GNG 2101

Design Project User and Product Manual

Remote Braking System

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RBS B15

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1 Introduction

This User and Product Manual (UPM) provides the information necessary for caregivers of those who uses the R82 Crocodile Gait Trainer (size 2) to effectively use the Remote Braking System (RBS) and for prototype documentation.

The R82 Crocodile required a front brake mechanism that could be operated remotely by a caregiver to stop forward motion of the gait trainer. To create this mechanism, models were created using SolidWorks and then printed using the Ultimaker 2+ 3D printer. The code for providing functionality to the parts were written in the Arduino IDE. This document will first give an overview of the remote braking system, then cover the setup configuration for the product, how to use the brake mechanism, troubleshooting and support, product documentation, and future work recommendation. The link to all the SolidWorks files for the 3D printed parts and the codes for controlling the motor wirelessly via a remote can be found in the Appendix Section of this report.

2 Overview

A pediatric gait trainer is a device that supports the weight of a user with mobility issues and helps the user practice walking. Children with mobility issues will often use a pediatric gait trainer to aid their movements and to achieve independent walking. However, because many gait trainers do not have brakes that stop forward motion, the user relies heavily on a nearby caregiver at all times, which prevents the user from gaining complete independence.

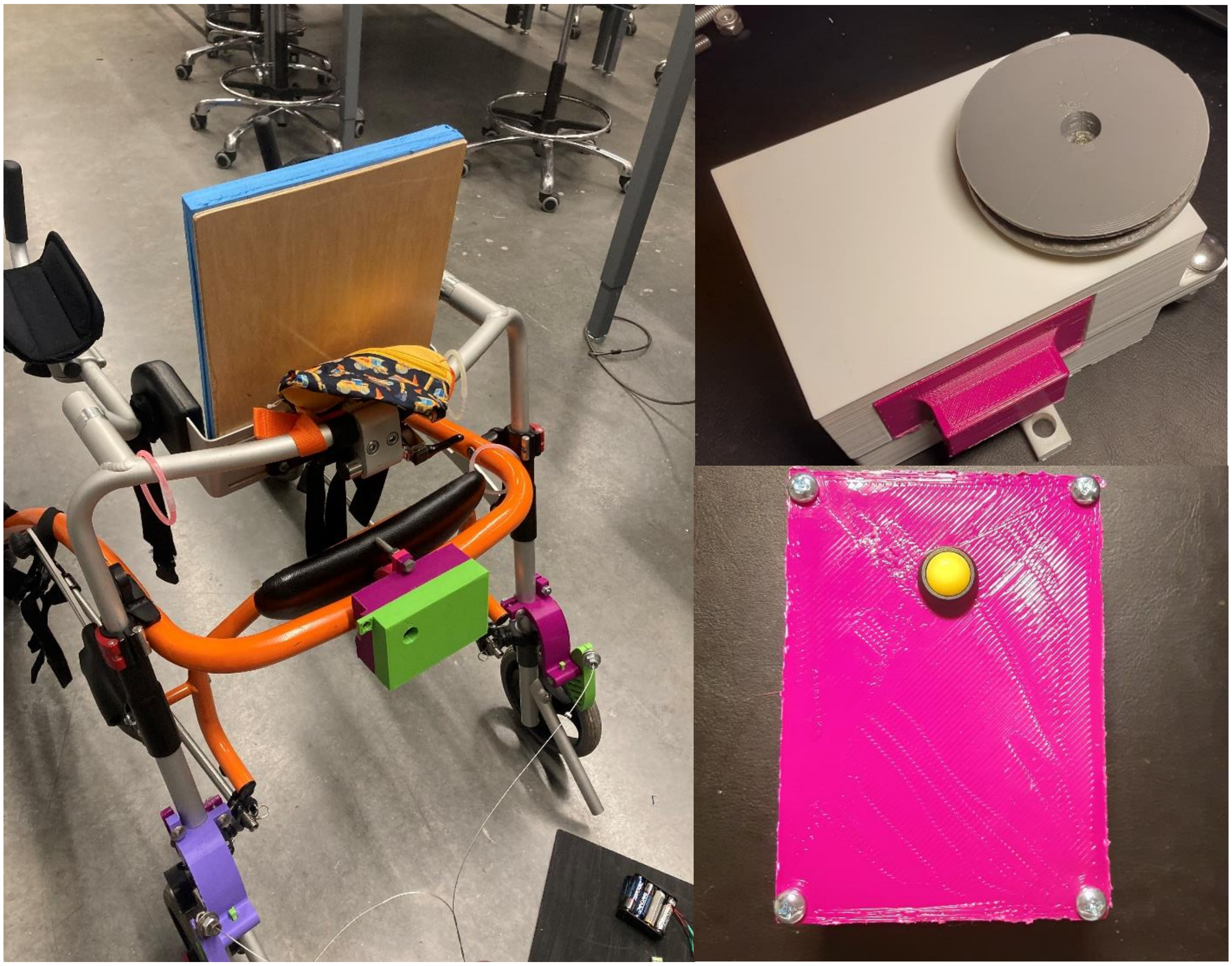

Figure 1 - *Final Prototype*

The key features of the remote braking system are:

- 3D printed brake pads which stop the rear wheels from turning forward
- 3D printed collars used to mount the brake pad
- 3D printed case which holds an Arduino, Bluetooth module, and motor that actions the cable system
- 3D printed remote which holds an Arduino and Bluetooth module, and is used to activate the motor

A collar is fastened onto each rear leg of the gait trainer, allowing a brake pad to sit on top of each rear wheel. This is so the teeth of the brake pad will land on the wheel when the motor, controlled by a separate handheld remote, actions the steel cables attached to the brakes. The following is a block diagram that illustrates the logic of the remote braking system.

