SMART Skateboard

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***ABSTRACT* — THIS SENIOR DESIGN PROJECT DISCUSSES THE DESIGN AND ASSEMBLY OF AN ELECTRONIC DEVICE TO BE ATTACHED TO THE BOTTOM OF A SKATEBOARDS WITH THE SOLE PURPOSE OF CLASSIFYING EACH INDIVIDUAL MANEUVER THE USER DOES BASED ON THE CLASSIFICATIONS THAT ALREADY EXIST IN THE SKATEBOARDING COMMUNITY (I.E. "KICKFLIP," "POP SHUVIT," ETC.). THIS ELECTRONIC DEVICE WILL BE PAIRED WITH A MOBILE APPLICATION, ALSO RESEARCHED, DESIGNED AND IMPLEMENTED IN THIS SENIOR DESIGN PROJECT, WHICH WILL ALLOW THE USER TO GET REAL-TIME UPDATES OF THE TRICK HE/SHE JUST PERFORMED. THE DEVICE WILL BE ATTACHED TO THE BOTTOM OF A SKATEBOARD, WHERE IT WILL BE RELATIVELY UNNOTICED BY THE USER. THIS ELECTRONIC DEVICE INVOLVES CREATING A CUSTOM PCB WITH MULTIPLE SENSORS INTEGRATED TO TRACK THE ORIENTATION OF THE BOARD AT ALL TIMES. THIS PCB WILL ALSO HAVE A WIRELESS COMMUNICATION CHIP TO ALLOW THE PCB TO SEND INFORMATION TO THE MOBILE APPLICATION AS FAST AS POSSIBLE.**

***INDEX TERMS* — BLUETOOTH, GYROSCOPE, ACCELEROMETER, MAGNETOMETER,WEARABLE.**

I. INTRODUCTION

Very rarely have the skateboarding world and the electrical engineering world ever met. Even in our fast-paced, open-minded society skateboarding is still somewhat thought of as an "underground" activity within most intellectual circles. This and tradition may be the reasons why skateboarding really hasn't much innovation, technologically speaking, in our great culture. We don't see very many scientists working on new skateboard materials, or doctors deriving formulas for sturdier joints for when skaters fall down a flight of stairs. We want to be the generation that brings the skateboarding industry a new light.

Our idea is to design a smart chip that anyone can attach to the bottom of their skateboard and, by linking it to a mobile app, it will keep track of the past tricks the user has landed. The application will also keep track of the user's speed, acceleration, as well as jump height. All this data should be readily available on a mobile phone application to skate with your friends.

Before this great idea (Original Intellectual Property: Syrmo), skaters had no way of logging their "gnarly" tricks unless there was a cameraman nearby. Our focus was to change this nuisance. By implementing a mobile app, where skaters can save every ridiculously dangerous trick they have ever landed, we can progress this very traditional culture towards the 21st century. No longer will skaters have to break bones to prove to their friends that they indeed did land the triple kickflip, now they can just pull it up on their phones.

Obviously, this idea has many different complications and implementations, yet nothing will quite be able to stop a "skater" from just grabbing the board with his hands and showing off a trick he didn't really land on the fancy new app he just downloaded. Nonetheless, the application will be a great tool for honest skateboarders.

Since we are on a quite strict time restraint with this project, we can't really take this device as far as we would like. We have decided to implement only "flat-ground tricks" meaning that there will be no ramps or railings to worry about, and we can just focus on the considerably simpler flat ground. Also due to time constraints, we will not be able to log every single trick ever landed. Although we would like to do this and it will be attempted, a reasonable goal for this project will be storing the last 5-10 minutes worth of tricks.

The ultimate goal for this project is to design a device that can be attached to the bottom of a skateboard, link with a mobile application, and tell the user what tricks he landed in his previous skating session.

II. REQUIREMENTS AND SPECIFICATIONS

The following section breaks down the overall goals of this project. These goals were the foundation behind developing the SMART Skateboard device. The first subsection, Section A, discusses the general requirements we laid forth before starting this project. These are written in generic, broad terms. Meanwhile, Section B breaks down these broad requirements into measurable specifics. These specifics were ultimately the main template for testing our created device and mobile application.

