A Standalone Foot Based Game Controller For Use Hands-Free Use

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***Abstract*—There has been a lack of accessible gaming controllers for individuals who have lost access to their hands, despite there being a sizeable amount of gamers who fall under that category. We were motivated to solve this issue since accessibility is not as widespread in the gaming industry as we would have liked. Our foot based controller, which allows users to input commands to video games solely using the feet will attempt to fill in this gap by providing a solution.**

***Index Terms*—Foot Based Controller, Iterative, Accessibility, Disability, Gaming**

I. Introduction

Gaming is an activity that generally requires the use of your hands and people without access to their hands, whether due to an accident or a medical condition, generally find themselves having limited options in terms of accessibility making it much more difficult if not impossible for them to partake.

It is relevant to solve, because with less accessibility options, people without access to their hands will have a diminished experience when gaming. They will either continue to play games with a barrier or they might quit gaming entirely which could affect revenue of gaming companies. In a survey done by disability advocacy organization Scope, it showed that 66 percent of gamers with an impairment or condition say they face barriers or issues related to gaming [1].

We addressed the problem by creating a controller that can be fully used with just a user's feet. This would allow gamers without access to their hands to be able to play games without much difficulty.

In this document we will be presenting the process that went behind designing and prototyping our custom made controller. The document will go over what documents and literature we reviewed, our workflow and iterative design process, our prototype progression and changes on each iteration, our QFD and System Usability assessment results, and lastly our takeaways from the design, prototyping, and assessment procedures.

II. Literature Review

The first scientific document we found was actually a presentation done by a Stanford professor, which provided information on the amount of arm amputees in the world. While we don't have an exact number of gamers who don't have access to their hands, the document did reveal that there were over 3 million estimated arm amputees in 2008 [2]. This helped us understand the scope of the issue we're trying to solve and it helped strengthen our justification.

We also looked online for devices that were similar and could provide inspiration to us. We found that there were several foot based controllers that had been researched and developed by various individuals, companies and organizations. One of them was an unnamed foot device that was presented at the 2018 18th International Conference on Control, Automation and Systems (ICCAS). In the scientific paper the researchers described their device as shaped like a shoe sole that used force and inertia sensors to detect input from the user's feet and then used a micro-controller unit, to transmit the data from the device to the user's PC via Bluetooth [3].

Another device we found was the Spring Stepper, whose goal was to provide seated VR locomotion that would be controlled by the user's lower body. It could attach to the user's feet with straps and could emulate real walking via springs in the device that would help the feet back to the initial position, thus mimicking the gait phases of support and balance. The device also utilized pressure sensors which the user could sit on. The user is then able to walk by moving their thighs, and the sensors detect the change in pressure. They also used the Vive Tracker to track the user's body rotation on a swivel chair to get the proper orientation in the virtual environment [4].

The last device we looked at was the 3dRudder which was a foot based controller that connects via USB and allowed the user to move in PC or PlayStation VR games. It has sensors that detects inputs from the user and can be mapped to forward, backward, left, right, rotate, and up and down movement [5]. All these devices and papers helped us come up with ideas that we would use in the design of our controller, for instance the use of force sensors to detect input from the pressure of the user's feet.

III. Methods

Our workflow is fairly similar to a iterative design methodology you could find online, with continual evaluations and changes applied to our design and prototype. First we came up with an initial design idea through interviews and surveys with different people. Then we built a digital prototype in Fusion 360 and developed technical drawings for the design. With the digital prototype we started to evaluate it and decide that we couldn't physically make it since some parts of the design were off. So we analyzed the issues and ideated changes for our design (with some help from professor Alvaro), which resulted in a largely new design. When we evaluated the new design's feasibility we thought it was good and buildable so we built a prototype using wood. We began testing the physical prototype and noticed problems as well (such as the joystick attachment not working), so we ideated changes and applied them (such as getting rid of the joystick connection entirely) to the prototype until we were happy with an end result. A flowchart of this process can be seen in Appendix A.