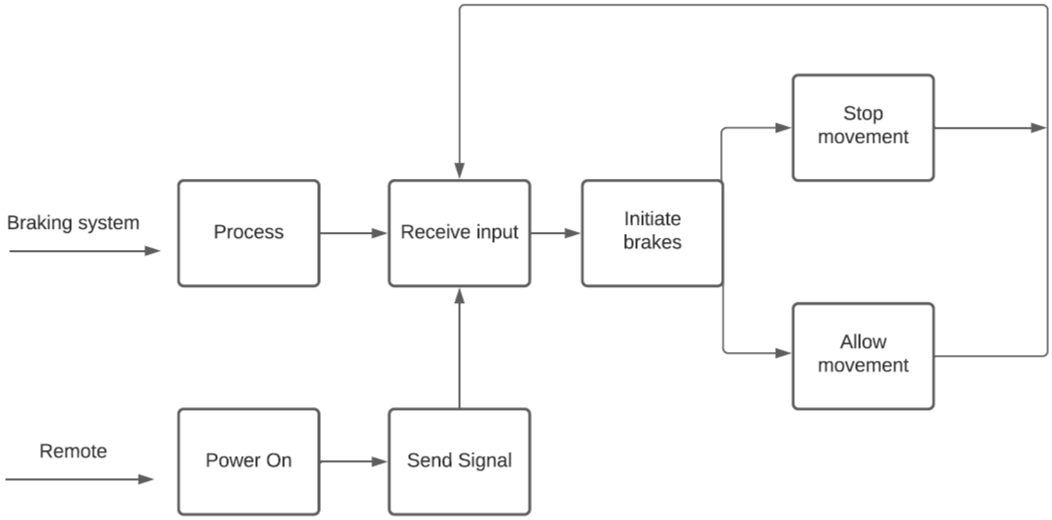

Figure 2 - Logic Flowchart

2.1 Cautions & Warnings

The edges of the 3D printed parts may be sharp; thus, when setting up the brake mechanism on the gait trainer, wearing gloves can help prevent any minor cuts. However, in the *Conclusions and Recommendations for Future Work* section, a detailed explanation of the changes that will be made to improve the 3D printed parts will be discussed, one improvement being the reduced number of sharp edges to prevent cuts. Furthermore, the battery tray in the case that houses the motor may be at risk of falling out, which could displace the circuit configuration that makes the system operational, and also leaving the electronics exposed to undesired weather conditions such as rain or snow. Again, a possible solution for future iterations of this model is discussed in the final section of this report.

3 Getting started

To use the automatic brake, the user only needs to follow three steps, which exist in a perpetual loop.

1. If the gait trainer is moving, then the user can press a button to stop the motion of the trainer.
2. The user presses the button again to release tension from the system.
3. The user lifts the brake pads off the trainer wheels to allow for motion once again. (Steps may be repeated as many times as desired, starting from step 1).

From the system's point of view these, three steps create a much longer list of resulting actions.

1. The button is pressed.
    a. A closed circuit is created between pin 8 and the ground pin of the remote Arduino.
    b. The Arduino relays the information to an HC-05 Bluetooth module which is also connected to the remote Arduino and tells it to change state (from 0 to 1).
    c. The remote HC-05 module relays the information to another HC-05 module, which also changes state (from 0 to 1).
    d. This second HC-05 module is connected to the motor Arduino, and when it changes state, the motor Arduino sends current to the servo motor, which is programmed to turn 180 degrees.
    e. The motor is connected to a spool which is attached to steel cable. When the motor turns it pulls the cable upwards.
    f. The cable is connected the back of a brake pad, when the cable is pulled upwards it rotates the brake pad.
    g. The teeth of the brake pad press against the wheel and prevent motion.
2. The button is pressed again.
    a. The Arduinos communicate in the same way as before, but state is changed from 1 to 0 instead of 0 to 1.
    b. The motor turns 180 degrees in the opposite direction so that it returns to the initial position.
    c. Tension is released from the brake cable.
3. The user lifts the brake pads
    a. The brake pad is rotated, and the teeth are removed from the wheel.
    b. The weights at the back of the brake pad keep it in this position. The gait trainer can now move, and the steps may be repeated.

3.1 Set-up Considerations

To set up the system, the user will first need to clamp all the components onto the gait trainer. Pieces that connect to the gait trainer will have a semicircular groove in them, and this groove fits around a bar of the gait trainer. The other section of the clamp goes on to the other side of the bar and the two sections are connected and tightened by a bolt and hex-nut. This technique is demonstrated by the images below.

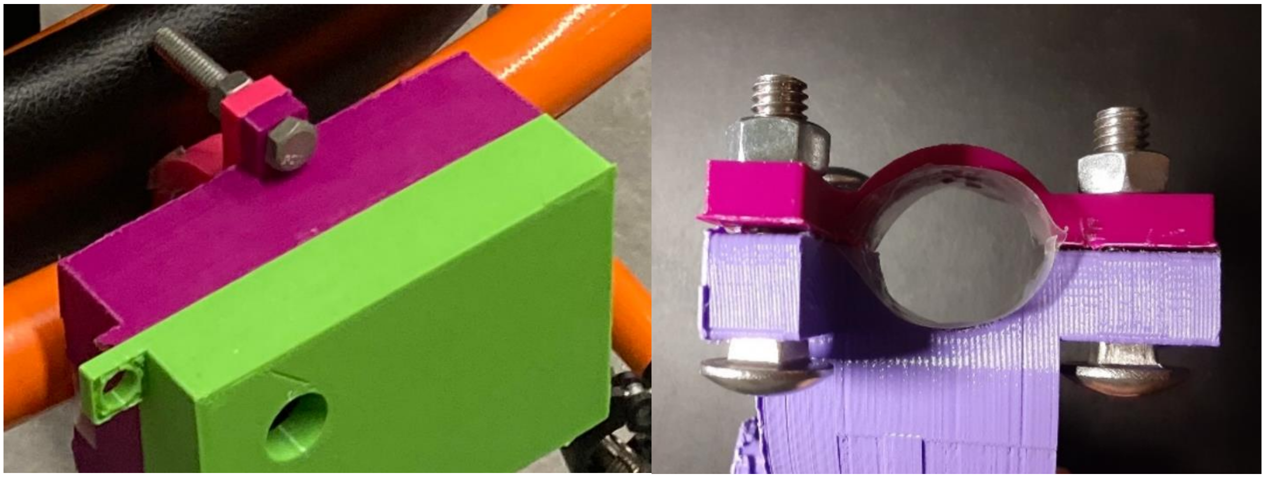

Figure 3 - Clamping Method

The motor case will need to be clamped to the back support bar, and the brake collars need to be clamped to the legs of the gait trainer, just above the wheels.

