sIoT-shoe: A Smart IoT-shoe for Gait Assistance (Miami University)

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Abstract

Gait analysis through the Internet of Things (IoT) is able to provide an overall assessment of daily living. All existing systems for predicting imbalance of walking in the elderly mainly consider the gait related parameters [2]. The objective of this study is to design and develop a next generation sensor embedded smart IoT-shoe that can detect abnormal walking patterns by analyzing foot pressure variations. The smart IoT-shoe will have a Low Energy (LE) Bluetooth communication module to discreetly collect insole pressure signals in a common environment using smartphone or smartwatch.

Background

Abnormal walking can be a chronic issue for many people, especially over the age of 65. This can be caused by walking incorrectly or having improper support for the foot along with various other medical issues. There are options for fixing these issues such as consciously walking different or using shoe inserts. The issue is many people do not realize that they have these issues or they do realize they have some sort of problem but not how to fix it. The average person can't tell what they are doing wrong when walking. Though these issues could be detected by a professional, most people don't see a need to go to a physician unless there is an immediate, or direct need.

Problem Statement

For this project we wanted to create smart shoe that can give the user feedback on any recognized walking abnormalities as fast as possible. Even though we think this will be more helpful for older users, the product will be useful for people of all ages. Using the concept of the internet of things (IoT), to detect and translate physical data from real world, the shoe will be able to provide real time results from the user's walking.

By developing a smart-shoe that can track weight distribution and abnormal walking patterns the user would be able to see the data for themselves through the application. The shoe will track the user's walking patterns and over the course of a few minutes be able to give the user different types of feedback, from the type of support the user needs, to ways to improve on their walking patterns every day. For example, if the application sees that the user puts more weight on their heels, a daily recommendation could be to try and put a little more weight at the top off the foot when walking. This sort of shoe will have the potential to help many different types of people who have these chronic foot issues.

Research Questions

Our research into gait analysis left us with a few questions:

- What sort of data will have a meaningful impact on the walking of individuals?
- How can we easily provide users with access to this data?
- What sort of conclusions can we form and present from the data collected?

We believe that the shoe is the most accurate location for gathering data on walking behavior.

By transferring this data over Bluetooth to a smart device we can both quickly gather and analyze data while providing real time feedback on walking abnormalities.

Design Criteria

In order to make the device useful in real world situations we must consider the following:

First, we need to make sure that the system can send data to various smart devices. This flexibility can allow a larger array of individuals to access the data. Secondly, the system should be small enough so that it would not affect people's daily habits.Finally, low energy is needed in order to operate for long periods of time so that people's daily lives will not be affected.

Methods (Design and Development)

After observing the design we intended to create, we were able to divide the work into two major portions, hardware and software. The hardware portion would require us to build and attach all the components to the shoe in some sort of compact manner. The software would require us to design an application to accept the low energy Bluetooth signal, gather data, and display feedback in a meaningful way. More details on these in the sections below.

Hardware

After obtaining the components to satisfy the system requirements, we were able to create the system prototype to test it. The circuit is mainly three parts:sensors to processor, processor to Bluetooth module, and the module to the smart device [5]. In the initial test, we used the Arduino Uno as the microcontroller to test the system. Later on we replaced the Arduino Uno with the Adafruit Pro Trinket [4], which is a smaller microcontroller with similar functionality. The connection between the microcontroller and the Bluetooth module can be seen in Figure 1 below.

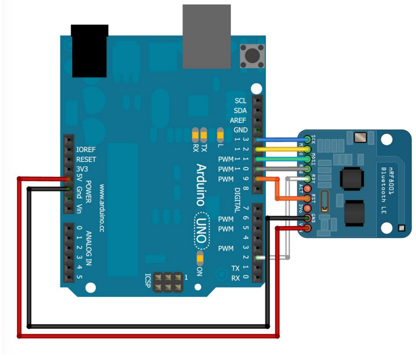


Fig. 1: Interference between Bluetooth module and Arduino Uno

This module is used to send data to the smartphone via LE Bluetooth [3]. Next we connected each analog pin of the Arduino to a pressure sensor as shown in Figure 2. In total, there are six analog pins connecting the Arduino Uno and the pressure sensors, and with a resistor.

