Weight-Controlled Electric Skateboard

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Abstract

This paper presents the design decisions and technical implementation of modifying an electric skateboard to be controlled solely by a user's weight distribution. The end product is an electric skateboard that accelerates when the user leans forward on their front foot and brakes when the user leans backward on their back foot. The finished prototype takes in the user's weight distribution from two sets of bathroom-scale-style load cells and converts it into a power output for the wheels. The development of this prototype intends to verify weight control as a viable and more intuitive method of electric skateboard control, which is currently dominated by the use of hand-remotes.

1. Introduction

Since the emergence of the first electric skateboard startup in 2012[6], the control system of electric skateboards has mainly remained a hand-held controller that is controlled by the thumb, communicating speed commands wirelessly to the skateboard. Other less mainstream control systems exist, but no legitimate company has ever made an electric skateboard that can be controlled solely by body weight.

All existing models on the market have a steep learning curve because of the disconnect between body position and acceleration. I began to develop a weight-controlled electric skateboard to verify that speed control can be achieved using only weight sensors and an algorithm. After verifying a weight-control system, I want to show that this system of control is more intuitive and easier to learn than current, existing models.

When an unprepared rider accelerates on a skateboard that is not weight-controlled, the board moves forward, and the rider's inertia causes them to fall off the back of the board. Similarly, when an unprepared rider brakes on a skateboard that is not weight-controlled, the board stops, and the rider’s inertia causes them to fall off the front of the board while the board stops moving. This phenomenon is widely observed and mentioned on existing electric skateboard websites. Boosted Board, the current top producer of electric skateboards, explains to their customers to "move the throttle wheel [on the hand controller], in small increments, keep a wide stance on the board, keep a low center of gravity, lean forward when accelerating, lean backwards when braking."[1]

My weight-controlled prototype seeks to synchronize body position and acceleration. Instead of having to lean forward and backwards to prepare for the acceleration and deceleration from a hand-controller, a weight-control system causes the board to accelerate when the rider leans forward and decelerate when the rider leans backward, ensuring that the board never changes speed when a rider has an unprepared body position.

In addition to making the control of an electric skateboard more intuitive, a weight-controlled electric skateboard removes the need for a Bluetooth or radio connection to the skateboard. This connection, usually achieved through a hand-controller or phone application, is a potential security hazard for electric skateboards, and hobbyists have shown that these signals can be fairly easily hacked.[9] The elimination of a hand-controller also frees up the rider’s hands, making it a more practical means of transportation.

2. Background and Related Work

The electric transportation market (excluding cars) has grown quickly since 2014, with an expected annual growth rate of 8.4% until 2025.[4] Figure 1 shows the growth and breakdown of the electric transportation market from 2014-2017, as well as the projected growth from 2018-2025. While electric skateboards hold a sliver of the electric transportation market, they are also growing and developing at a rapid rate as global awareness of carbon emissions has increased.[4]

The rise of electric skateboards fully began in 2012, when a company called Boosted Boards raised almost half a million dollars on Kickstarter, over four times what they originally sought. [6] Since then, dozens of companies have emerged with various products and features. However, there still does not exist an established company which produces boards that use weight distribution, and

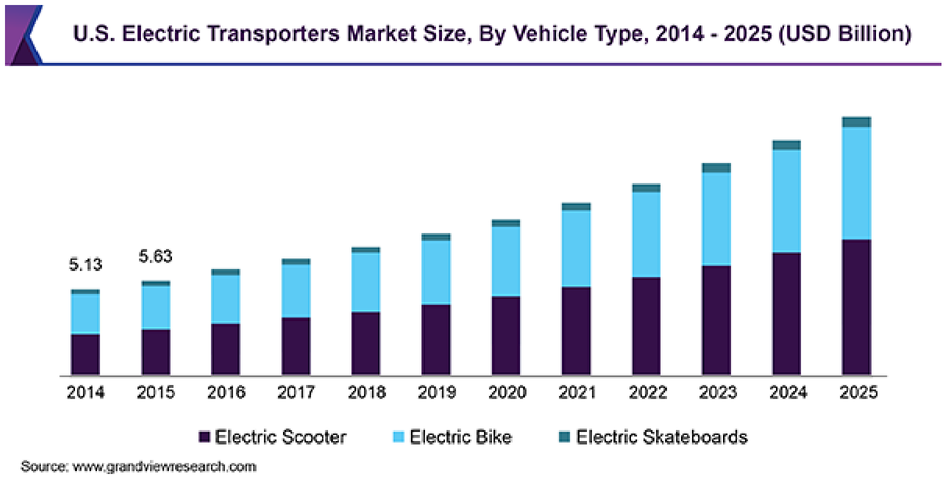

Figure 1: The Projected Growth Rate of Electric Transportation, Created in 2017. [4]

none that claim to do so with only load cells.