IV. Results

A. Prototype Progression

In our first iteration of our prototype, we used an idea that we created based on feedback from initial sketches and interviews with different people. At first our device was going to used gyroscope to detect the user tilting the board and use that as input. The device would also feature a cushion at the bottom to make tilting easier.

However by Assignment 2, we decided to a 2 degrees of freedom sliding based system using a joystick instead of the gyroscope, because we thought that would be easier. We also removed the cushion and separated the top and bottom boards, since we weren't using the gyroscope tilting mechanism anymore.

Then just before Assignment 3, we talked to professor Alvaro about our design since we weren't sure about certain aspects of our controller such as how to accomplish joystick movement with our initial design since the original base was small. After conversing with him we reworked our idea into a "box within a box" idea. Where our controller would retain the sliding motion while having better support and utilize a 3D printed ball joint attachment to control a joystick at the base of the controller. For the assignment we stuck with this idea and made the controller shell out of wood and used wax paper to allow the board to slide, however we weren't able to integrate the electronics with the board due to time constraints.

Our final design saw us reducing the amount of force sensors from 6 to 2 due to shipping issues, unable to properly use the joystick due to 3D printing and wiring issues and adding LEDs to indicate power and button presses. A visual timeline and summary of our prototype progression can be seen in Appendix B, the technical drawings for the final prototype can be seen in Appendix C, and the electronics for the final design can be seen in Appendix D.

B. QFD and SUS results

For our QFD we surveyed several people and found that out of the five customer requirements they gave us they placed more importance on the re-centering feature, lower sliding friction and adjustable end-zones for different feet sizes. As for our customer competitive analysis, users thought that re-centering, a feature we were unable to implement due to scope but would be something we'd consider if we moved forward with the product and lower slide friction, which we achieved using wax paper, was most important to our device while appropriate device weight was more important for the 3D Rudder. The full QFD house of quality minus the technical competitive assessment can be seen in Appendix C.

For our technical competitive assessment we thought that our device had advantages in areas such as the amount of buttons as well as material friction, whereas the 3dRudder largely excelled at have a good rest state. The technical competitive assessment chart portion of the QFD can be seen in Appendix F.

We had 8 people fill out our SUS survey, all but one outlier had a score of 70 or above, with the average of all of the scores being 78.4375 indicating that people found our controller very usable overall, a breakdown of both the scores and what answers what questions got is in appendix G.

V. Takeaways

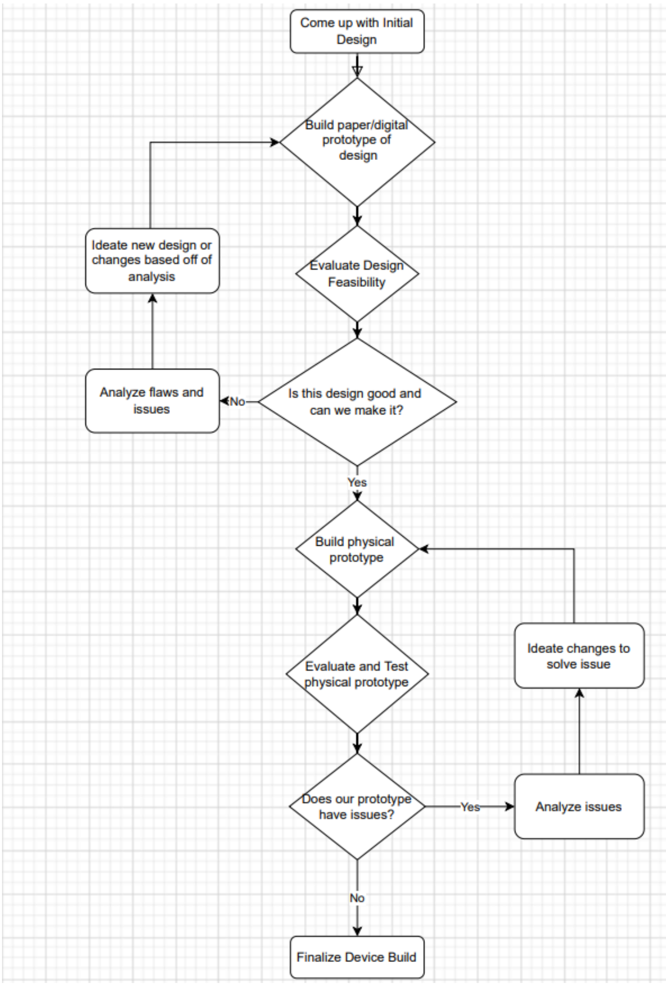
There were several key lessons we learned through developing this controller. First we learned that we shouldn't tunnel vision on initial ideas. We tried to stick with our original design with minimal changes for half of the time allotted to the project despite it having issues we couldn't address, such as our initial design having a small base that made us unsure of how to accomplish joystick movement, and a central region between the base and board that would not likely have been able to support the board's weight. If we were to do things differently we would be more open to new and different ideas, especially in the early phase of the project.