A. Project Requirements:

This segment focuses on the user's end of the design, laying out the backbone to our device while keeping the details to a minimum. Ultimately ensuring the success of our device through the following sections.

i.) Weight

The weight of our device must be as negligible as possible. This is an important requirement for any wearable device, especially one that's attached to a skateboard. Too much weight will put extra strain on the user and affect the overall enjoyment of the user. The weight can negatively affect the physics of skateboarding, making it harder for the user to flip the board or to soar in the air. This is why it is important to market the product with the minimum weight possible.

ii.) Battery Life

This is also a very important aspect for any embedded device, especially mobile ones. If the battery life is too short, the user will be burdened with frequent charging sessions. They will, in turn, be unable to skate as long as they normally do. Another issue a short battery life could create is having the battery drain just as the user performs their best maneuver. A bad battery will force the device to fail to capture it, causing frustration for the user.

User satisfaction was of the utmost importance for us while developing this project, and it was the main focus of our group during the entire creation of the SMART Skateboard device. If the device is not user-friendly, then the entire project serves little purpose besides proof of concept. This is precisely why it is important to market the product with the maximum battery life possible. This was one of the more difficult requirements, since we were at the mercy of the electrical components we chose and created. Regardless of difficulty, the battery life of the device had to be maximized.

iii.) Durability

Our device will endure some strenuous impacts during the testing and demonstration phases of this project. Most electronic devices don't have to endure this sort of force, but our device is attached to the bottom of a skateboard. Skateboards can last many months for a casual user, and the constant impact that just one skating session endures is enough to break most PCBs and any attached electrical components. Our designed holster, holding the device, need to be able to endure the typical wear and tear experienced by most skateboards. This requirement was a challenge, seeing as none of us are mechanical engineers and have little knowledge of the right materials needed to resist the impact most skateboards encounter.

iv.) Cost

It is important to market the product at as little cost as possible, this factors into overall user satisfaction as well as serving as a limitation to the overall design of the device. The typical price for today's skateboards is about $150. The SMART Skateboard device needs to be as inexpensive as possible. There is not too large of a market for devices like these, so finding the exact cost of production was a bit of a challenge until we created the full bill of materials. Also, we kept in mind that the skateboarding market is funded predominantly by teenagers and their parents. Skateboarding has typically been a middle class hobby throughout the years so money is not abundant in this market. This is just another reason to keep production prices as low as possible.

v.) User Interface

This project is marketed as having a real time user interface to ensure that the user can receive instant feedback for the tricks they perform. The results have to be delivered to the user as quickly as possible. Delays in information will only produce a bottleneck effect in the software processing, ultimately annoying users. Since user satisfaction is our main priority, this bottleneck effect is essentially unacceptable.

vi.) Proper Trick Classification

The device not only needs to be able to operate at a fast pace, but accuracy is also a major component of the software. We need our device to be able to accurately decipher each trick landed while minimizing latency to ensure the best experience for the user. Processing speed only means so much when the device cannot properly identify each trick.

Since there are so many different types of skateboarding tricks, we decided to implement our device to properly identify the basic flatground tricks. These are tricks that can be performed without the use of a ramp or drained swimming pool. Most skateboarders learn these basics before ever attempting the complex, more difficult tricks.

vi.) Wireless Range

Skateboarding is a mobile sport, and many skaters don't keep their phones in their pocket during a session. For these reasons, we needed to ensure that the wireless range of our device was maximized as fully as possible. Many times, a fellow skateboarder will hold the user's phone while he/she skates. The SMART Skateboard needs to account for that by operating in a large enough range where this will not be a problem. This was another requirement that was limited by the components we chose. It is unlikely that the communication range can be altered after the device was fully created. therefore, research played a major role when selecting the right wireless communication component.

B. Project Specifications:

This subsection focuses on defining the above requirements into quantifiable, measurable goals. Each of the requirements from the subsection above simply outlined general goals we wanted to accomplish before we began designing our SMART Skateboard device.