Today, there is much competition in the electric skateboard market. MarketWatch lists 13 companies leading the industry.[3] All but a select few of these companies use hand-controllers, which usually exists as separate remote or phone application used to control the speed of the skateboard. In Section 1, the differences between the hand-controller and my weight-control are highlighted.

There are other control systems available that are worth noting.

One Wheel is a type of electric skateboard with a single, large wheel in the middle with a platform to stand on extending to either side. It works more like a Segway in that the angle of the tilt of the platform controls the speed. While not technically a skateboard, this product is most similar to my weight-controlled electric skateboard's use of body position to control the speed of the board. The One Wheel, however, does not use any load cells or actual weight sensing to control the board. Everything is done with the angle of the platform, making it a completely different type of control system from what I am developing.[2]

Zboard is an electric skateboard company that also wanted to do away with the hand-controller. Zboard has small foot pedals on their skateboard that work like gas and brake pedals on a car. This is different from a weight-controlled skateboard because a rider's body can still be unbalanced when they hit these pedals. In addition, the rider's feet must always be in the same place to control the board, because the pedals are in a set location on the board's deck. With weight-control, the exact location of a rider's feet don't matter, allowing for different sizes and stances of riders. Zboard emphasizes the hands-free aspect of their board instead of the ease of learning and intuitive control, separating it from my weight-controlled board.[10]

Stark Mobility claims to have created a board called the Starkboard that uses a gyroscope and weight sensors to control its electric skateboard using weight. This product would be most similar to my prototype. The only difference between what Stark Mobility claims and my prototype is that they use a gyroscope and weight sensors[7] whereas I just use an algorithm and weight sensors. However, Starkboard crowd-sourced its funding and seems to be struggling as a company. There are mixed reviews of their product, and the website has had them listed as "sold out" from October 2019 until the time of this paper in January. No records of their quarterly reports nor any mention of a patent can be found. Without access to their board, no technical specifications mentioned, and very limited evidence of actual success, it is difficult to determine how similar it is to my weight-controlled prototype, or if it is even functional. With unverifiable technology and no products currently available, Starkboard remains an unknown technology that claims to be similar.

None of the existing products focus on learnability and intuitiveness as their primary goal. One of the main downfalls of electric skateboard as a means of transportation is the danger and difficulty of riding. With weight-control, my electric skateboard seeks to remove the difficulty in balancing forward and backward, allowing the rider to focus on steering.

3. Approach

In order to verify the weight-control technology, I had to make a testable prototype then assess its safety, consistency, and ease of use. The entire prototype also had to be under $500. To clarify the terminology used for electric skateboards and skateboards in general, Figure 2 contains a diagram of a skateboards parts. This paper mainly refers to the trucks, deck, and risers.

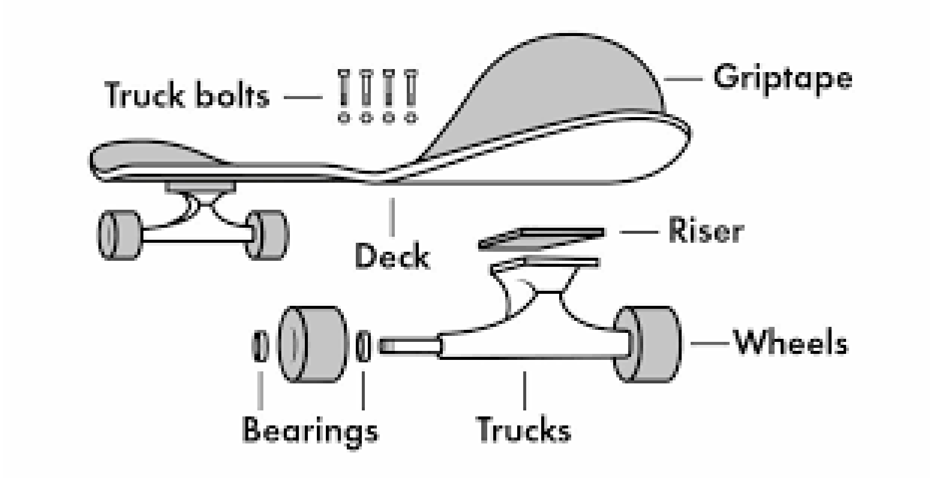

Figure 2: The Main Parts of a Skateboard for Reference in the Rest of the Paper.
[8]

3.1. Design Considerations

To create a weight-controlled electric skateboard, load cells on either end of the board would certainly be required. Other sensors such as hall effect sensors to measure wheel speed or a gyroscope to measure acceleration changes could also be implemented, but I decided against the use of any addition sensors because of the limited budget for the board and all the hardware and wiring had to fit on the underside of the deck. Adding many additional sensors that are not vital to the implementation of the project would create additional wiring that could get too bulky.