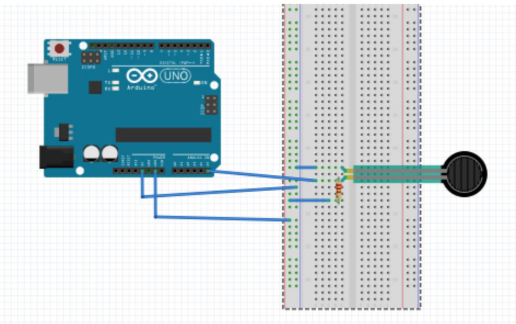


Fig. 2:Arduino Uno and Pressure Sensor Connection

After making the connections, the pressure sensors were placed as shown in Figure 3. We based the sensor placement off of the most important pressure areas on the foot. So as seen below, the most important pressure areas are the forefoot and the rearfoot. In both the regions we used three sensors in a triangular formation. We did this so that we could get accurate readings on both the left and right sides of the foot, in addition to the front and back of the foot.

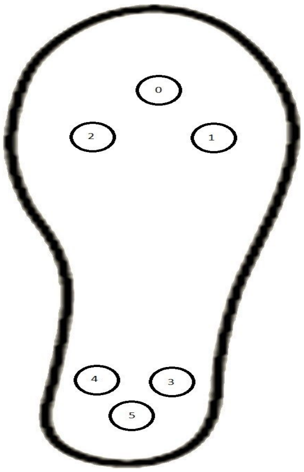


Fig. 3: Sensor anatomical location

Fig.4 : Early Prototype of IoT-Shoe

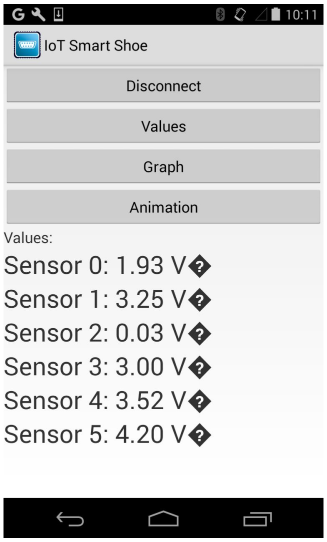
Software

When designing software for the system, there are two devices we must consider programming for, the arduino microcontroller and the smartphone of our choosing.

The code for the microcontroller was relatively straight-forward. First we used a simple library to advertise our device so that is was detectable over Bluetooth. Next we created some simple code to continuously read in data from the pressure sensor and send that data over Bluetooth to the smart device.

Developing for the smartphone was a little more complex. For this we started with sample Bluetooth communication code provided by Nordic Semiconductor (1). This gave us the core functionality to search for discoverable Bluetooth devices, connect with them, and send/receive data. With this core functionality in place we were left with storing the data received, analyzing, and then presenting the data in an elegant way. As the device currently sits this is where a majority of the work remains.

We have laid out a general plan for displaying this data which comes in the form of three different screens. The first screen will simply continuously display the raw data from the sensors and print it too the screen as seen in Figure 5. This will be the most clear way to see exactly how much pressure is being distributed across the shoe. The next screen will be a graph of the pressure received over time similar the graph in Figure 6.



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Values:
Sensor 0: 1.93 V�
Sensor 1: 3.25 V�
Sensor 2: 0.03 V�
Sensor 3: 3.00 V�
Sensor 4: 3.52 V�
Sensor 5: 4.20 V�
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Fig. 5: Sensor data reading

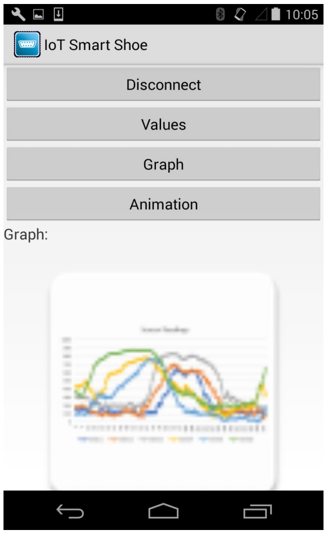

Fig. 6: Real time pressure variation

This will be an interesting screen as you will be able to see the graph rise and fall as you take steps and shift weight across the shoe. The final screen that we are currently planning to develop will display an image of a person walking, jogging, sprinting, etc. This screen does not relay a ton of information but it's a sort of interesting view of how the shoe will be able to analyze was the user is doing.

Results

The following Figure 7 is the plot of the voltage and the pressure. To obtain this plot we used varied weights to see the output voltage from the pressure sensor associated with it. We did this in order to test the weight threshold of the sensors to make sure that it would meet our system requirements. As the plot shows, the voltage increases logarithmically . In this case, when the voltage is high, the small voltage change means large pressure change. It is noticeable that the sensor shows a large variation in voltage up until around 13 pounds, which corresponded to about 4.75 V.