However, once the designing process began, we came up with much more precise and calculable characteristics for our device. Table 1 expresses each of these specifications, along with the device's component which is involved, and the tangible goal we aimed to achieve. This table essentially served as our initial blueprint while developing initial designs for our wireless device.

Table 1: Specifications of the SMART Skateboard

Component	Parameter	Design Specification
Entire Device	Total Weight	Under 32 oz.
Entire Device	Impact Resistance	5 ft free-fall
Entire Device	Cost	Under $250
Power Supply	Battery Life	Over 5 hours
Motion Sensors	Accuracy	Within 10%
Wireless Sensors	Range	6 ft minimum
Software	Latency	Under 5 sec.

Once we created the initial prototypes for the SMART Skateboard device, we realized that some of the specifications we set forth would be accomplished easily. For example, the range of the wireless communications chip was well over 6 feet. Meanwhile, we also understood other specifications, such as withstanding a 5 foot free-fall impact, would be quite challenging given our specific expertise.

III. BASIC FLATGROUND TRICKS

There are seven basic skateboarding maneuvers, referred to as tricks, which are performed on flat ground which we aim to correctly identify. Nearly all of the advanced tricks in the sport are some type of combination of the basics. To deliver a reliable product and meet user satisfaction, it is important that we fully understand the activity that we are developing this product for. Most engineers aren't too immersed in the field of skateboarding, so this section is dedicated to clearing some of that up.

The device we created measures the orientation of the board and can assess the specific trick that is being performed by keeping constant track of the orientation of the board. The tricks defined in the next section are the main maneuvers we looked to define with our software and hardware components. Obviously, there are many more tricks in the world of skateboarding, but due to time constraints we focused on the basic ones that basically all skaters can perform. Please note, the stance of the user is extremely important for the proper identification of the tricks. The user having his/her right foot forward or left foot forward, dictates the name of the trick. For example, a kick flip for a left foot forward rider has the same exact rotation as a heel flip for a right foot forward rider. This is a dilemma we had to take into account when developing our software.

i.) Ollie

The ollie is the quintessential basis for all skateboarding tricks. Much like humans learn how to crawl before they walk, skaters learn how to ollie before they can perfect any other flat ground trick. An ollie is the simplest trick we aimed to identify with the SMART Skateboard device. The ollie is initiated when the rider stomps down on the tail of the skateboard, causing the nose of the board to pop up. The tail of the board hitting the ground causes the entire board to experience a reactive force upwards. This propels the board into the air. The rider must jump synchronously with the skateboard and use the other foot to level the board out so that it is parallel with the ground and then land. In terms of sensor readings, the Ollie is just a change in the positive z-axis with no sideways rotation and a slight tilting in the forward direction. The trick is performed when the z-axis component of the sensors reach the baseline determined at the beginning of the trick.

ii.) Backside Shuvit

Much like the Ollie, the Backside Shuvit begins with a downward push of the tail. In fact, all of the flat ground tricks that the SMART Skateboard device will be identifying begin the same way, with a downward push of the tail causing an upward pop of the rest of the skateboard.

After the rider stomps the tail of the skateboard, using the same foot that stomps the board down, he/she scoops the tail behind them. This causes a reactive force that propels the board into a 180-degree rotation. This rotation is clockwise for a left foot first (otherwise known as regular stance) rider. The sensor would read acceleration in the positive z-axis with a rotation about the vertical axis. This trick is completed once the z-axis component of the sensor returns to its original height, keeping in mind that the device will have a final orientation that is 180 degrees from its original position about the vertical axis.

ii)Frontside-Shuvit

The Front side Shuv-It is almost identical to the Backside Shuvit. The only major difference is the direction of the rotation about the vertical axis. The Front side Shuv-It rotates the board in the counterclockwise direction for regular stanced riders. The software in the mobile application of the SMART Skateboard device is almost identical to the Backside Shuv-It, so we had to ensure that the rotational analysis is accurate for both regular stanced rider and goofy stance (right foot forward) riders.