A series of steps is needed to assemble the brake pad to sit on top of the wheel. The components necessary are labeled in the following figure:

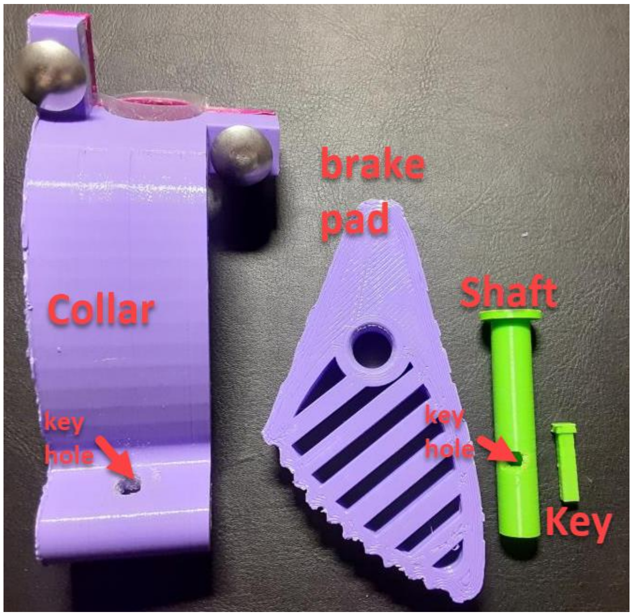

Figure 4 - Brake Pad Parts

First, the shaft goes through the hole of the brake pad. Afterwards, put the shaft and brake pad through the hole in the collar, lining up the keyhole on the shaft to the keyhole on the collar. Next, the key will slide into the keyhole, locking the brake pad in place.

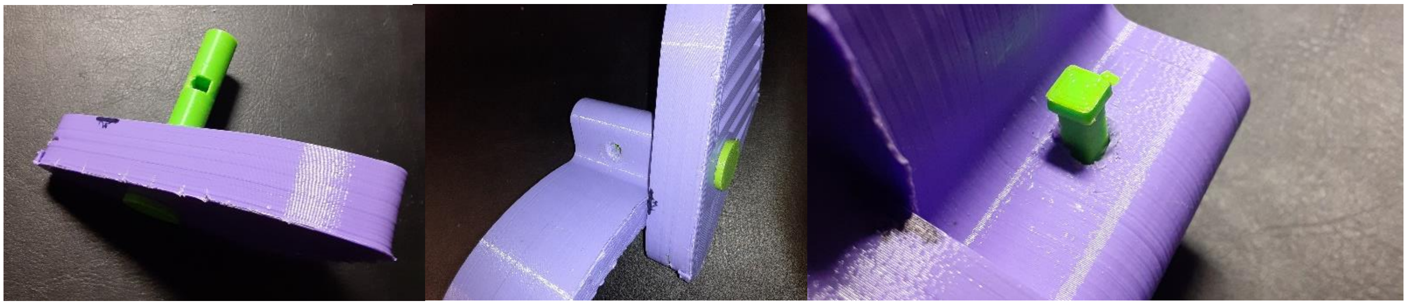

Figure 5 - Brake Pad Assembly Steps

Next, the spool. First, take a screw that’s around 2.9mm in diameter and attach it to the side of the motor with a hollow circular cut. Then, we take that screw and fasten it to the motor.

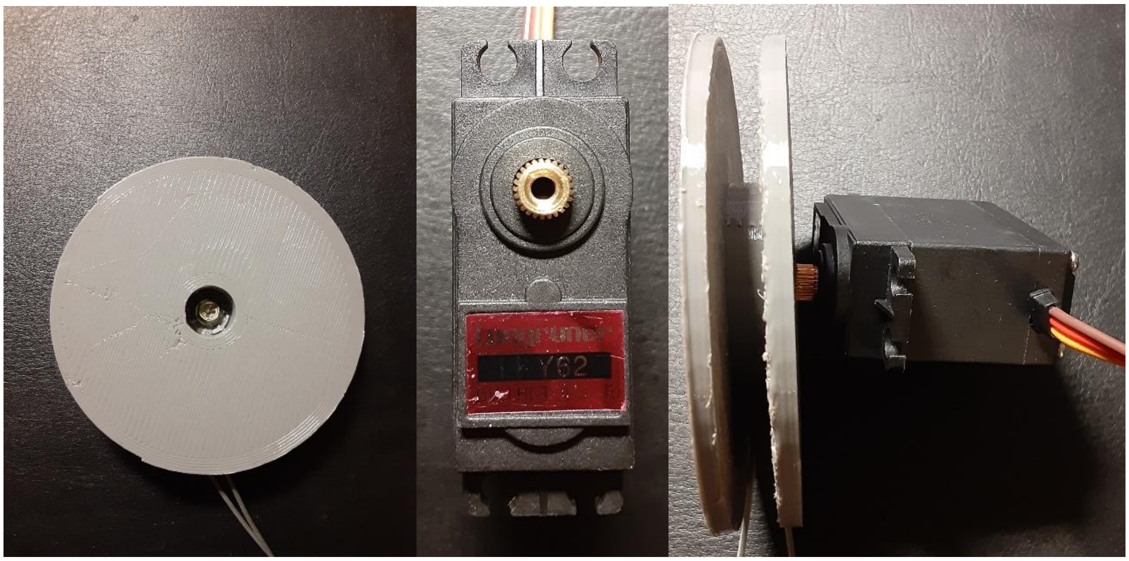

Figure 6 - Spool and Motor Assembly

The next, and last step of setup is to attach the middle of the steel cable to the hook found in the spool, and to hook either end of the cable into the back of the brake pads.

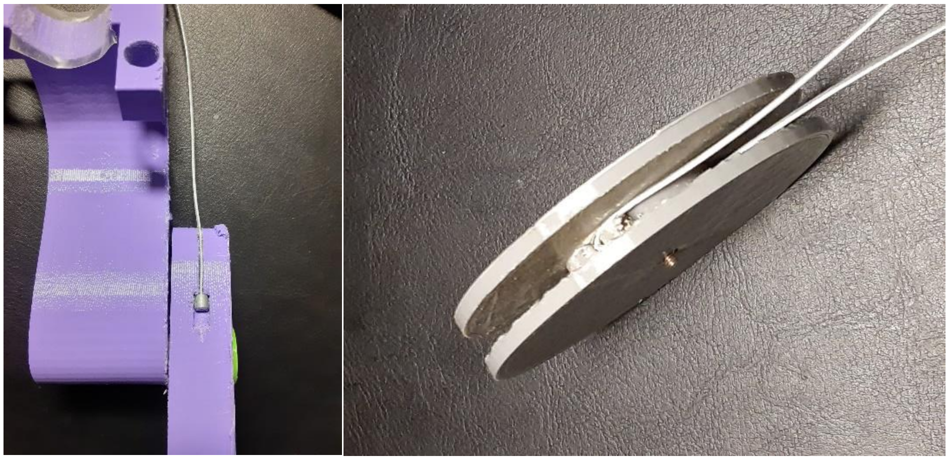

Figure 7 - Cable Setup

Every so often the batteries will need to be replaced, the batteries holders can be removed from the casing by sliding out the removable shelf, and from there it is easy to replace the batteries. As for the remote battery, the remote case must be unscrewed, and then the battery can be unclipped from its connecting wires and replaced.

