Pressure Sensitive Ski Boots

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Overview

The most important aspect of skiing is balance. If a skier is not in balance, he/she cannot control his/her skis and will likely fall. Unfortunately, many skiers are not aware of when they are unbalanced. Furthermore, they are not aware of how their weight changes as they ski because they are focusing on other things such as where to turn. Subtle changes in weight distribution could help even the most advanced skier improve their technique. To solve this problem I built pressure sensitive ski boots. These ski boots use force-sensitive variable resistors embedded in ski boots to monitor a person's weight distribution, records this to an SD card and provides audio feedback when a person is leaning too far back. Such a device could help beginners and advanced skiers alike improve their technique.

My pressure-sensitive ski boot system uses an Arduino Nano board to record pressure readings from each of the four sensors in the ski boot. It then writes these readings to an SD card. The system also includes an audio jack which connects to headphones. These headphones then beep when a person is leaning too far back. Finally, the module has a record button and LED so that a person could specify when he/she wants the module to record data. Below I describe in detail the hardware and software behind the pressure-sensitive ski boots.

Hardware

Recording Module

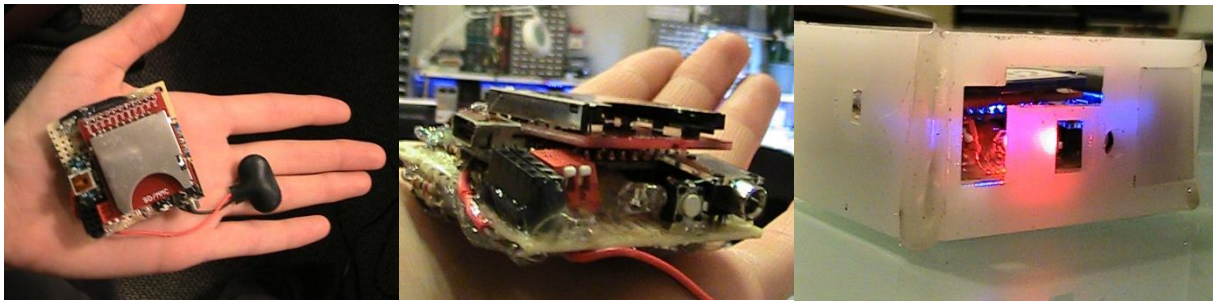

Figure 1 Left: Top view of final circuit. Center: Front view of final circuit. Right: case.

I used an arduino nano as my microcontroller, as well as an SD breakout board available from SparkFun, a generic LED, pushbutton, audio jack, power switch, and 9V battery holder. Fig 2 illustrates my final circuit. Because I was going to test this while skiing, I needed my recording module to be compact and robust. Therefore, I soldered my circuit to a PCB and covered the circuitry with hot glue to ensure components would stay still. I built a case (with holes for the record button, SD card, and USB drive) for my device to ensure further protection (Figure 1, right).