Another lesson we learned was that understanding physical sense of scale is important. Throughout our project we had a lot of problems with sizing, from the 3D printed joystick attachment being too small causing it to print incorrectly and thus be unusable, to the controller itself being too big to effectively transport. If we could do things differently we would likely try to get materials/placeholders earlier to help us understand and iterate on the physical size of our project.

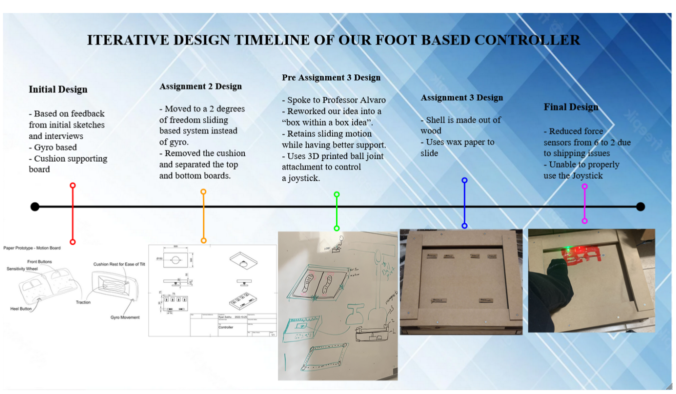
In general we found planning to be much easier than implementation, to make a functioning prototype was much more difficult than a non-functioning physical prototype, which was more difficult than making the models, which in turn was far more difficult than simple sketches of the ideas. Each stage of planning played an important role in coming to the final prototype, however the ease of planning made us wait too long to move on the next stage several times, ultimately not allowing us to identify several key issues until it was too late to find solutions. If we were to do things differently we would try to get through each stage more quickly and more fluidly step back and forth to better identify and address different issues at different stages.

The last lesson we learned was that iteration and being flexible is quite important. There were many hiccups in our project that forced us to adapt and change our design such as some wired connections being loose in the final prototype, and our early design being hard for us to visualize and build. If we could do things again we would be less afraid of and more proactive about changing parts of the design that are problematic or out of scope.