The main challenge of using only weight sensors as input for desired acceleration is the noisy data produced by the weight sensors as the board travels across uneven surfaces. There are also auxiliary problems such as rider weight, flaws in rider form, and sensor inconsistencies.

As the board travels across uneven terrain, the force between the rider's foot and the wheels varies. As an extreme example to help clarify the problem, if rider goes off of a jump, such as riding off of a curb or a ramp, the force on the weight sensors will diminish in the air. When the board hits the surface of the road after a jump, the force on the weight sensors will be much higher as the rider's vertical velocity is slowed down and the rider's body weight is on the skateboard. The same phenomenon occurs on a smaller level as the rider rides across uneven pavement or gravel. As a result, my system needed to be able to deal with the variation of a sensor and return the correct output of the rider's intent. In other words, the prototype must have the board slow down when the rider leans backward, regardless of the variation on the force sensor due to inconsistent pavement.

To address this phenomenon, I knew I would have to create an algorithm that factors in multiple data points of weight into the speed output it would give the powered wheels. Other ways could have been to add additional sensors and hardware, but considering that this project is under the Computer Science Department, I also tried to use as little hardware as possible and do as much as possible through software.

3.2. Hardware Considerations

There were two main options with the hardware of electric skateboard, each with its own pros and cons. The first option was to build an electric skateboard from parts. There are a handful of tutorials online to assist with this process. The main advantage of this method would be the flexibility in design. The trucks and deck could be chosen with the specific purpose of fitting load cells for measuring weight between them, and it would be easy to wire my control system directly to the Electronic Speed Control (ESC), which regulates the speed of the electric motors. It would also be cheaper to build a skateboard from scratch.

The disadvantage of building from scratch was the amount of labor required for research that had already been done. I did not want to spend the entire semester trying to put together a skateboard and have a very limited amount of time to adjust my algorithm for speed control.

The second option was to purchase an existing electric skateboard and modify it so that it took speed input from my algorithm instead of the radio signal hand-held controller. This method would avoid the construction process of the motors, wheels, batteries, ESC, and input receivers. However, purchasing an existing electric skateboard would add many unknowns, such as how the load cells would connect between the deck and trucks of the board. It was also unclear how exactly to give the board the speed input. All models within the budget use a signal from a wireless radio receiver to control the speed. To control an electric skateboard through weight control, I would have to find some point in the communication path from the radio hand-controller to the ESC where I could intercept the signal, cut it off, and replace it with my own desired speed signal from my weight-control algorithm.

I decided to purchase an existing electric skateboard and modify it. I determined that the risk of unknowns was less daunting than the time it would take to reconstruct something from scratch that already existed as a product.

4. Implementation

4.1. High Level Overview

The end-to-end flow of creating the weight-controlled electric skateboard prototype will help provide clarity and motivation for the subsections listed below.

My desired effect is for the rider to put more weight on their forward leg to accelerate and put more weight on their back leg to brake. If the rider maintains equal weight on both legs, the board should neither accelerate nor brake.

The high-level implementation is as follows:

- Load cells located at both the front and back trucks of the board continually send their weight data to a microcontroller.
- The microcontroller analyses the data and determines whether the board should be accelerating, braking, or maintaining speed.
- The microcontroller sends a specific voltage output corresponding with each of the options listed in the previous bullet point to the radio hand remote, which has been deconstructed to take input signal from the microcontroller instead of the user's hand movements and is attached to the bottom of the board.
- The hand remote outputs a wireless radio signal which controls the speed of the board based on the accelerate, brake, or maintain signal from the microcontroller.

The following subsections will justify and explain the process of arriving at these high-level decisions to implement weight control for an electric skateboard with the final goal of creating a more learnable and intuitive control system.

4.2. The Unmodified Electric Skateboard

The electric skateboard purchased online was a Backfire G2 Black. It was controlled by a hand-controller that contained a knob where the user would place their thumb, which is labeled (1) in Figure 3. Rotating the knob forward would accelerate the board, and backward would cause the board to brake.

The board can only accelerate in one direction. This allows the knob control to be simple and prevents the potentially dangerous situation of the wheels accelerating in the direction opposite of the board's velocity, jerking the rider off of the board. Switch (4) in Figure 3 allows the direction of wheel rotation to change, but only when the board in completely stopped.

Figure 3: The Backfire G2 Hand-Controller. (1) The knob to control speed. (2) Power for the remote. (3) Switch to control fast or slow mode. (4) Switch to change direction for powered wheel rotation. [5]

4.3. Physically Attaching the Load Cells

The ideal load cells are compression and tension load cells. These have screw-in connectors that allow the connection of the trucks to the deck to be done without the original bolts. The load cells would measure the true force between the trucks and the deck and send that to the microcontroller. These load cells, however, were well out of the price range.

I decided to use cheap, 3-terminal load cells commonly found in bathroom scales. These were the only load cells that could handle body weight and be purchased in the price range.

