that this program will be analyzing the sole of the foot thoroughly. An 'enter' button is placed in the centre of the screen. The 'enter' button indicates the user that analysis will begin when this button is pressed. The user can close the program at any time by pressing the cross button present on the upper right corner. The placement of this cross button follows the general convention and is present on all windows of this program. Figure 20 depicts design options; the user can either continue the program or quit it.

*Figure 20: Design option - either to continue or quit the program*

### 6.2.1.1 Enter Patient's name

To emphasize the importance of this step, the box to enter the name is placed in the centre of the screen. This step is important because it helps in organizing the results as the name of the patient is displayed along with the resulting images. Figure 21 depicts the box that will prompt the user to enter patient's name and "enter button" to save this data.


*Figure 21: Name dialogue to prompt the user to enter patient's name*

### 6.2.1.2 Analysis

After the data is read from the SD card, analysis begins to produce results that could be easily read by the user. This process is depicted by the scanning motion of the foot on the screen, and indicates the user to patiently wait. As soon as the analysis is completed, results page opens. There is also a stop button on the lower right corner, as illustrated in Figure 22. This allows the user to terminate the analysis. This lower right location for the stop button was chosen because it is easier to locate as the user's brain is already trained to look at this side of the window for any kind of termination (e.g. cross button on the upper right corner).

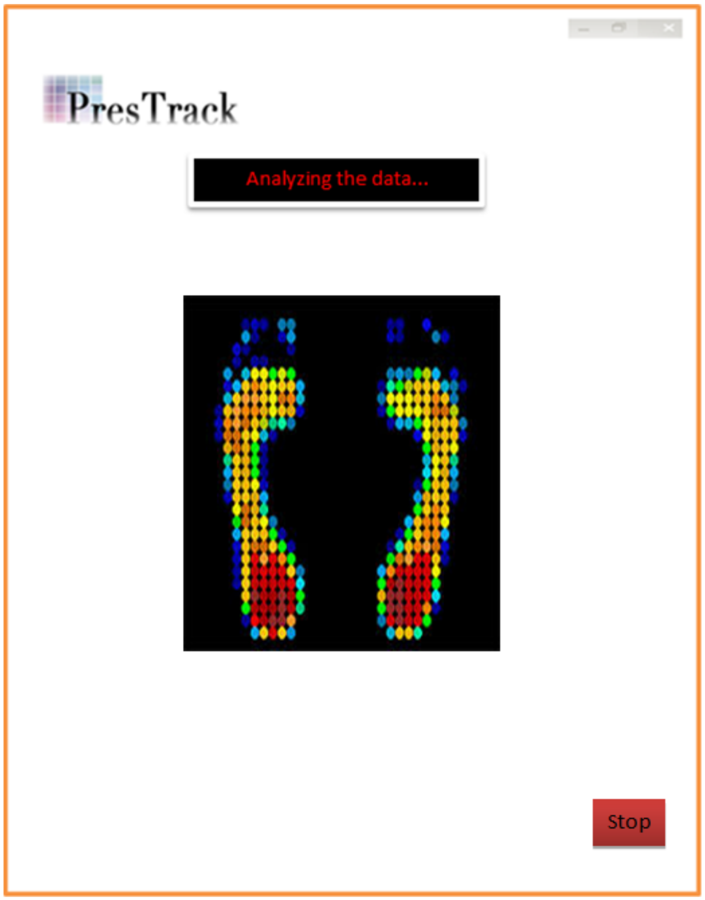



*Figure 22: Data Analysis page*

### 6.2.2 Results

#### *6.2.2.1 Data Presentation*

The results page is designed such that the physician gets the option to view the patient's foot in different perspectives in order to better diagnose its condition. In order to avoid an overwhelming amount of information in the results page, we have divided the information into multiple tabs to allow efficient access to the required information. This is also in accordance with the specifications mentioned under the *Analysis Program Requirement* section of the *Functional Specification for the Plantar Foot Pressure Analysis System*. The navigation tab on the left side of the results page lets the physician to look at the pressure mappings on the foot, areas of peak forces at the heel, and angles of dorsiflexion and pronation, as illustrated in the Figure 23. These three categories were chosen because the pictorial form helps in quick analysis of patient's condition. It aids the physician to form a better picture in his head about the patient's foot. There is also an option to view detailed data in tabulated form. A legend is placed right next to the images for convenience and quick description. A text box showing patient's name, date and time of data collection is placed right above the legend. This box is easily noticed by the physician and assists him/her in keeping these details in mind while evaluating the results.