Appendix A
Process Flowchart

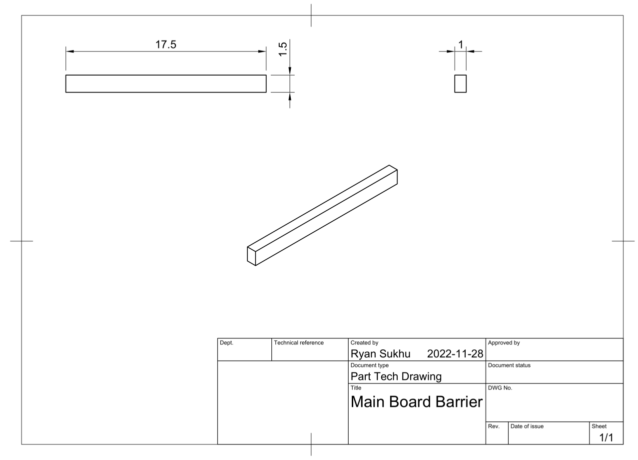


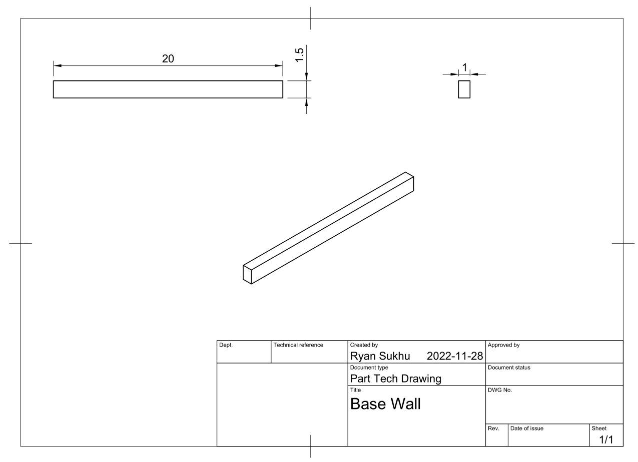
Appendix B
Iterative Design Timeline

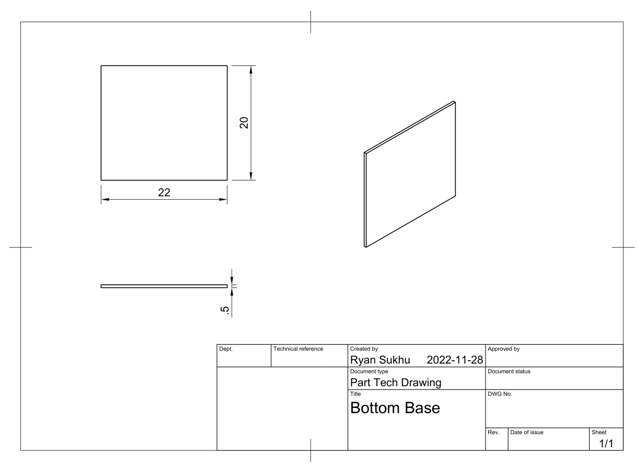


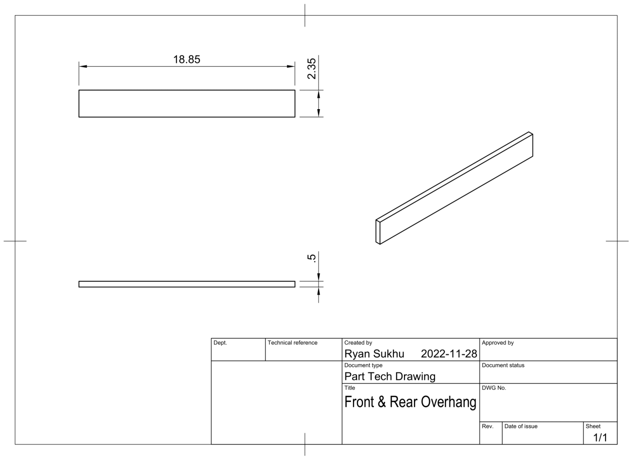
Appendix C
Technical Drawings

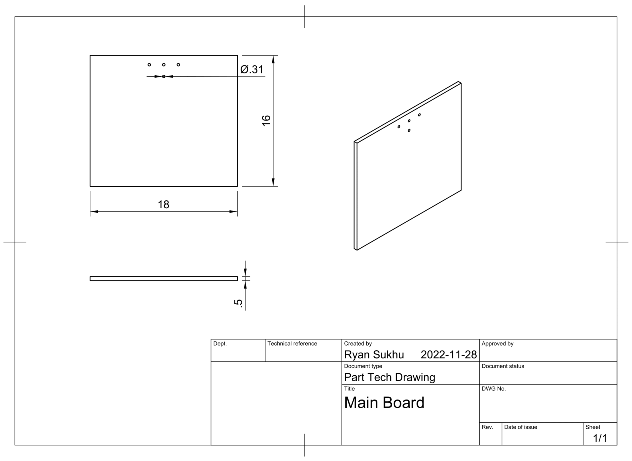
Individual Parts

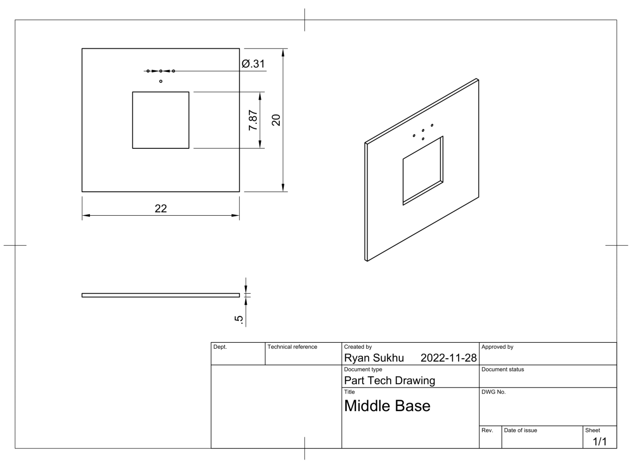


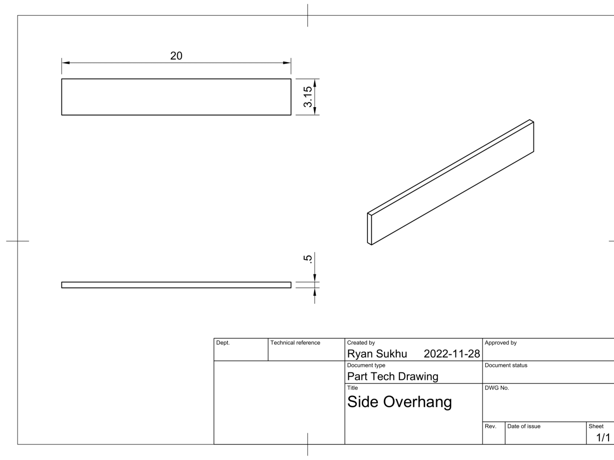




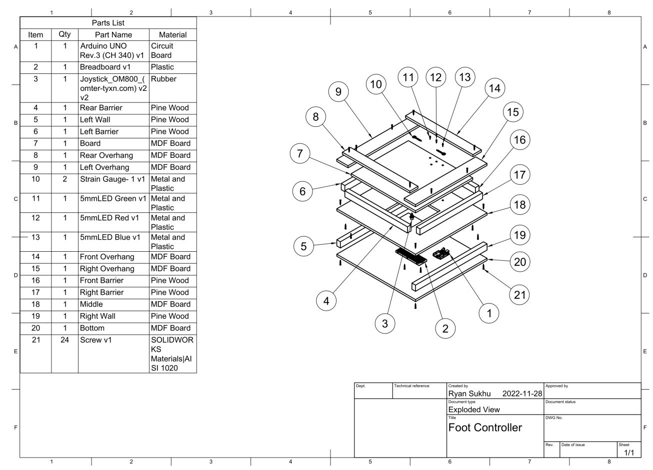




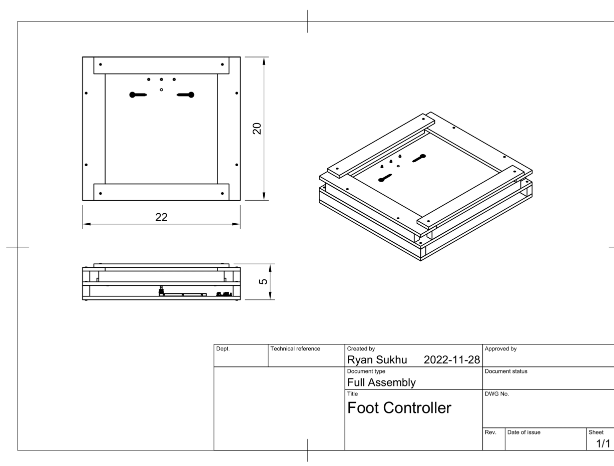




Assembly



Item	Qty	Part Name	Material
1	1	Arduino UNO Rev.3 (CH 340) v1	Circuit Board
2	1	Breadboard v1	Plastic
3	1	Joystick_OM800_(omter-tyxn.com) v2 v2	Rubber