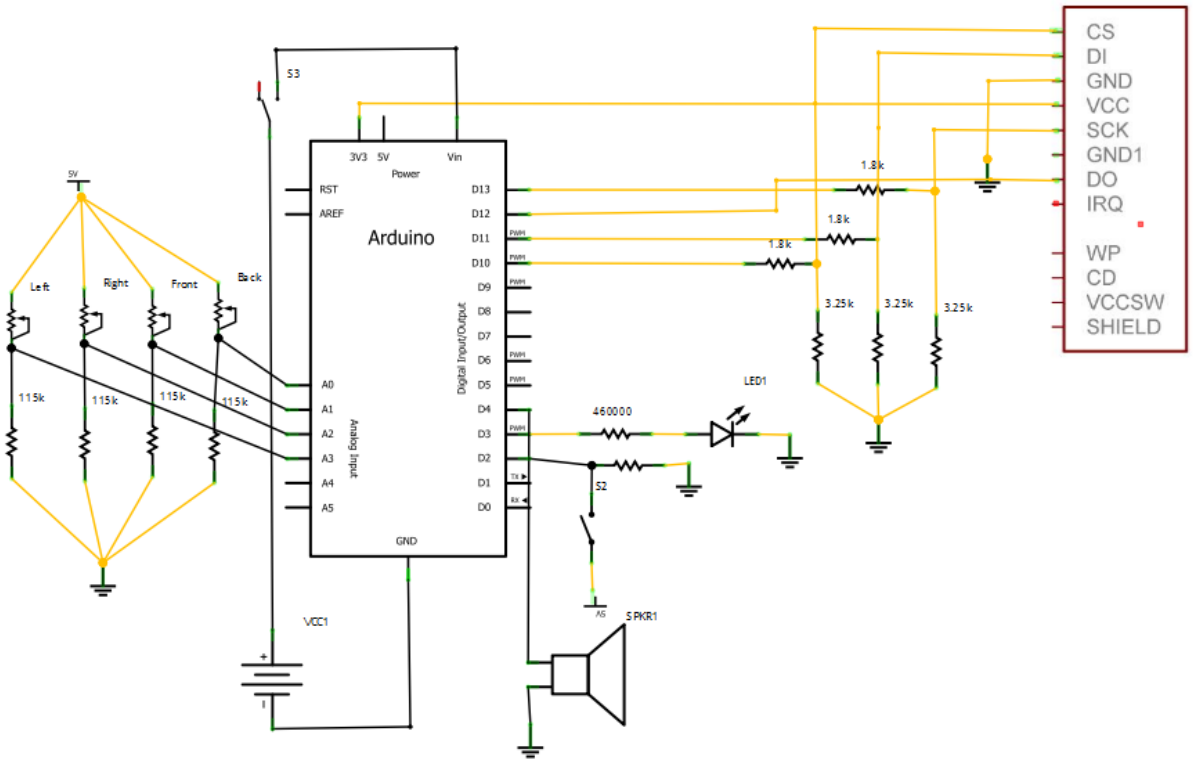

Figure 2 Circuit diagram of recording module.

Ski Boots

Figure 3 Left: sensor placement. Center: Fully instrumented boot. Right: Liner with sensors.

As mentioned above, I instrumented a ski boot with four Flexiforce pressure sensors (sku: SEN-08685). The sensors provided high resolution pressure readings for up to 100 lbs. I ran a few short tests to determine which areas exhibited the most pressure when a skier was leaning forward, back, left and right to determine sensor placement. The left sensor was directly under the big toe, the right sensor under the pinky toe, the back sensor underneath the heel and the front sensor was on the tongue of the boot (Figure 3). Three of the sensors were placed on the outside of the ski boot liner, and one (front sensor) was placed on the inside of the ski boot liner.

Software

There were several software components in my recording system in addition to the software running on the recording module.

Visualizing data

I created a small program to visualize the pressure readings from the sensors for demonstrative purposes. The program read sensor readings from the serial port and displayed them over time. This program used an example from Sofian Audry as inspiration.

Synchronizing with Computer Time

Because I wanted to record the exact time of the pressure readings to be able to later synchronize these with GPS readings, I needed to synchronize the Arduino time with the computer's time. Fortunately, the Arduino community had provided a library for doing this. I was able to use this library with a few small modifications to successfully synchronize the Arduino with computer time and record timestamps.

Recording Module

While the main challenge of the recording module was in laying out and manufacturing robust hardware which would work in the field, one challenge that came up in software was the need to write data to an SD card. This would be a fairly difficult task if I had to make my own SD card protocol. Fortunately, Charlie Robson had written a library to write values to an SD card fairly easily. I was able to use this library (with a few tweaks) to write data to the SD card.

Deployment and Data Collection

Figure 4 Recording module being deployed.