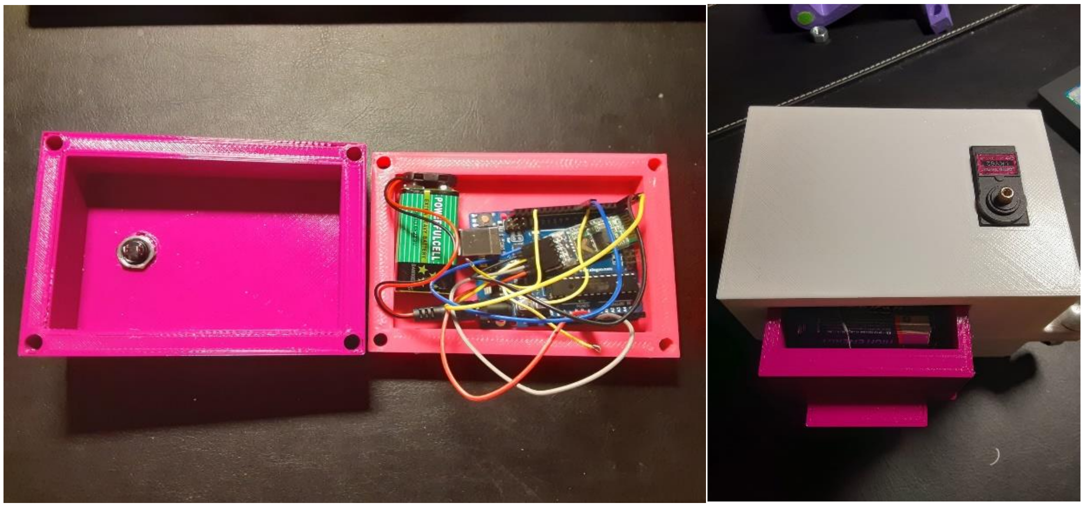

Figure 8 - Batteries

3.2 User Access Considerations

The system can be easily used by pressing the button to engage the break. However, to prevent the user from being hindered by the break a simple mechanism to remove it was added. A pin maintains the connection between the brake pad and the collar was added. If the pin is removed the brake pad can be removed from the wheel and the gait trainer can be used without being encumbered by the brake.

3.3 Accessing the System

To turn on the system both the remote and the motor must have batteries. The remote uses a nine-volt battery. The motor requires six AA batteries that can be added to the motor by taking out the magenta tray that holds two four AA batterie holders, shown in figure 8.

3.4 System Organization & Navigation

The remote has a single yellow button that when pressed causes the brake to engage by tensioning the brakes connected to the brake pad. If the button is pressed again the cables connected to the brakes are removed from tension. After the cables being removed from tension the user can manually set the brakes to disengage.

3.5 Exiting the System

To fully deactivate the system, the batteries must be disconnected from the circuit. For the nine-volt battery this can be achieved by opening the case and unclipping the battery from its connecting wire. For the AA batteries, the battery holder can easily slide out of the casing so the batteries can be removed.

4 Using the System

Remote

To use the braking system, it is important to know how to use the remote. The remote's usage is quite simple to understand. When using the remote first you must ensure that the remote is powered with a battery and be sure to be within the functional range of the remote. When the brakes are disengaged, press the yellow button on the remote to engage the brakes. When the brakes are engaged, press the yellow button on the remote to disengage the brakes.

If the batteries on the remote need to be changed, the remote case can be opened by loosening the nuts on each corner and detaching the wires from the button. Details are shown in section *3.1 Set-up Considerations* and *3.3 Accessing the System*.

5 Troubleshooting & Support

Error Messages or Behaviors

Brake not responding: If brake is not responding, ensure that the batteries are not dead. Next, ensure that the remote and the braking system are within range of each other. After that, make sure that there is nothing that could be obstructing the signal of the Bluetooth modules. If all else fails, contact support.

Button not responding: If button is not responding, ensure that the batteries are not dead. Next, ensure that the remote and the braking system are within range of each other. After that, make sure that there is nothing that could be obstructing the signal of the Bluetooth modules If all else fails, contact support.

Special Considerations

If the remote or device has been shaken or dropped from a considerable height, there is a chance that the connection of the wires may have loosened. If this has occurred, contact the support, and report the details of your problem.

Maintenance

Maintenance of the remote braking system is quite easy and quick to do. With the more frequent maintenance being a regular change of batteries as they lose charge after long term use. Less frequent maintenance for this system is the tightening of the brake wires as bicycle brake wires are known to stretch after years of use.

Support

Contact a group member via email:

- For technical issues you can contact Tony (ttam092@uottawa.ca), or Juan (jrami053@uottawa.ca).
- For mechanical/physical issues you can contact Zane (zshep015@uottawa.ca), Sam (stan058@uottawa.ca) or Sukhshant (slitt030@uottawa.ca)

6 Product Documentation

The final prototype was created using a synthesis of mechanical, electrical, and software systems. The software connects to the electrical system via Arduino, which is a programmable motherboard that uses Arduino IDE to communicate between the hardware and software and send current in specific ways. The motor connects the electrical system to the mechanical system, seeing as it is connected to both the Arduino and the tensioning cable.