Physically attaching the load cells between the trucks and deck was the main difficulty with these load cells. Looking at Figure 4, the blue circle extends upward from the face of the page, providing a single point where the load cell will press up against a flat object. The outer rim of the load cell is traditionally used to attach to the bottom of a bathroom scale, and is usually just attached with glue. The red circles extend downward into the face of the page past the outer rim of the load cell. The load cell can only measure compression between two surfaces and cannot measure tension.

Because of this construction, the load cell cannot simply be wedged between the flat surfaces of the trucks and the deck. There needed to be some buffer in addition that could hold the edge of the load cell, but allow the red circles to move up and down.

The riser (See Figure 2) on the Backfire G2 Electric Skateboard is a thick rubber pad. I unscrewed the trucks from the deck, cut holes in the riser for the red circled objects to flex, and wedged two load cells between the riser and the deck for both the front and back trucks, as shown in Figure 5.

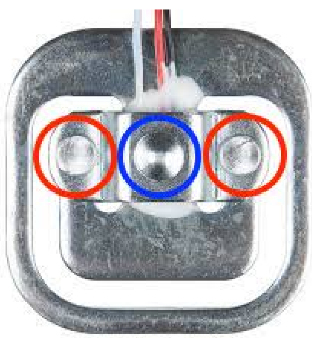

Figure 4: A single load cell. The blue circle and outer rectangular edge press against opposing surfaces. The red circles must be free to move up and down.

Figure 5: Load Cells in Final Attachment.

I screwed the original bolts to connect the trucks to the deck until they were firmly fastened. Because this puts pressure on the load cells before the rider steps on the board, I measured that both the front and back sets of load cells had equal force. I super-glued the nuts in place to keep this pressure constant, even when the board vibrates while riding over rough surfaces. Because these load cells were pre-loaded with weight from the connection between the trucks and deck, the algorithm for speed control could not use true weight. The relative weight between the front and back load cell would be the only data available for speed control. However, the switch from absolute weight to relative weight actually ended up being a necessary step even if the load cells could measure true weight because my algorithm needed to account for riders of varying weights.

4.4. Electrically Connecting the Load Cells

The load cells need a HX711 amplifying chip to make their signal readable by an Arduino microcontroller, which is the microcontroller used for this prototype because of its easy interface and ease of programming.

There are two load cells on each side of the board because each load cell is only rated to 50kg. To allow for all weights of passengers, the load cells needed the capacity to measure up to 100kg accurately on each side. Therefore, the two load cells at each truck needed to work together to measure a weight. A half wheatstone bridge wiring of the load cell wires allowed their signals to combine together in the desired fashion. This wiring and the connection to the HX711 is shown in Figure 6.

A half wheatstone bridge connects the white wire of one load cell to black of the other, and vice-versa. These are then connected to the E+ and E- pins of the HX711. The red wire of one load cell is connected to the A+ and the red wire of the other is connect to the A- of the HX711.

Because the weight is measured independently at each truck, this entire setup must be done on both sides. Therefore, there are 4 load cells in total and 2 HX711 chips.

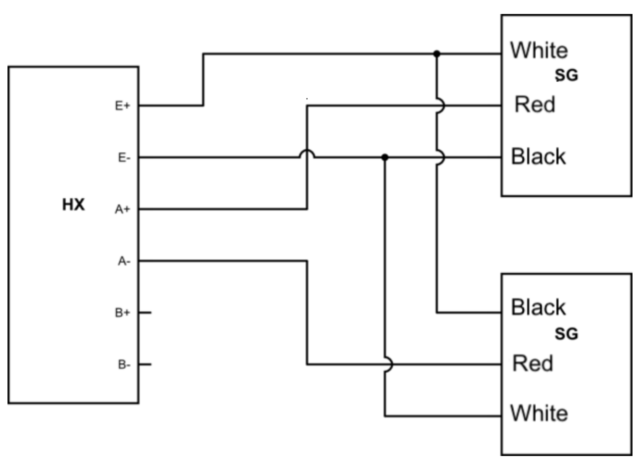

Figure 6: Load Cells in a Half Wheatstone Bridge connected to a HX711 Amplifying Chip

The other side of an HX711 chip contains 4 ports: VCC, SCK, DT, and GND. For both HX711 chips, the VCC pin is connected to the 5V power pin on the Arduino, and the GND pin is connected to the GND pin on the Arduino. Both HX711 SCK clock signals are connected to the same clock port on the Arduino, which was arbitrarily chosen to be digital port 2. The DT data port for the back truck and HX711 is connected to pin 3, and the front truck and HX711's data port is connected to pin 5.

Because of this connection, the clocks on the both chips are synchronized, all the load cells are powered, and the front truck and back truck weight data can be read through digital pins 5 and 3 into the microcontroller, respectively.