iii.) Backside and Front side 180

The Backside and Front side 180 are both just a slight variation of the Ollie. After the rider pops the board upward, the rider and the board spin 180 degrees together. The Backside and Front side designation indicate the rotational direction of the board with respect to the rider's stance. Although this trick is actually quite simple in both skating and mathematical terms, the change in orientation of the SMART device is exactly the same as the two variations of the Shuv-It. This created a dilemma for us. We had no way to scan the skateboarder's orientation during tricks, especially if the user is not holding his mobile device, so there is virtually no way to decipher between a Shuvit and a 180 without some sort of additional sensors attached to the user. We weren't able to implement such a technology in the allotted time, but we have come up with some ideas about how to implement a new sensor to account for this nuisance. One such example was to use the phone's orientation as a guide to track the user's orientation, but the exact details of this idea are still unclear.

iv.) Kickflip

Possibly the most well-known skateboarding trick in the world, the Kickflip begins the same way as the Ollie. Once the board is popped up in the air by the back foot, the lead foot, instead of flattening the board like an Ollie, the rider flicks his foot up and towards the inside of the board. The rider's toes end up flipping the board 360 degrees about the horizontal axis, parallel to the long side of the skateboard. Figure 1 shows a visual of the Kick flip. In terms of sensor readings, the device reads the initial pop just as it would for any other trick, then reads a 360-degree orientation about the horizontal axis parallel to the skateboard. Once the board is finally in the same z-axis location as before, and the board traveled the full 360 degrees, the trick is recorded as having been successfully landed.

Figure 1: The Kick flip

Used with permission from Skatepark of Tampa

v.) Heel flip

The Heelflip is the counterpart of the Kickflip. Instead of sliding the lead foot inwards towards the body, the rider slides his foot out away from his/her body. This causes the heels of the foot to create a 360-degree rotation about the parallel axis of the board. The sensor reading would be very similar to that of the Kickflip, besides the rotational direction of the 360-degree spin.

vi.) Advanced Tricks

The tricks detailed above are just the basics in the skateboarding world, and they were the main focus of this project. However, the same technology can be implemented to identify much more complex tricks, such as the 360 Flip, which is a combination of the 360 degree Shuvit and a kickflip. Our device needs to perfect these basic tricks before attempting to tackle the much more complex ones.

IV. RESEARCH

This section gives a brief overview of the countless hours of research we conducted as a group to ensure this project was designed and implemented correctly. Much of the information we discovered has been omitted due to a lack of relevance to the overall design of the project.

After headlining this section by detailing some similar projects and products in the first subsection, we continue in the next subsection to show a small glimpse of the hardware research required for the SMART Skateboard device. Once the hardware research has been discussed, the final subsection details the relevant software research that correlates specifically to our senior design project's mobile application.

A. *Similar Projects and Products:*

i.) Syrmo

Syrmo was an ambitious project launched by a group of Argentinian skateboarders on Kickstarter in 2014. They sought to offer a lightweight and portable product that would attach to any skateboard and collect data. Syrmo's product idea is very similar to ours, in that it sought to identify many different components of a skateboarder's skating session. We first heard of Syrmo while browsing Kickstarter in our off time. It would have an Android and iOS application to receive data transmitted over Bluetooth.

Syrmo's mobile application would have had a 3D animation to replay which trick was performed. The user would be able to share this on multiple social media platforms such as YouTube and Facebook. Syrmo's design was supposed to have a geolocation system to know where each trick is performed and for the ability to share new locations with your friends. This is a much more in-depth version of what we are trying to accomplish with the SMART Skateboard.

Syrmo took to Kickstarter to raise money for mass production, but the campaign was cancelled with only $7,164 out of $40,000 raised. As of November 2016, the product is still yet to reach the market. The aim of the SMART Skateboard is to create a much more bare version of Syrmo's design. Our goal at the beginning of this senior design course was simply to apply our foundation of Electrical and Computer Engineering skills to an interesting project that will allow us to grow our knowledge.

ii.) Trace

Trace was another ambitious wearable action sports project launched on Kickstarter. Unlike Syrmo, Trace would track and provide analytics for surfing and snowboarding and originally skateboarding. Trace's product is compatible for surfboards and snowboards as well. The team had more experience than Syrmo, with a PhD and pioneer of GPS tracking systems, Dr. Lokshin, as their CEO, Trace actualized their mass production goals.