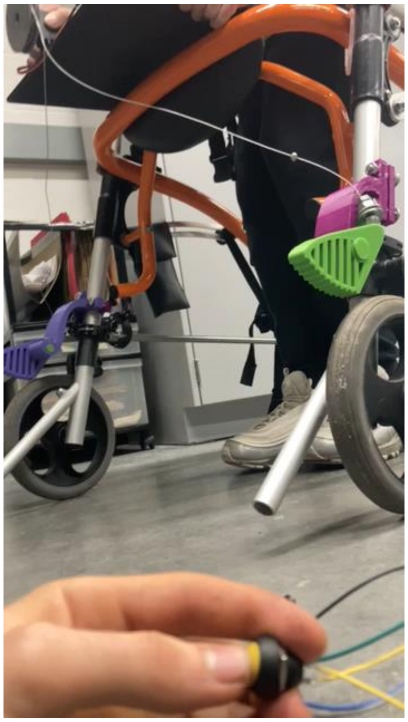

Figure 9 - *The Combination of Electrical and Mechanical Systems*

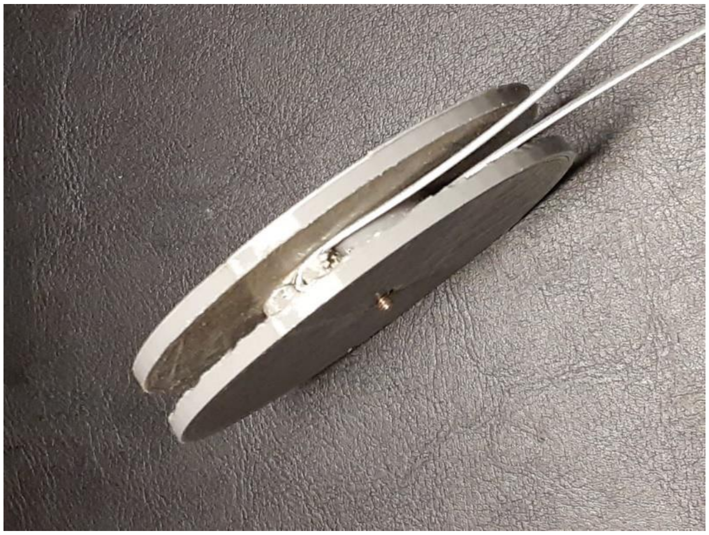

Figure 10 - *The Motor Spool Connected to the Tensioning Cable*

Mechanical System

Bill of Materials - Mechanical

Table 1 – Mechanical Components BOM

Material	Source	Cost
3D Printed Plastic	Ultimaker 2+ 3D printers in the Makerspace, located in the University of Ottawa's STEM building	$0
Derailleur Cable	https://www.canadiantire.ca/en/pdp/supercycle-bike-inner-derailleur-cable-0737448p.html	$8.49
Hex Nuts (10)	https://www.canadiantire.ca/en/pdp/hillman-finish-hex-nuts-zinc-1610472p.html#srp	$2.80
Hex Bolts (10)	https://www.canadiantire.ca/en/pdp/hillman-grade-2-hex-bolts-zinc-1617929p.html#srp	$2.80
3/16" x 2 1/2" Bolts and nuts kit	https://www.homedepot.ca/product/paulin-3-16-inch-x-2-1-2-inch-flat-square-head-slot-stove-bolt-with-nut-zinc-plated-7-pcs-/1000120814	$2.97

Equipment list

- CURA Ultimaker 2+ 3D Printer.
- Hand tools (power drill, files, screwdrivers, and other tools to smooth down and remove supports from 3D printed parts).

Instructions

The mechanical aspect of the design consists of 3D printed models, bolts, hex-nuts, and a steel cable. These parts are shown below to demonstrate how they were connected to one another. The 3D printed parts were connected to one another using clearance fits and locking keys.