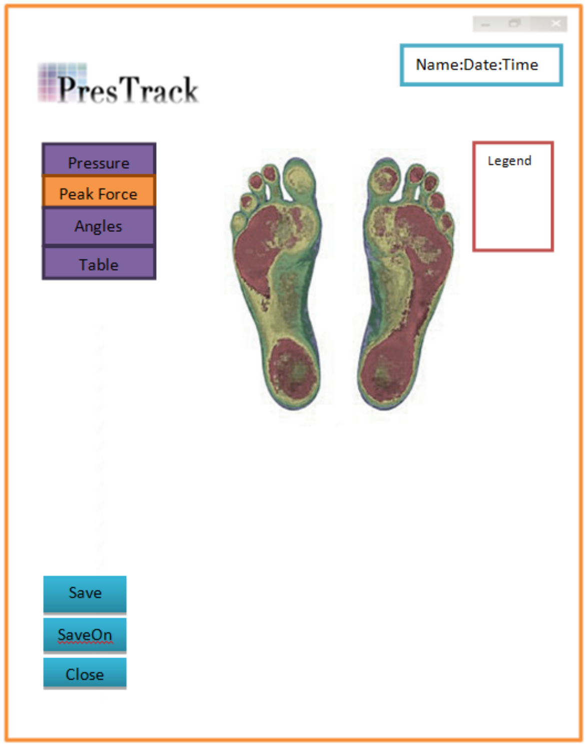



*Figure 23: Results page displaying various parameters that were analyzed by the software*

#### 6.2.2.2 Buttons

The bottom left corner of results page has three buttons. Placing these buttons together makes them prominent and convenient for the user to navigate. Also the right side of the page usually bears button for termination of the program, whereas the left side is chosen to save the results of the program and successfully closing the program once the results are displaced. The three buttons placed are Save, SaveOn and Close. The “Save” button gives the user three alternatives for saving the results – computer hard disk, USB or email. The “SaveOn” button lets the physician have a quick comparison of activities recorded on different occasions. This helps the physician to understand the trend in pressure variation at different times of the day. The “Close” button successfully closes the program once the purpose of running the program is accomplished.

When the user presses the “SaveOn” button, they are taken to the next page, as illustrated in the Figure 24. The results are organized in tabulated form and can be easily reviewed by the user by selecting the patient’s name. On the lower left corner, there are two buttons – compare and compare last. For convenience, they are placed right below the table. As the name suggests, the “Compare” button lets the user browse through the names of the file stored in the table. By clicking on the downward arrow, the user chooses the desired files and the results are compared. The “Compare Last” button compares the current entry with the last data entry.


*Figure 24: Window displayed upon pressing the 'SaveOn' button which displays all the previous stored data*

# 7 System Test Plan

The system test plan consists of multiple test outlined in the Appendix A below to ensure that the hardware (electronic and firmware) components function properly and produce the expected output

# 8 Conclusion

In this document, PresTrack has emphasized user comfort and safety in every aspect of its design – from hardware to software for accurate data reading, and also in its design of the final prototype and GUI that the user will interact with. In addition to this, the design spec will allow PresTrack's engineers to add the concluding parts by simply referring to this document along with aiding any engineers that will work further to modify the functionality of our product. Finally, we are confident that with this design, we can introduce a new gold standard for researchers and doctors alike, in their endeavour to proactively cure Plantar Fasciitis.

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# 10 Appendix A

## 10.1 Individual components

| Component | Areas to be tested | Test to be conducted |
|---|---|---|
| **FSR sensors** | Change in resistance when force is applied | Connect individual sensors to the multimeter and apply force to the sensor to observe the change in resistance |
| | Ensure that body weight can be accommodated by the sensor | Place the sensor under the heel of the foot to ensure that the sensor could detect the force applied by the body weight |
| | Compensation for hysteresis | Assume the output voltage is directly dependent to the loading history as a moving integral. Obtain an equation for compression force which is dependent on current output voltage and the moving integral. [16] |
| | Compensation for shear | Place the sensor in a situation simulating prolonged shear loading [16] |
| **Gyroscope** | Ensure that the device is calibrated | Using the digital gyroscope, placing the gyroscope on a flat surface when the device is switched on to calibrate the axes to zero |
| | Ensure that data is being collected | Connect the gyroscope to the Arduino and extracted some dummy data |
| **Accelerometer** | Ensure that the device is calibrated | |
| | Ensure that data is being collected | Connected the accelerometer to the Arduino and extracted some dummy data |
| **Arduino** | Ensure that the Arduino powers on | Connect the Arduino to the power supply and see the LED turn green |
| | Ensure that the required ports are working | After ensuring the individual components are working accurately, they are connected to the Arduino. Collect the data from the sensors to ensure that the ports are working |
| **Multiplexer** | Ensure that input and output ports are working | Using a dummy data, collect the data in the Multiplexer and |

| | | |
|---|---|---|
| | | ensure that the desired input is can be extracted from the outputs |
| **Data logging shield** | Ensure that data logs in | Connect the SD card to PC and open the file containing the data analysis |
| | Identify how much data can be stored | Run the system for a 1 hour with different tests indicating the frequency of sampling data |
| **Battery** | How long it can power on the Arduino | The battery will power on the Arduino for long periods of time to estimate the battery life |