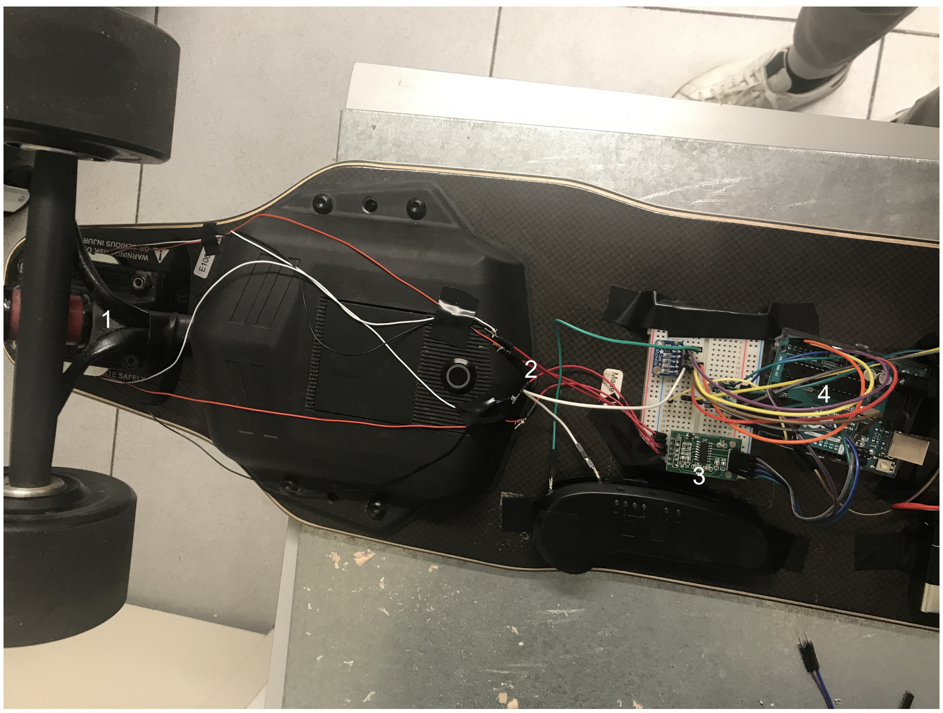

Figure 7: Actual Wiring of the Back Truck Load Cells, Amplifier, and Arduino. (1) Load Cells. (2) Half Wheatstone Bridge Wiring. (3) HX711 Amplifier. (4) Arduino Microcontroller.

4.5. Electrically Connecting to Powered Wheels

Connecting the Arduino Microcontroller to the Skateboard ESC in order to control the speed of the wheels could be done in 2 ways: directly wiring into the skateboard's ESC or wiring into the hand controller to electrically imitate a person physical turning of the speed knob.

Eventually, the method of electrically imitating the hand-remote signals was used.

4.5.1. Failed Direct Wiring Wiring directly seemed a more straightforward way to approach the problem and removed the security hazard of using a radio signal mentioned in Section 1. After opening up the battery and hardware compartment of the Backfire G2 electric skateboard, however, there was a box that was completely sealed with rubber with only a few connectors for the battery and wheels sticking out. An antenna for receiving the signal was visible out of the sealed circuit board, but the circuit board itself could not be accessed.

There was no way to attach a wire from the Arduino microcontroller to the sealed circuit board.

4.5.2. Using the Hand Controller Wiring into the hand controller to electrically imitate a person physical turning of the speed knob was the only other easy way of sending a speed signal from the microcontroller to the wheels.

The hand controller could be taken apart without shattering the casing. The speed knob on the hand controller functioned using a hall effect sensor. The knob can be seen in Figure 8. Two magnets would rotate over the sensor as the user turned the speed knob, which would then output a voltage based on the strength of the magnetic field. If the user rotated the knob all the way forward so one magnet was directly over the sensor, the voltage would jump to its max of around 3.3V. If the user rotated the knob all the way backward so the other magnet was directly over the sensor, the voltage would jump to its minimum of close to 0V.