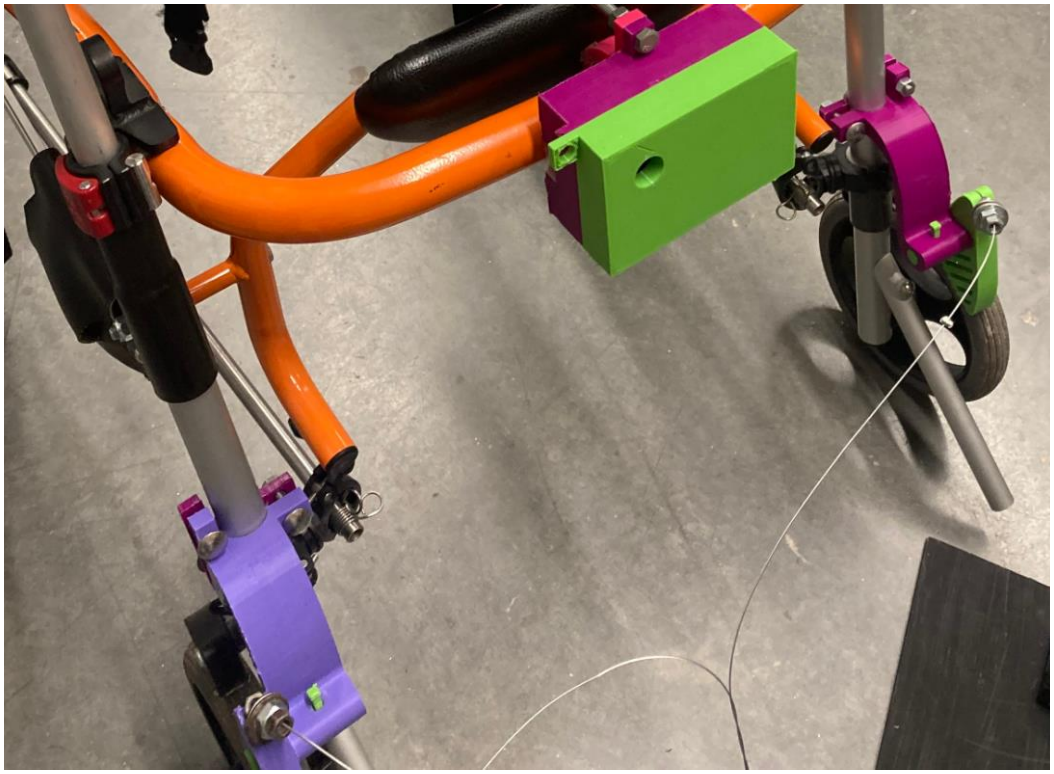

Figure 11 - Mechanical Components

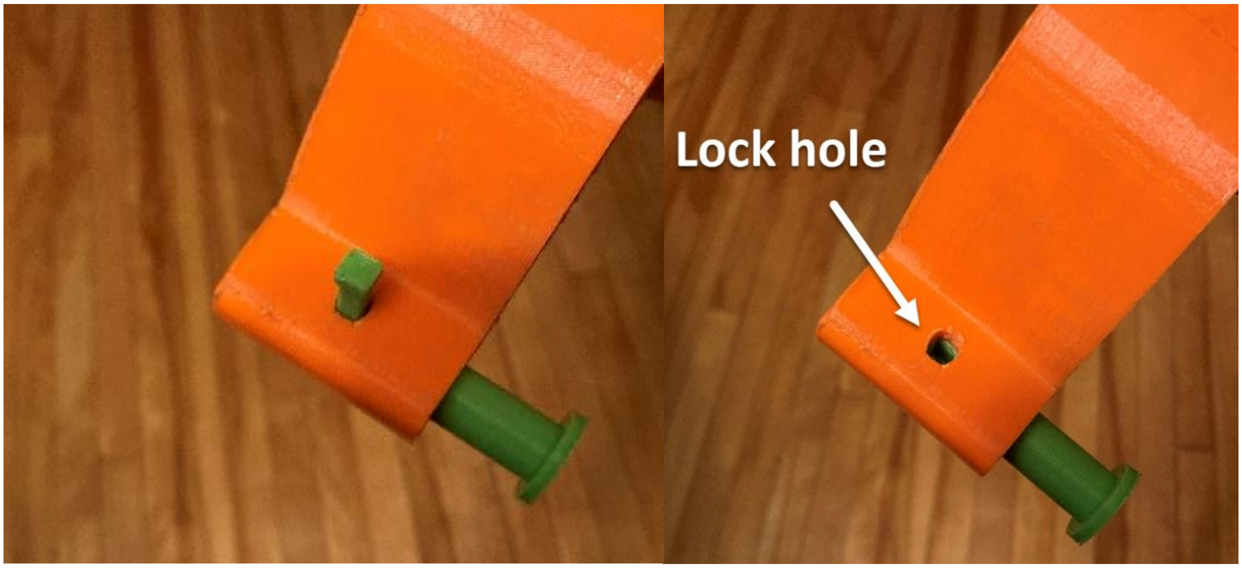

Figure 12 - Locking Mechanism

The 3D printed parts were modeled in SolidWorks and printed using PLA plastic. SolidWorks was chosen as the optimal CAD software because it contains mechanical analysis features, and PLA was chosen because of its availability, as well as the cost and time constraints of the project. The steel cable, which is a bicycle derailleur cable, was chosen because it has very high tensile strength and it has a head which can be hooked into the brake pad (pictured below).

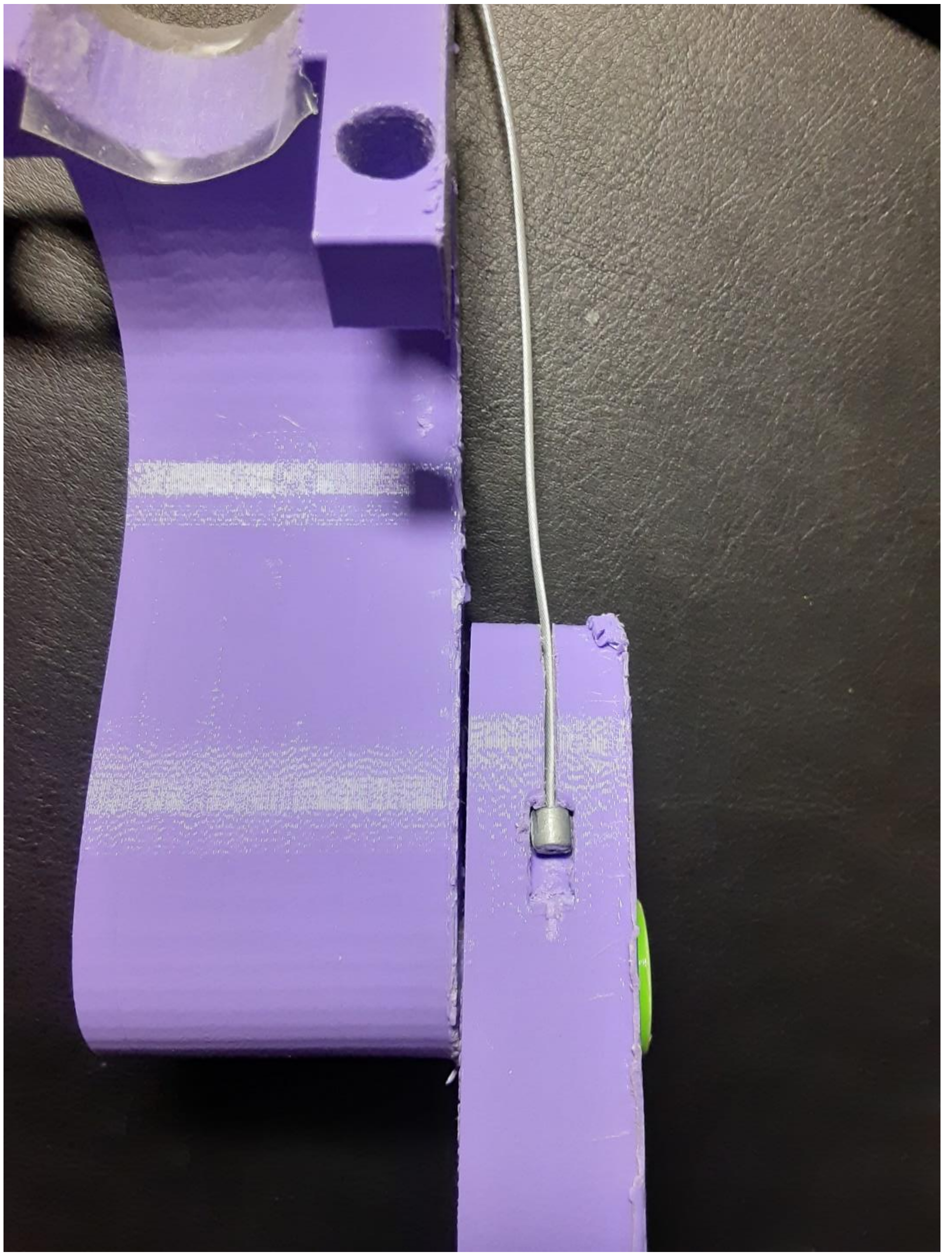

Figure 13 - Cable Head in Brake Pad

Testing & Validation

The 3D models were tested in SolidWorks using force analysis and material properties. The model was then iterated until we knew that the maximum stress was below the yield stress. Once the models were printed, we tested them on the gait trainer to ensure that it had the proper fits and was capable of stopping motion without deforming.