Trace also ended up turning to Kickstarter to fund their campaign for mass production, and they actually reached their goal. Ultimately raising $161,260 out of $150,000, they are currently selling the product for $199 on their website and on Amazon. But curiously, it no longer offers support for skateboarding.

B. Hardware Research:

i.) Embedded Device Options

There are various microprocessors on the market with different prices and functionality. It is important to compare the I/O pins provided by the microcontrollers, the cost of each one, the power consumption, and what resources are available in the community to aid development. Below, we have included a table where we compare several different microcontroller options.

Table 2: Embedded Device Options

Device	Advantages	Disadvantages
Arduino Mega	-Abundant digital I/O - Rich open source network	-Cost -Excess Pins -Hard to deconstruct
Arduino Uno	-Ideal number of I/O pins -Rich open source network -Easy to deconstruct into breadboard	-Low memory
TI MSP430	-Low cost device -Taught in UCF curriculum	-No relevant sample code readily available
Raspberry Pi	-Powerful -Rich open source network -Large memory	-High Cost -Unnecessary components

ii.) Power Supply Options

The research we conducted on the power supply options for the SMART Skateboard was quite extensive. We researched several different types of power connection options before we even entered the realm of power supplies. The power supply options for the SMART Skateboard were much more limited than other electrical projects.

Since our device is mobile, wall plugs wouldn't have made sense. Our power supply needed to be mobile, rechargeable, durable, and supply enough voltage to power on the microprocessor of the SMART Skateboard. Table 3 outlines a few of the options that were considered to power the SMART Skateboard, as well as the advantages and disadvantages of each option.

Table 3: Power Supply Options

Power Supply	Advantages	Disadvantages
Alkaline Batteries	-Easy to configure for ideal voltage	-Non-rechargeable -Need multiple for ideal voltage
Coin Cell Li Batteries	-Small in size -Low weight	-Low Voltage -Non-rechargeable
Flat Pack LiPo Batteries	-Flat in shape -Wide range of outputs -Rechargeable	-Possible damage after large force endured.

Naturally, there were many other options researched. We even researched the composition of car batteries to see if that could be easily replicated. However, the above options were the main focus of implementation. It should seem clear from Table 3 which one was selected.

iii.) Sensors

There were three main types of sensors needed to implement everything the SMART Skateboard sought out to do. The first of these is an accurate gyroscope to measure the rotation of the board about three separate axes. Table 4 shows the summary of our gyroscope research with the top three options we discovered.

Table 4: Summary of Gyroscope Research

Gyroscope	Details
ITG-3200	-LPF that can be programmed -Low current draw -Fast interface (400kHz)
MAX21000	-Small in size -Low power -Fast power on time -Low latency -High bandwidth
MLX90609	-On chip calibration -Wide operating temperature range

We discovered that similar products used a barometer to measure the altitude of their device. Although this is quite surprising, with a highly accurate barometer it was indeed possible to measure in the z-direction. Table 5 summarizes the research we conducted on barometers that we found to be relevant towards the optimal design of the SMART Skateboard.

Table 5: Summary of Barometer Research

Barometer	Details
MPL225A1	-Wide range of supply voltage -Low power -Measures pressure and temperature -High Accuracy
BMP180	-Low Power -Fully calibrated -Very small in size

The last sensor we needed to add maximum accuracy to our data gathering is an accelerometer. This sensor can tell us the acceleration and speed at which the board is travelling. This ultimately allows us to make out information much more precise. Table 6 shows a summary of our accelerometer research.