4	1	Rear Barrier	Pine Wood
5	1	Left Wall	Pine Wood
6	1	Left Barrier	Pine Wood
7	1	Board	MDF Board
8	1	Rear Overhang	MDF Board
9	1	Left Overhang	MDF Board
10	2	Strain Gauge- 1 v1	Metal and Plastic
11	1	5mmLED Green v1	Metal and Plastic
12	1	5mmLED Red v1	Metal and Plastic
13	1	5mmLED Blue v1	Metal and Plastic
14	1	Front Overhang	MDF Board
15	1	Right Overhang	MDF Board
16	1	Front Barrier	Pine Wood
17	1	Right Barrier	Pine Wood
18	1	Middle	MDF Board
19	1	Right Wall	Pine Wood
20	1	Bottom	MDF Board
21	24	Screw v1	SOLIDWORKS Materials|AISI 1020



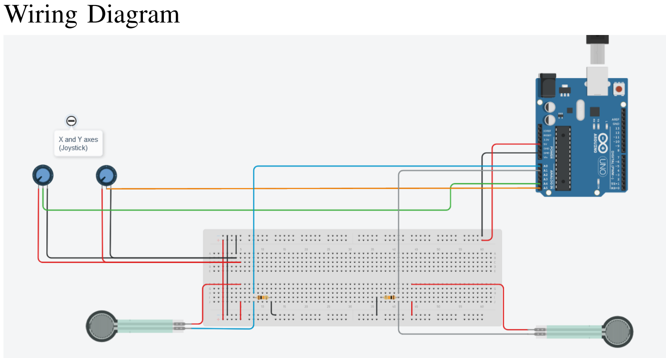
Exploded View Animation: https://youtu.be/h6TuenkW1JA

Bill Of Materials