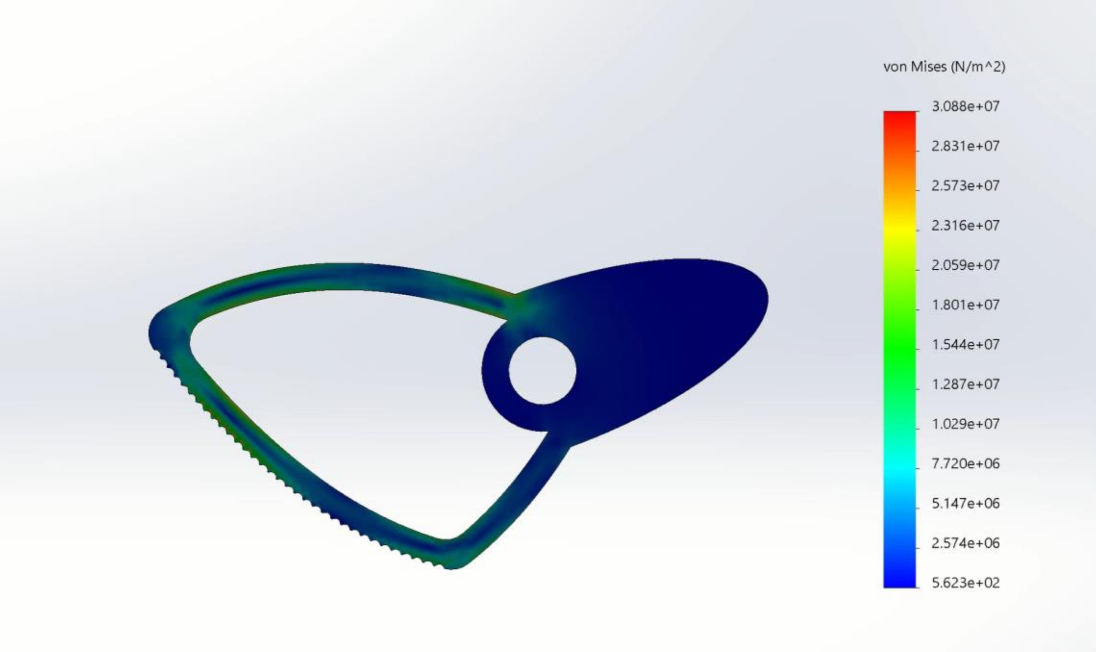

Figure 14 - SolidWorks Force Analysis

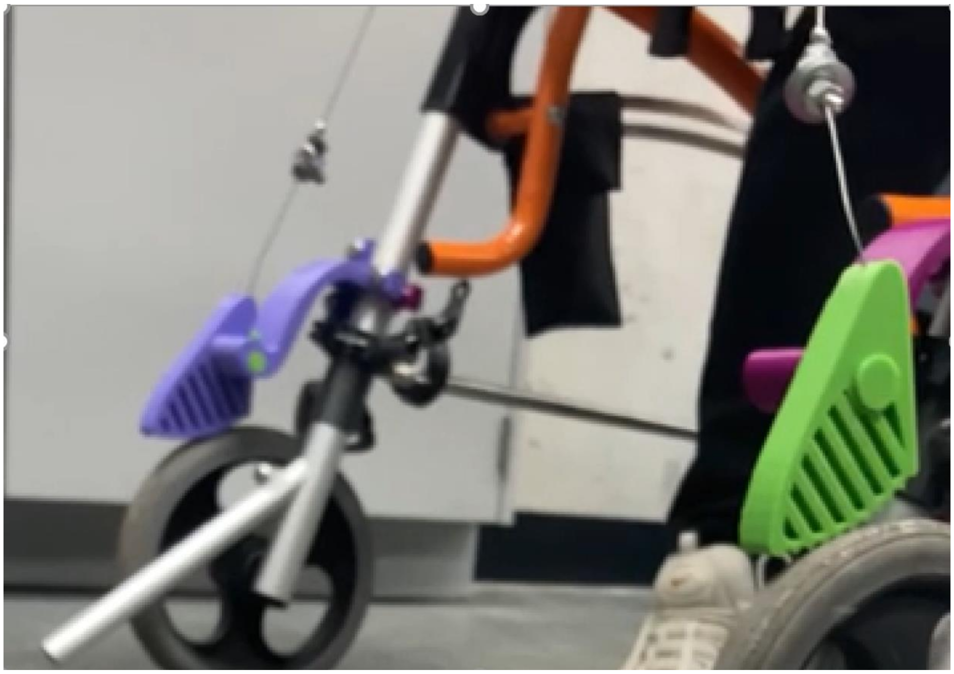

Figure 15 - Brake Pads Stopping Forward Motion

Electrical and Software System

Bill of Materials – Electrical and Software

Table 2 - Electric and Software Components BOM

Material	Source	Cost
Servomotor	https://edu-makerlab2021.odoo.com/shop/product/servo-motor-76#attr=349	$6.18
Momentary Button	https://edu-makerlab2021.odoo.com/shop/product/push-button-switch-81?search=button#attr=147	$0.71
Male-female cable (8)	https://edu-makerlab2021.odoo.com/shop/product/jumper-wires-44?search=jumper+wires#attr=46	$0.80
Male-male wire (5)	https://edu-makerlab2021.odoo.com/shop/product/jumper-wires-44?search=jumper+wires#attr=45	$0.50
HC-05 Bluetooth module (2)	https://edu-makerlab2021.odoo.com/shop/product/bluetooth-module-9?search=HC-05+Bluetooth+#attr=255	$25.98
Arduino UNO (2)	https://edu-makerlab2021.odoo.com/shop/product/arduino-5?search=Arduino#attr=5	$40.00

Equipment list

- Soldering Iron
- Arduino IDE

Instructions

Two electrical circuits were created, the first being the remote circuit, which was made by connecting an HC-05 module, a momentary button, and a nine-volt battery to an Arduino using male and female connector wires. One end of the button is connected to pin 8 of the Arduino while the other is connected to the ground pin. The battery is connected to the power input, and the Bluetooth module is connected to the RX, TX, ground, and 5V pins. The second circuit was the motor circuit. A couple of 4-AA battery holders were soldered together in series and connected to an Arduino, via the Vin pin. A servo motor was connected via pins, 6, GND and 5V, and an HC-05 module was connected via RX, TX, GND and 3.3V pins. AA batteries had to be used in place of a nine volt, because they provide more power at the same voltage, and the 9-volt did not have enough current to power the motor.