Table 6: Summary of Accelerometer Research

Accelerometer	Details
ADXL377	-Easy implementation -Small in size -Low current draw
ADXL362	-Low power consumption -Low noise -Wake-on-shake feature

iv.) Wireless Communication

The SMART Skateboard requires an optimal communication package between the mobile phone and our mounted device. We researched several serial communication options such as SPI, I2C and RS232 as well as several wireless communication interfaces such as Classic Bluetooth, Wi-Fi, and BLE. We also did some research on the NFC (Near Field Communication) but the optimal range for NFC is much lower than the 6 feet we defined as a specification.

v.) Holster

From the start, we realized that the holster was going to have to be created in a CAD software. The only research we needed in this area, was to become proficient in a software we had little experience in. The actual holstering method seemed clear from the start.

C. Software Research:

i.) Mobile Device Options

The mobile device is another key feature to fully bring the project to life. These days a robust mobile application is no longer just a nice addition to a product, it is a necessity. There are three main options here: Windows 10 mobile, iOS, and Android. Figure 2 shows the difference in interface for each.

Figure 2: Windows 10 vs iOS vs Android

Windows 10 mobile is written in a familiar C# language and is constantly growing, but it is the least desirable of the three in terms of demand. iOS is probably the most secure development technology with a large demand in the West, but iOS is not open source meaning source code is not viewable. Android has the largest global user base out of all big three, but Androids are notoriously low on memory.

V. COMPONENTS

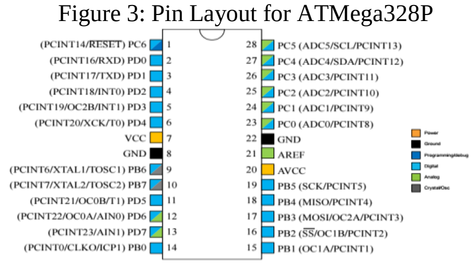
Section V outlines all of the components we ended up selecting to build our SMART Skateboard. The components we chose reflected the advantages of the previous section as they pertain to our senior design project.

A. Hardware Components:

i.) Microcontroller

We decided to use the ATMega328P from the Arduino Uno. We chose this because we didn't need many pins on our SMART Skateboard, therefore the smaller Uno was a better fit. Also, the main chip on the Uno (the ATMega) is easily removable. Figure 3 shows the layout for the ATMega328P taken from the datasheet.

Figure 3: Pin Layout for ATMega328P



ii.) Power Supply Selection

The most optimal power supply for the purposes powering up of this project is the Silver Flat Pack Lithium Polymer batteries. These batteries are ideal because they are available in a wide range of voltage options, they are dimensionally minimal, and most importantly they are rechargeable.

iii.) Sensor Selection

Gyroscope - L3GD20H
Barometer - BMP180
Accelerometer - LSM303DLHC

iv.) Wireless Communication Selection

The best option for the SMART Skateboard's wireless communication design is to use Adafruit's Bluefruit LE nRF8001 Breakout using SPI to drive it.

v.) Holster Selection

We used SolidWorks to design a 3D rendering of our PCB holster. This design, once finalized, is then taken to a 3D printer. The final holster we create is lined with foam to cushion the PCB from the constant impact of the daily use of the skateboard.

B. Software Components:

i.) Mobile Device Selection

The team has decided to focus most of the software on Android devices. However, our software development program selection can ultimately allow us to go cross-platform.

ii.) Software Development Environment

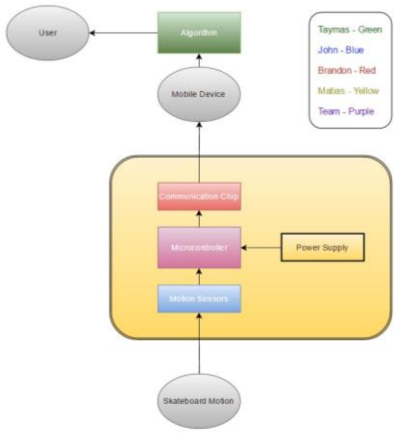
We chose Unity because it is easy to implement cross-platform compatibility and it comes with a 3D game engine included.