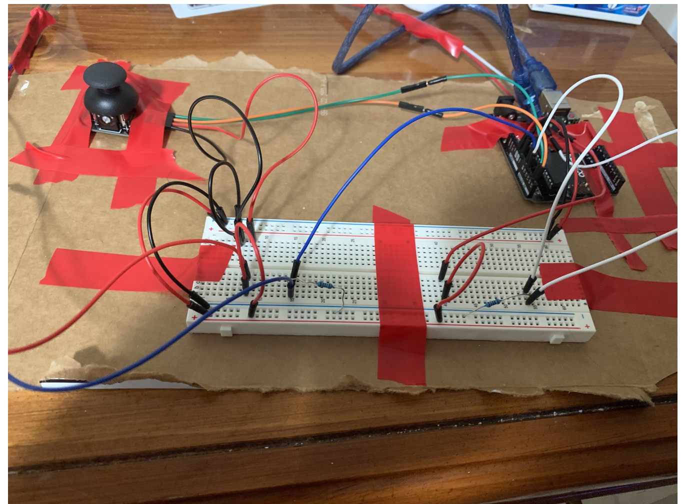
Item	Quantity	Component Name	Material
1	1	Arduino Uno R3	Circuit Board.
2	1	Breadboard	Plastic.
3	1	Joystick	Rubber.
4	1	Rear Barrier	Pine Wood.
5	1	Left Wall	Pine Wood.
6	1	Left Barrier	Pine Wood.
7	1	Board	MDF Board.
8	1	Rear Overhang	MDF Board.
9	1	Left Overhang	MDF Board.
10	2	Force Sensor	Metal and Plastic.
11	1	Green LED	Metal and Plastic.
12	1	Red LED	Metal and Plastic.
13	1	Blue LED	Metal and Plastic.
14	1	Front Overhang	MDF Board.
15	1	Right Overhang	MDF Board.
16	1	Front Barrier	Pine Wood.
17	1	Right Barrier	Pine Wood.
18	1	Middle Board	MDF Board.
19	1	Right Wall	Pine Wood.
20	1	Bottom Board	MDF Board.
21	24	Screw	Steel.