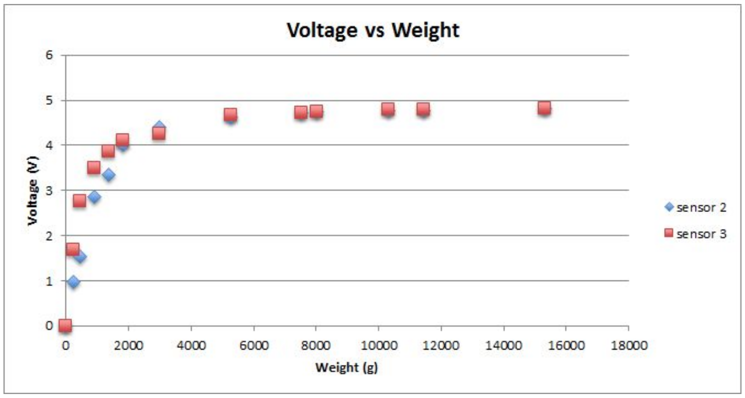

Figure 7: Sensor Sensitivity

In Figure 8 you can see the six analog pin output voltages plotted vs the running time. This figure represents the sensor variation seen as a person takes a few steps. One peak to the next of a single output represents the period of a step. Since we have a certain sampling rate, which is 100 data points per second, we are able to determine the actual duration of a step. As seen in the graph below the sensors in the heel of the foot peak before the sensors in the forefoot. Additionally you can see that each sensor has a different peak value based on the region of the foot and the amount of force placed on it. Also, when people take steps, the pressure on toe and heel are different since the total contact areas are different.

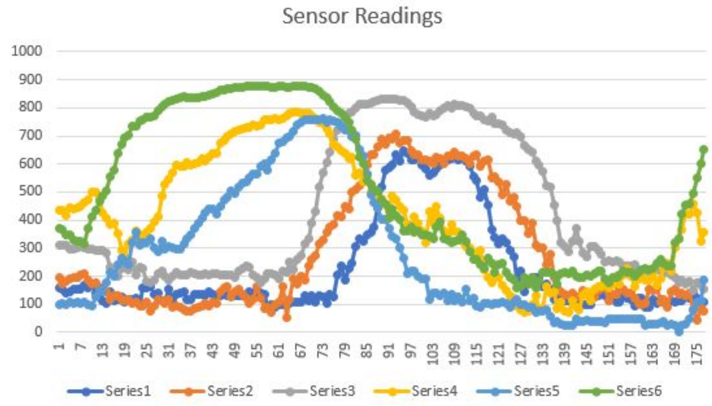

Fig. 8: runtime data graph

Discussion/Outcomes/Performance

In the future we intend to test our prototype on nursing home patients who have chronic gait disease and gather data and feedback. As it currently stands we intend to make various improvements:

- Continue to make the prototype more compact and visually appealing.
- Further develop the smartphone application to better relay information and improve accuracy.
- Expand the application so that it can be run on most smart devices so that data can be easily accessed during daily activities.
- Implement a way to effortlessly share gait information via email or text message.

Cost

Provided that only one smart IoT-shoe is designed, we are expecting the total cost per IoT-shoe would be approximately $325 as per the breakdown below:

Cost Breakdown

Technology	Adafruit Pro Trinket	$10
	Bluefruit LE	$20
Sensor	Six Piezo-resistive	$150 ($25 each)
Circuit Materials	IC, Printed Circuit Board (PCB)	$30
Software	Smartphone App with UIs	$25
Labor	Manufacturing Shoe	$90
Total		***$325***

References

[1] https://github.com/NordicSemiconductor/Android-nRF-UART

[2] Majumder J., ElSaadan Y., ElSaadany M., Ucci D., Rahman F. “A Wireless IoT System Towards Gait Detection in Stroke Patients” in Proc. of the IEEE International Conference on Pervasive Computing and Communications (Percom), Kona, Big Island, Hawaii, USA, March 13-17, 2017.

[3] Guerin R. et al. “Bluetooth Technology Key Challenges and Initial Research”. Proc. SCS Communication Networks and Distributed Systems Modeling and Simulation CNDS, 2012, 157-163.

[4] https://www.adafruit.com/product/2000 [Last Accessed: 14 April 2017]

[5] https://www.adafruit.com/product/1697 [Last Accessed: 14 April 2017]

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We are excited to see what it will become!

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