## 10.2 Sensor Placement

| Component | Areas to be tested | Tests to be conducted |
|---|---|---|
| **FSR Sensor** | Ideal location of the sensor | Research peer review paper and study the pressure map across the feet to isolate key points for the sensor placement |
| | Distance of the sensor from the surface of the insole | Connect the sensor after incorporating into the insole to see the distance that the sensor can be placed within the insole and still read accurate results |
| **Gyroscope** | Ideal location of the sensor | Place the sensor in different regions around the ankle to accomplish extracting accurate while maintaining comfort |
| **Accelerometer** | Ideal location of the sensor | Place the sensor in different regions around the ankle to accomplish extracting accurate while maintaining comfort |

## 10.3 Integrated Unit Testing

| Component | Areas to be Tested | Tests to be conducted |
|---|---|---|
| **FSR sensor into the shoe insole** | Comfort | The newly integrated insole is worn by our own team members as well as friends and family to identify the comfort level |
| | Accuracy of data | The Arduino extracts the data |

| | | |
|---|---|---|
| | | from the sensors from team members and they are matched with those pressure map extracted from the F-scan machine |
| | How long the data extracted from the sensor is viable | The insole are worn for long periods of time by different team members, following which the data is periodically checked to see data disruption and corrupted data |
| **Accelerometer and Gyroscope with the MUX to the Arduino** | Comfort | The newly integrated insole is worn by our own team members as well as friends and family to identify the comfort level |
| | Accuracy of data | The Arduino extracts the data from the sensors and they are compared with peer reviewed journals for accuracy and reliability |
| | How long the data extracted from the sensor is viable | The data extracted is compared to those of peer reviewed journals to account for corrupted data |
| **Arduino with the MUX** | Rapidly select the inputs get desired output | The sensors are connected to the MUX and the software is utilised to extract the data from each individual sensors separately |
| **Arduino with data logger** | Ensure that the data is logged in | The SD card inserted into the Arduino Uno is removed and connected to the PC to ensure that the data was successfully logged into the SD card and if it can be read |
| **Electronic infrastructure** | Ensure the compatibility of various components | Test for proper ventilation so that the system does not get over heated and provide sufficient space for the wiring of the components |
| **Insole with FSR integrated with MUX** | Ensure that the data is being logged into the MUX | Extract the data from each individual FSR sensors through the MUX by appropriately choosing the input ports. |

## 10.4 Usability Testing

| Component | Areas to be Tested | Tested to be conducted |
|---|---|---|
| **FSR sensors in the insole** | Comfort | The newly integrated insole is worn by our own team members as well as friends and family to identify the comfort level |
| | Ensure that it can withstand day to day living conditions | Will be worn in place of normal shoes by executive members of PFPAS with hopes of replicating their daily routine. |
| **Gyroscope and accelerometer** | Comfort | The newly integrated insole is worn by our own team members as well as friends and family to identify the comfort level |

## 10.5 Software Testing

| Component | Areas to be Tested | | Tests to be conducted |
|---|---|---|---|
| **GUI** | User interface | Comfort and effectiveness | Friends and family of the group members are requested to use the GUI to verify if the GUI is user friendly and self-explanatory |
| | | Ensure that data is displayed | Run the GUI with data extracted from one of the patients and allow the user to view the results |
| | Algorithm | Algorithm extracts and analyses data | Extract data from the SD card and ensure that the data is appropriately analysed and depicted correctly |
| | | The accuracy of the pressure map | Sample data will be analysed by PFPAS and the F-scan for comparison |