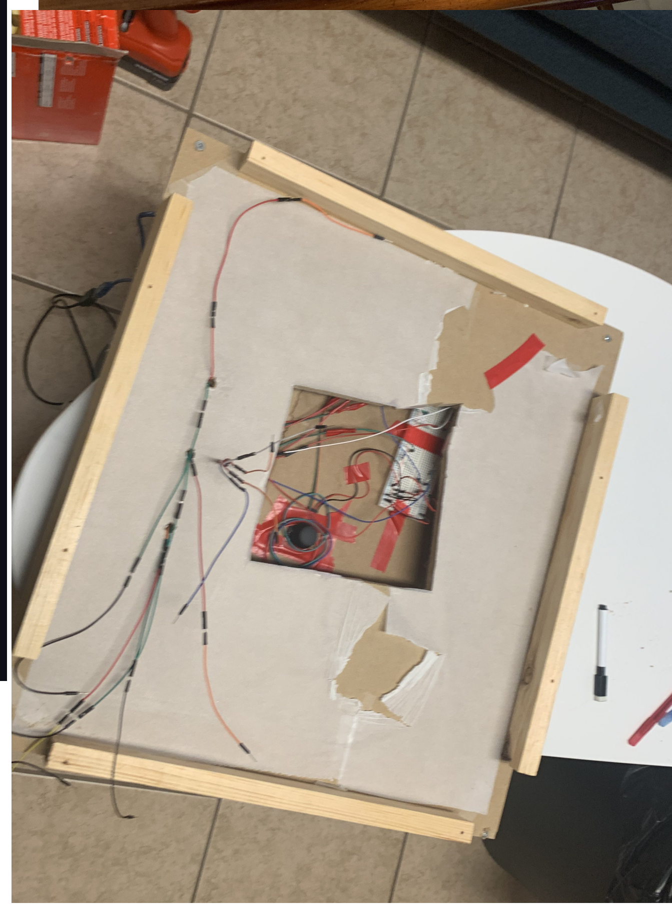
Appendix D
Electronics

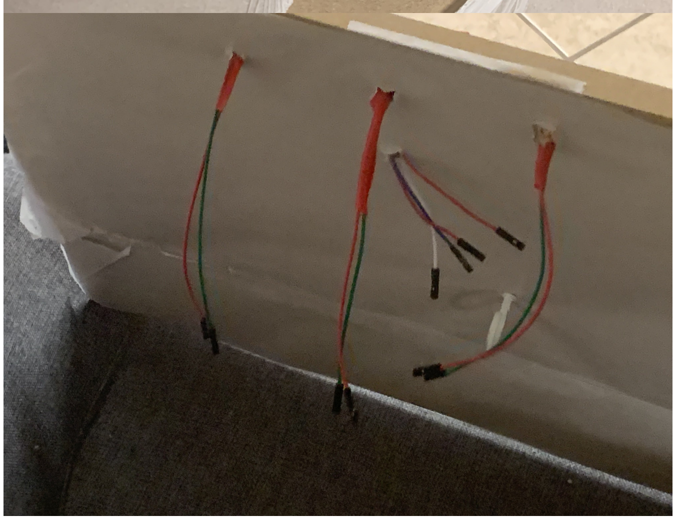
Wiring Diagram



Physical Wiring





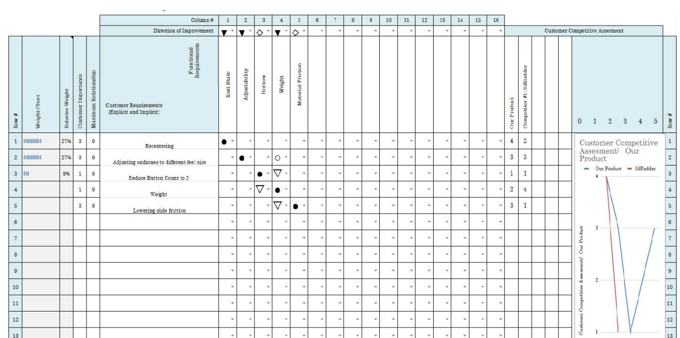


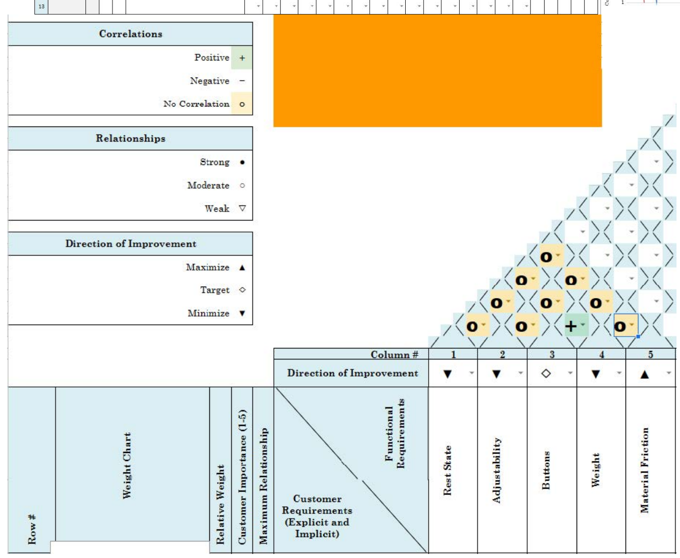
Bill Of Materials

Electronic Bill Of Materials

Quantity	Component Name	Description of Component
1	Arduino Uno R3	A microcontroller board that will be used to handle input and output.
1	Breadboard	Used as a hub to organize the wires, resistors, etc.
2	Force Sensor	Sensor that will be used to detect and respond to pressure, acting as a button.
2	10k Ohm Resistor	Used to apply resistance to the force sensors.
1	Red LED	Used to show that the controller has power by lighting up.
1	Green LED	Used to show that the left force sensor button is being pressed by lighting up.
1	Blue LED	Used to show that the right force sensor button is being pressed by lighting up.
3	330 Ohm Resistor	Used to apply resistance to the LEDs.