VI. DIAGRAMS AND PROTOTYPE

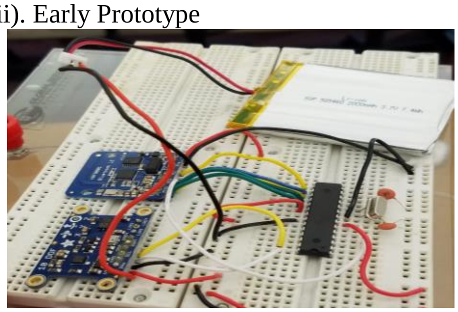
This section details a few diagrams of the SMART Skateboard's design. Also shown in this section is one of the rudimentary prototypes created before finalizing project's design.

A. Hardware:

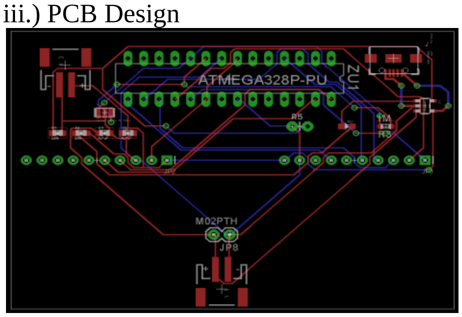
i.) Block Diagram



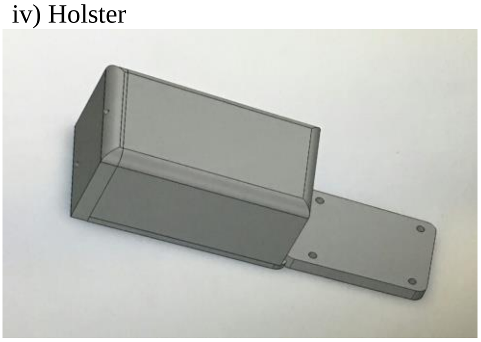
ii). Early Prototype



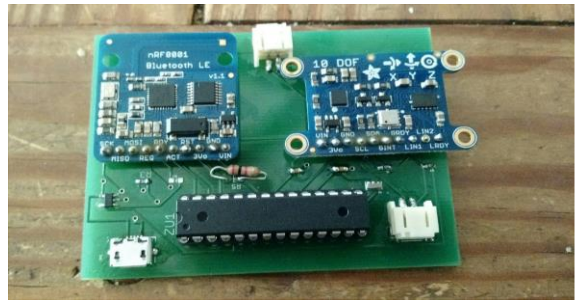
iii.) PCB Design



iv) Holster

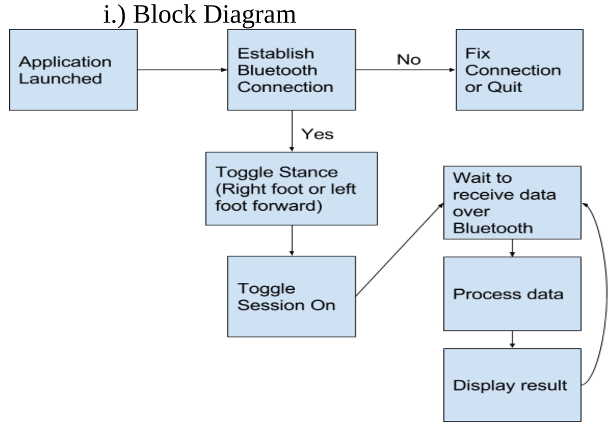


v) finished product

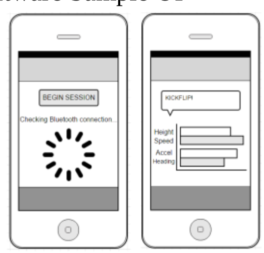


B. Software

i.) Block Diagram



ii.) Software Sample UI



VII. CONCLUSION

This course has been one of the most challenging two semesters of our academic careers, but at the same time we learned just as much in these past few months as we have in all of our prior years combined. Not only did this project teach us how to transform an idea into a physical, functioning product, but we also learned how to operate as a truly professional team. The SMART Skateboard is a simple concept with many difficult details. We took on the challenge of this project because the entire team believed in the mission. It has been an exciting yet stressful process to get the SMART Skateboard off the ground.