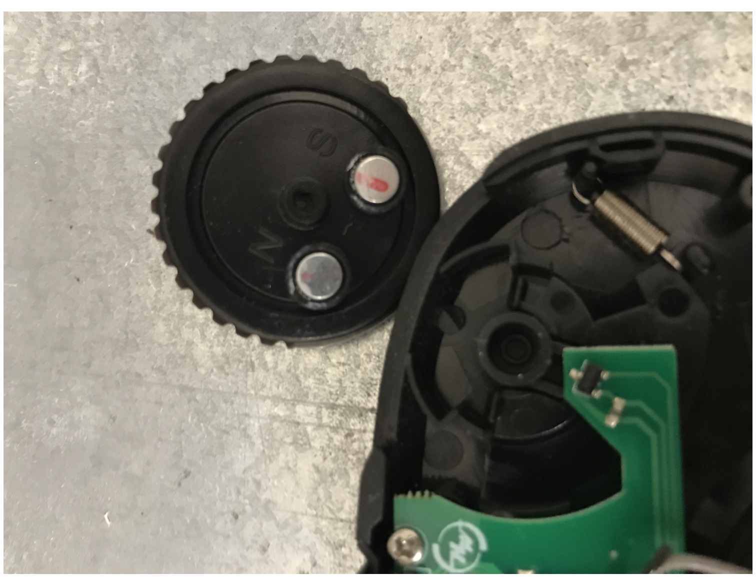

Figure 8: The Hall Effect Sensor on the Deconstructed Hand Controller

Using an oscilloscope, it was determined that the power into the sensor was 3.3V, and the power out ranged from 0V to 3.3V. At an output of 1.75V while connected to the electric skateboard, the wheels were provided neither power nor braking. Voltages above 1.75 provided power to the wheels, and voltages below 1.75 provided braking. These were also constant voltages instead of pulse width modulation (PWM).

Once the sensor's behavior was determined, the sensor was removed from the circuit board and the electrical contacts that were originally connected to the sensor were exposed. The Arduino was connected to the hand remote in the following fashion, using Figure 9 as reference:

- The ground pin on the Arduino was connected to the top ground pin contact.
- Because the Arduino microcontroller cannot output analog voltages, I connected a MCP4725 Breakout Board digital to analog converter chip (DAC) to the Arduino, and connected the DAC VOUT output to the right output pin contact of the hand controller.

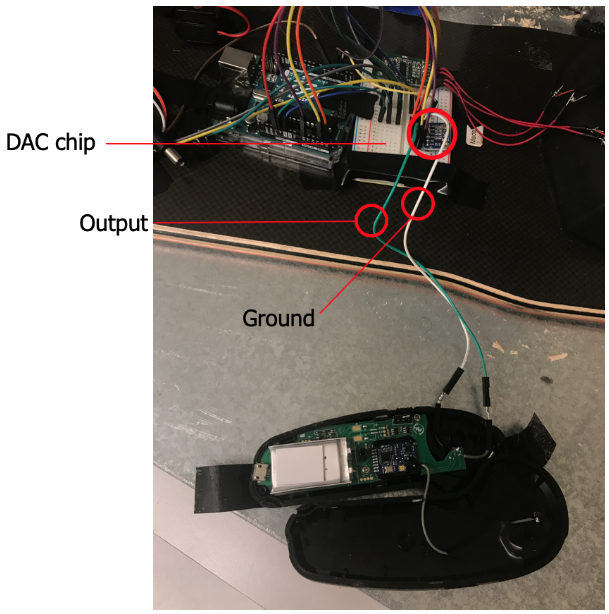

Figure 9: The DAC Wired to the Skateboard Hand Controller

The DAC was wired to the Arduino as follows:

- The 3.3V pin on the Arduino was connected to the VDD DAC pin.
- The ground pin on the Arduino was connected to the GND DAC pin.
- The A4 pin on the Arduino was connected to the SDA DAC pin.

- The A5 pin on the Arduino was connected to the SCL DAC pin.
- The DAC VOUT connected to the skateboard hand controller's output, allowing the Arduino to output analog values.

An Arduino IDE library was provided for the DAC chip, allowing a simple interface for outputting a desired voltage to the hand controller. After connecting the Arduino to the skateboard hand controller, the Arduino could be programmed to output voltages to move the powered wheels at the full range of speeds and braking capacities.

4.6. Writing the Algorithm

With all of the wiring done, weight sensor data could be read into the Arduino and an output voltage could be sent from the Arduino to make the wheels move. The next step was creating an algorithm to convert the weight sensor data into output voltage in an intuitive and learnable way. The rider should lean forward and backward to accelerate and decelerate, respectively.

4.6.1. Noisy Data Handling Due to the phenomenon mentioned in Section 3.1, leaning forward on the board does not always correspond to the front load cell reading more weight than the back load cell. For example, if the rider is leaning forward but the front wheel goes off of a curb, then the back wheel, which is still on the ground, will read more weight than the front load cell. If my algorithm didn't have some way to account for this data, then the board would brake while the rider was leaning forward, effectively flinging the unprepared rider off the board that they assumed would continue to move forward and accelerate.

With load cells as the only input into the algorithm, averaging many samples of the data accounts for the situations such as the one mentioned above. I used a ring buffer similar to the one shown in Figure 10 to make weight data values persist for 20 samples. After testing the sensors, a new value was found to enter the buffer approximately every 0.025 seconds. After experimental testing, the most comfortable time for persisting samples is around 0.5 seconds, which is why the buffer was decided to have 20 values. A new value that enters the buffer will move through the buffer, and eventually be removed after 20 samples. When requested, the buffer will return the average of all the samples currently inside.

Using this method of noisy data handling, the average difference over a half second between the front weight sensor and back weight sensor was constantly determined. Using this value, the rider's intent of a forward lean, backward lean, or even weight was determined.