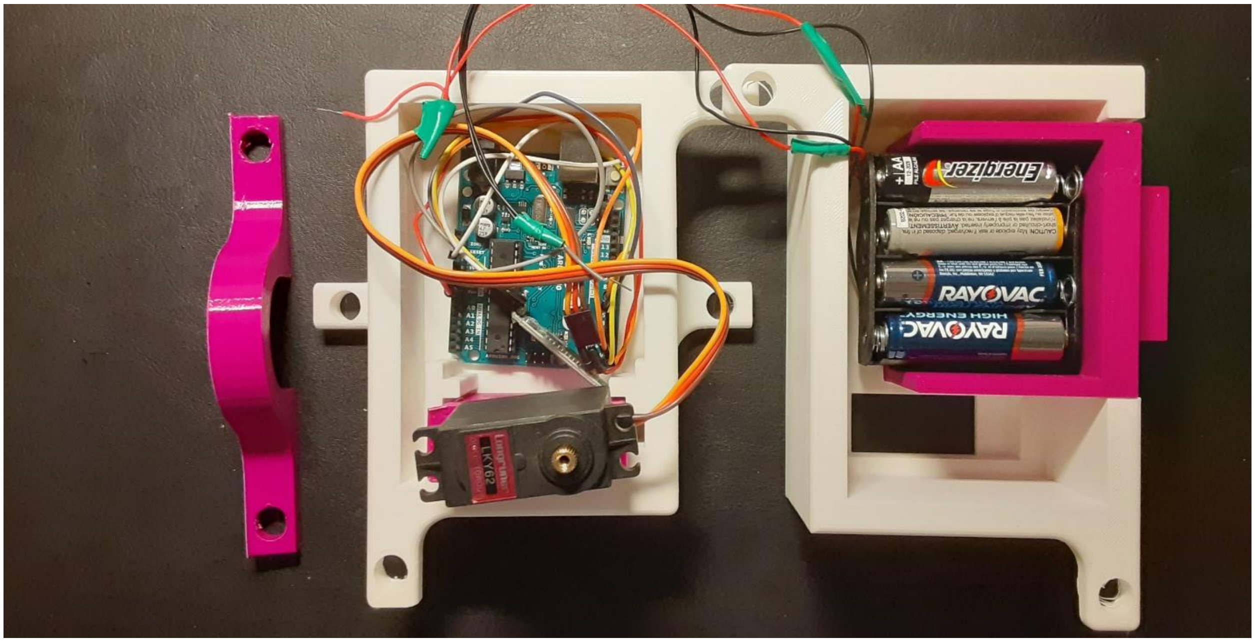

Figure 16 - Motor Circuitry

The software component was written in the Arduino IDE. To control the servo motor the servo library was used. In case a different kind of motor is used, such as a stepper motor, a different library may be necessary. The HC-05 Bluetooth modules were configured to one be master and one slave. The Bluetooth module set to master was configured to only connect to a single device and not be discoverable. This setup was done because there is only one controller so giving the master Bluetooth module the ability to connect to other unknown devices could lead to software vulnerabilities.

The Arduino code follows simple logic. The code for the remote waits for the user to press the button. While the button is pressed the button sends a signal to the motor. This causes many signals to be sent to the motor. The motor code waits to receive a signal from the user. Once a signal is received the code cleans all the extra signals sent by the remote. After cleaning all the extra signals, the code changes the state of the motor. If the motor is in position 180 it is changed to position 0 and if the motor is in position 0 it changes to 180.

Testing & Validation

To test the range of communication between the two circuits, we measured the maximum separation at which the two Bluetooth modules remained connected to one-another and found it to be approximately 100ft, which was much higher than our ideal value of 30ft. Software testing was done by debugging and iterating new code until the program ran smoothly.

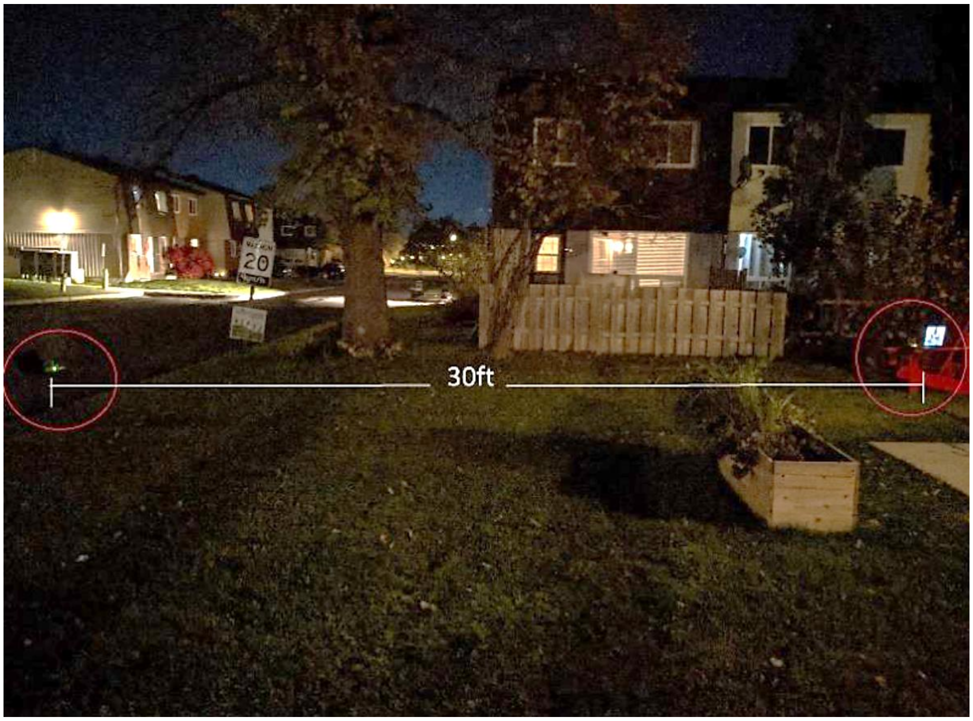

Figure 17 - Testing and Validation

Conclusions and Recommendations for Future Work

Throughout this project the group encountered a number of problems and developed multiple solutions. With problems such as weak bolt hole structures, too small case sizing, and the inconvenient battery holder. The weak bolt hole structure caused a prototype to break apart into pieces causing it to no longer be viable to tighten around the gate trainer. The group solved this issue by extruding the holes larger to increase its strength and to fillet its edges to help strengthen the extruded ends even more. With the 3D printer printing smaller than anticipated the group realized the addition of tolerances would prevent the same issue from occurring again. The battery holder needed to hold more batteries than a single battery holder could hold causing us to use two making it harder for maintenance and useability. With the design of a holder to hold both battery packs, we were able to overcome this hurdle. If we were given a few more months to work on this project we would first replace the 2 separate battery packs for 1 to make it easier for maintenance. The second thing that would be changed is the size of the remote as it currently is larger than desired due to the size of the battery. Due to the lack of time, we were unable to make the remote's battery more accessible as they currently require the entire remote to be disassembled in order to change it. With this project completed the group was successful in creating a product, the client needed with having all their expectations met.

APPENDICES

APPENDIX I: Design Files

The figures in this report (example, figure 1) consists of the 3D printed parts necessary for the remote braking system. The source for these 3D printed parts, along with the code that provides them functionality can be found in Table 3 below.

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
SolidWorks Files	https://makerepo.com/jrami053/1042.gng2101-b15-rbs	Dec 5th, 2021
STL Files	https://makerepo.com/jrami053/1042.gng2101-b15-rbs	Dec 5th, 2021
Code	https://makerepo.com/jrami053/1042.gng2101-b15-rbs	Dec 5th, 2021
Project Deliverable Files	https://makerepo.com/jrami053/1042.gng2101-b15-rbs	Dec 5th, 2021