I was fortunate enough to be able to take my pressure sensitive ski boots skiing with me to collect data. As Figure 4 illustrates, I threaded the wires through my boot and pants and put the recording module in a Ziploc bag to protect against water. Unfortunately, I only had 16 Mb of space so was only able to collect about 40 minutes of skiing for two days. I found that my design was durable—the module still worked even after I fell directly on it and cracked the case in half. Also, the battery lasted both days. Since the Arduino consumed 20 mA when not recording (100 mA when recording), power was not an issue. I found that the record button was a little difficult to press, however, because it was inside the case. In the future I would put the button much closer to the case exterior so that it's easier to press.

One concern I had was that I would feel the sensors while skiing which would be distracting. However, I found that this was not an issue; I couldn't feel the sensors at all!

Preliminary Results

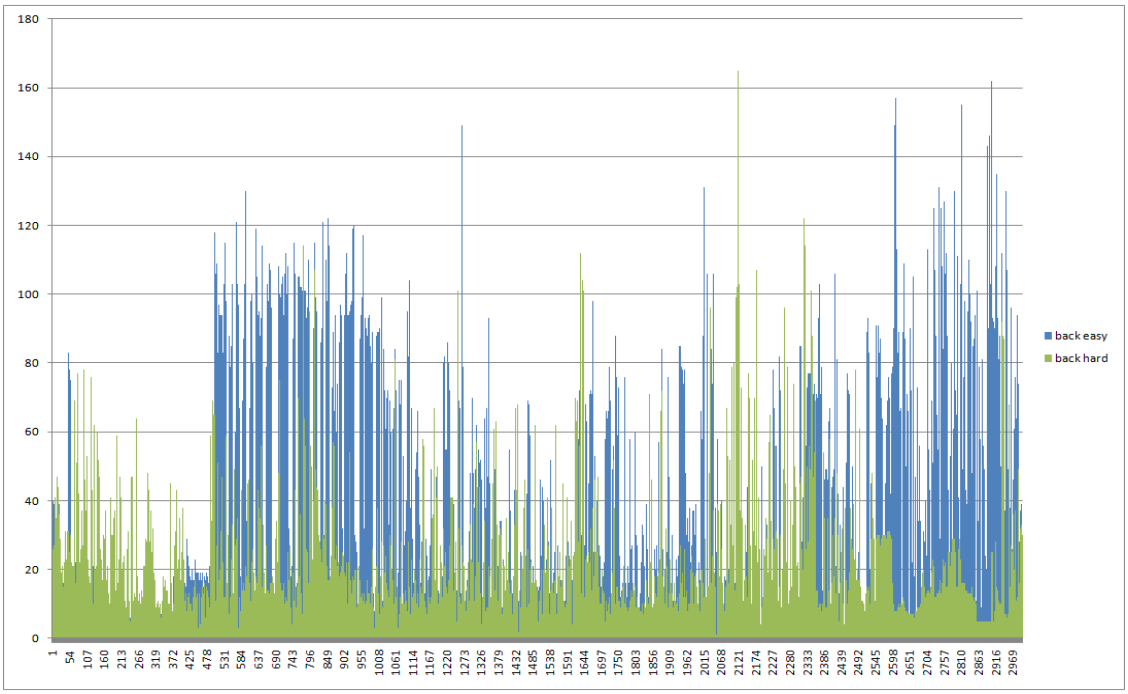

Figure 5 Back pressure when skiing on an easy and difficult run. Surprisingly, the skier leans back more on easier runs.

While I was not able to collect much data during my initial pilot test, I found a surprising result about how I distribute my weight on easy and difficult runs. While I initially believed that I would be leaning back more on difficult runs (because they were more difficult and thus I'd be off-balance more often), I actually found that I lean back more on easier runs (Figure 5). This is probably because I'm more relaxed on easy runs and don't pay as much attention to leaning as far forward as when I'm on difficult runs.

Future Work

In the future I hope to make a wireless version of the pressure sensitive ski boots which communicates to a cell phone via Bluetooth. I'd like to take this new version and create a map of how I distribute my weight when I'm skiing.