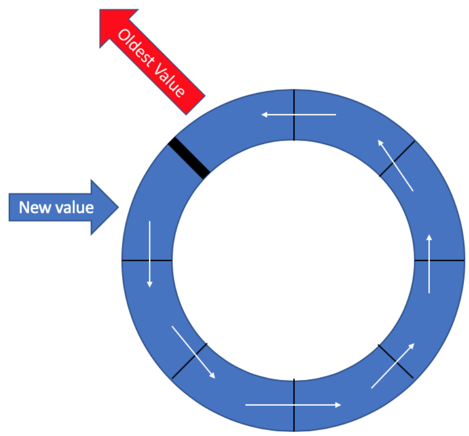

Figure 10: A Ring Buffer Used to Store Weight Data Points

4.6.2. Initial Attempt With Increasing Output Voltage My initial attempt was to have the skateboard hold a voltage when the rider's weight was evenly distributed. Leaning forward would increase the voltage, standing even would maintain the voltage, and leaning back would decrease the voltage. Video 1 on the Google Drive corresponds to this initial faulty attempt. I incorrectly assumed that a constant voltage would correspond to a constant velocity from the skateboard. However, holding a constant voltage would cause the skateboard to continue to accelerate as the board continued to work to get the rider's weight up to speed, leaving an alarming feeling when the rider felt like they should be maintaining speed, but the board would continue to accelerate. From this attempt, I realized that only 1 high voltage was needed for accelerating and 1 low voltage was needed for braking. A longer period of time leaning forward on the board would lead to higher speed, and a longer period of time leaning backward on the board would lead to more braking, which was the desired behavior.

4.6.3. Final Attempt Without Increasing Output Voltage My final attempt used a constant voltage for accelerating, and a constant voltage for braking. Because of the weight of the rider, setting the acceleration voltage to around 2.5 volts created a smooth acceleration up to a speed of a fast jog over around 5 seconds. Setting the braking voltage to around 0.75 volts created braking that was neither too slow nor too jarring on the rider. These voltages corresponded to the signal of speed up or slow down coming from the ring buffer mentioned in section 4.6.1. In addition, if the rider maintained around equal weight on both feet, the board would coast with no braking or added acceleration.

From experimental testing with individuals of 150 lbs, 180 lbs, and 230 lbs, a 30 lb difference appeared to be the best one-size-fits-all value for determining whether a rider intended to put equal weight on both feet or lean forward or backward. To add theoretical values, if the ring buffer's output over .5 seconds was 29 lbs greater on the front sensor than the back sensor, the board would coast without any power or braking. If the the ring buffer's output over .5 seconds was 31 lbs greater on the front sensor than the back sensor, the board would start accelerating.

In addition, the board is outfitting with a bail-off safety feature. When the load cells sense that the rider is no longer on the board, the wheels lock in place, halting the board in its tracks and keeping it from continuing forward without a rider on it. This is a feature that is not available with current models of hand-controlled electric skateboards.

The video of the working electric skateboard is posted under Video 2 on the Google Drive. Figure 11 shows the bottom of the finished board.

4.7. Evaluation

The end goal of creating a weight-controlled electric skateboard was to assess if weight-control is more intuitive and easier to learn than a hand controlled electric skateboard.

These metrics are inherently arbitrary and will vary drastically from person to person.

I created a form with the following options, most of them listed from 1-5 (1 is small and 5 is large) with a few short answer:

- How much experience do you have riding a skateboard?
- How much experience do you have riding an electric skateboard?