# 11 Appendix B

## 11.1 Pseudocode for MATLAB's GUI

1. Click on the PresTrack icon to launch the program
2. (Home page) A page with the company logo appears with the following buttons:
    a. Enter button – this takes the user to next page (Step 3)
    b. Cross button – quits the program
       Before quitting a message pops – "*Are you sure you want to quit*?" with two options – "*YES*" and "*CANCEL*"
        1. YES – program closed
        2. CANCEL – program continues
    c. Minimize button – to minimize the window
    d. Maximize button – to maximize the window
       (Buttons b, c and d are common in all the windows)
3. This page prompts the user to insert the SD card :
   This step is bypassed if the SD has been inserted and detected.
    a. On finding the SD card, message is displaced – "*SD card found!*"
    b. If this step is not successful error message is displaced. Few examples:
        i. If SD card not found, display: *"SD card not found"*
        ii. If relevant files not found, display: "*Files to be analyzed not found*"
        iii. If SD card is empty, display: "*SD Card is empty*"
           Now the user gets two options:
            - Try again button : Goes back to step 3
            - Quit button : Quits the program
4. After detecting the SD card, a page prompting the user for the patient's name pops up:
    a. There is a box to enter the patient's name
    b. There is an enter button that the user will press once the name has been entered.
    c. Once the enter button is pressed the program moves onto the new page. If the user presses the enter button without entering the name, a message appears-"*Please Enter the name first*", and stays on the same page.
5. Analysis Page (After the name has been entered the program moves straight to analysis)
    a. A wait icon is displayed while the data is being analyzed (we thought this could be a set of feet showing a scanning motion – maybe I'll explain this better when we see each other). Also a message would appear on the screen – "Analyzing *the data..."*
    b. Stop button – Its present on the right side bottom corner, in case the user wants to stop the analysis.
       On pressing this button, a message appears on the screen –
       "Are *you sure you want to stop the Data Analysis?"* With options "*YES*" and "CANCEL"
        i. YES – Stops the data analysis, and new message appears :
           "*What would you like to do?"* with options "*Quit the program* "and "*Insert new SD card*"
            - Quit the program – closes the program

- Insert new SD card – takes the user back to step 3

ii. CANCEL – continues with Data analysis

c. If this step is unsuccessful error message is displaced – “ *Data Analysis Unsuccessful*” with options: “ *Quit the program*” and “*Insert new SD card*”
   - Quit the program – closes the program
   - Insert new SD card – takes the user back to step 3

   (It would be ideal if we mention why exactly the analysis failed – maybe data is corrupted or not enough data points collected)

6. Results page - the patient’s name, date and time of activity are shown on the top right side of the page
   a. Our primary image is shown-a pair of feet showing the isobars (areas of the same pressure). There is a legend next to the showing the different levels of pressure
   b. On the left side of the image there are number of tabs to see other results
      i. Peak force – Peak forces are shown on our primary image (the feet)
      ii. Angles - 3D image of the foot depicting the angle of dorsiflexion and pronation
      iii. Table – It has
         1. Peak forces, showing the peak forces at the different landmarks
         2. Angles, showing the angles of dorsiflexion and pronation
         3. Frequency values for dorsiflexion and pronation
   c. Save button - When this is pressed all the images, tables of peak forces and angles and the raw data are saved in one folder

      A message appears “*Where would you like to save the data*? “
      With options – “*Computer hard disk*”, “*USB*”, “*Email*
      1. Computer hard disk – Asks for the location where the data would be saved, *“Please enter the location*”. Press enter button, right below the box
      2. USB – checks for externally connected devices. If USB not found, message appears, “Please insert the USB”. Press save button, right below the box
      3. Email – Compresses the folder. Asks for the email addresses of the recipients, “*Please enter the email address*”. Press send button, right below the box. There is also a more button to enter more than two email addresses
   d. SaveON button – On pressing this button the user is taken to a new page. The current data is saved and placed on the table present on the page. This table has data from various activities. You can click on any table entry to view it. Results as before would be displayed. Entries are sorted by date and then time.
      i. Compare button- for comparison with activity that was recorded on a different occasion (e.g. compare morning and end of the day activity).

         On clicking this button, the menu expands and the user is prompted to browse through the file names by clicking on the down arrow button and select the files of interest.

ii. Compare Last button -For comparison of previous and current instance

iii. On pressing either of the two buttons, new results comparison page opens

1. Primary images of the two instances are shown side by side
2. Tabs on the side are the same as before. However this time they show a comparison of the different instances
3. Save button - When this is pressed all the images, tables of peak forces and angles and the raw data are saved in one folder (Naming convention of the folder –Cresults followed by name followed by file1 and file2 : Cresults_J.Smith_file1_file2).

A message appears "*Where would you like to save the data*? "

With options – "*Computer hard disk*", "*USB*", "*Email"*

- Computer hard disk – Asks for the location where the data would be saved, *"Please enter the location*". Press enter button, right below the box.
- USB – checks for externally connected devices. If USB not found, message appears, "Please insert the USB". Press save button, right below the box.
- Email – Compresses the folder. Asks for the email addresses of the recipients, "*Please enter the email address*". Press send button, right below the box. There is also a more button to enter more than two email addresses.

4. GO Back Button – This button appears left bottom of this page. This Takes the user back to Results page
5. Continue Button – This buttons appears below the go back button. And takes the user back to the previous page

e. Close button – to close the program

On pressing this button message appears – "*Are you sure you want to close the program*?" With options "*YES*" and "*NO*"

1. YES– the program closes
2. NO- the program stays on the last page