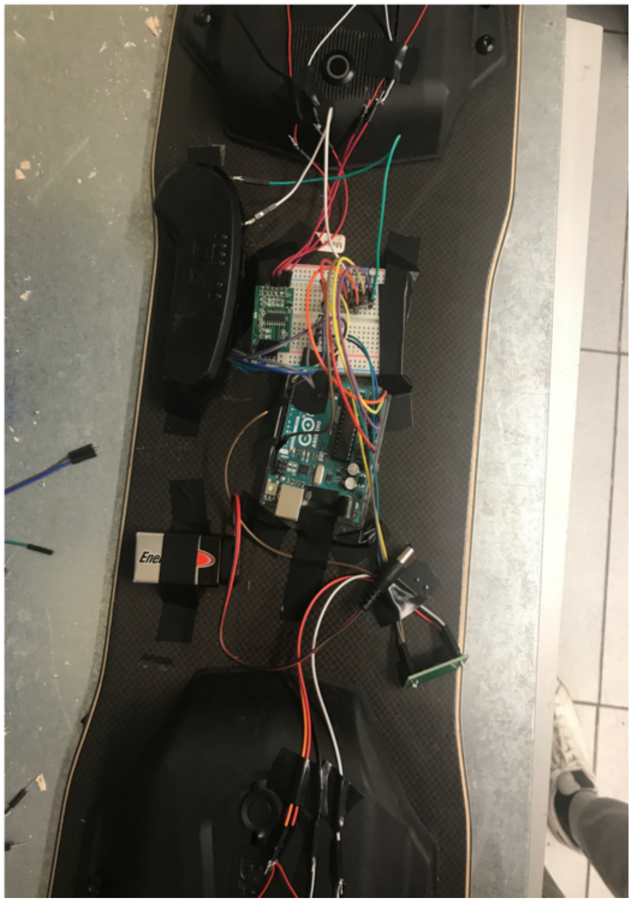

Figure 11: The Finished Wiring of the Weight Controlled Skateboard Prototype

- How many times did you bail off before getting up to speed (hand controller)?
- How much control did you feel like you had over the board (hand controller)?
- How safe did you feel on the skateboard (hand controller)?
- How many times did you bail off before getting up to speed (weight control)?
- How much control did you feel like you had over the board (weight control)?
- How safe did you feel on the skateboard (weight control)?
- Was it easier to balance on the hand controlled board, or the balance-controlled one?
- Which one was more fun to ride?

The data drastically changed between people who have ridden an electric skateboard before and those that did not.

4.7.1. Bailing off Rates "Bailing off" refers to the action of jumping off the board while moving in order to preserve one's safety or comfort.

For the 10 participants that had not ridden an electric skateboard before, they averaged 8.4 times bailing off the hand controlled skateboard before getting up to speed. Those same participants averaged 2.3 times bailing off the weight controlled skateboard before getting up to speed.

For the 4 participants that had ridden an an electric skateboard before, they averaged 0.5 times bailing off the hand controlled skateboard before getting up to speed. Those same participants averaged 1.5 times bailing off the weight controlled skateboard before getting up to speed.

From these two groups of participants, it appears that it is easier to learn how to use a weight controlled electric skateboard from the very beginning than is to use a hand controlled skateboard. However, it appears that people who are already familiar with a hand controlled electric skateboard are only slightly quicker to learn the weight controlled skateboard.

4.7.2. Balancing For the 10 participants that had not ridden an electric skateboard before, they 9/10 said they could balance better on the weight controlled than the hand controlled skateboard.

For the 4 participants that had ridden an an electric skateboard before, 3/4 said they could balance better on the hand controlled skateboard.

4.7.3. Safety For the 10 participants that had not ridden an electric skateboard before, they averaged a 2.2/5 for how safe they felt on a hand controlled skateboard. Those same participants averaged averaged a 2.0/5 for how safe they felt on a weight controlled skateboard.

For the 4 participants that had ridden an an electric skateboard before, they averaged a 4.75/5 for how safe they felt on a hand controlled skateboard. Those same participants averaged averaged a 3.25/5 for how safe they felt on a weight controlled skateboard.

It appears that neither group of participants felt remarkably safe on a weight controlled electric skateboard. The ones who had experience on a hand controlled skateboard felt very comfortable on a hand controlled skateboard, but felt much more unsafe on a weight-controlled electric skateboard.

4.8. Summary

4.8.1. Conclusions The technique of weight control using only load cells for input works as a valid control system for electric skateboards. Riders who have experience riding electric skateboards still prefer hand control over the weight control system. However, riders who have no experience riding electric skateboards pick up riding the weight controlled skateboard more quickly than the hand controlled. From the rather limited test data, riding a weight controlled electric skateboard appears to be easier to learn than riding a hand controlled electric skateboard.

Since 9/10 riders said they could balance more easily on the weight controlled electric skateboard, the method of weight control seems more intuitive than hand control for first time riders.

The problem with weight controlled electric skateboards as a means of transportation is safety. First time riders and experienced riders alike all do not feel very safe on a weight controlled board. Weight control seems intuitive to start, but does not give riders the comfort and level of control that they eventually develop on a hand controlled electric skateboard.

While this prototype proves it is possible to achieve consistent weight control using only load cells for an electric skateboard, it is much more difficult to master than a hand controller, even though it is easier to balance initially on a weight controlled skateboard.

4.8.2. Future Work If I were to continue to develop the weight controlled electric skateboard, I would first waterproof the bottom of the board. It was difficult to test during the winter months at Princeton due to the weather. I would also look into not just using a constant voltage for acceleration and braking. While functional and intuitive, it does not allow the user full access to the power of the electric skateboard motor or braking capabilities.

Another possible step would be to add more sensors such as a gyroscope or even a camera to analyze body position to judge the riders intent with more clarity. Using a ring buffer to average the data points provided consistent safety ensured the skateboard made no unexpected accelerations or decelerations, but it provided the user with around a half second of latency between body movement and acceleration. Any less latency, however, introduced unexpeced accelerations and decelerations. More sensors must be added to decrease this latency and maintain the correct speed control.

4.8.3. Honor Pledge I pledge my honor that this paper represents my own work in accordance with University regulations.

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