1	Joystick	We tried to use this for sliding board motion but were unable to implement it though it is still physically there
24	Wire chains	Used to connect various electronic components to the breadboard and Uno. (Based on number of physical chains not tinkercad)

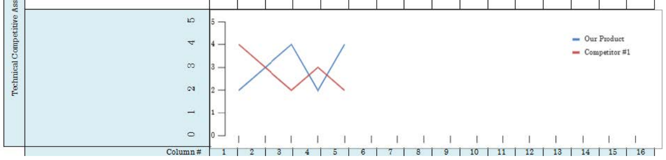
APPENDIX E
QFD HOUSE OF QUALITY





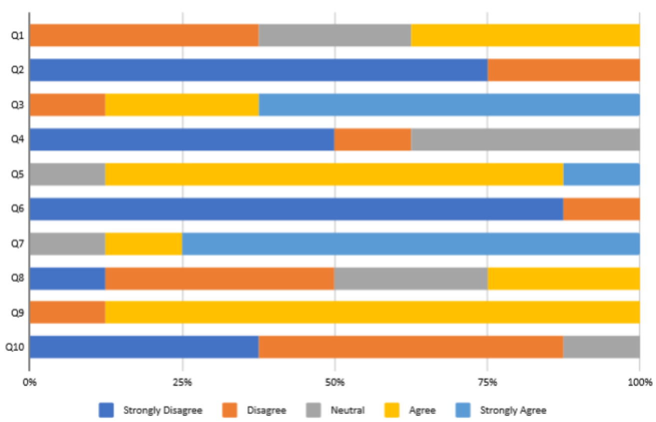
APPENDIX F
QFD TECHNICAL COMPETITIVE ASSESSMENT CHART

Target	Rest State	Adjustability	Buttons	Weight	Material Friction											
Max Relationship	9	9	3	3	9											
Technical Importance Rating	5.454545.45454.818181															
Relative Weight	43%	33%	14%	55%	61%											
Weight Chart																
Our Product	2	3	4	2	4											
Competitor #1: 3dRudder	4	3	2	3	2											
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16



APPENDIX G
SYSTEM USABILITY SCALE (SUS)

Paticipant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
	I think that I would like to use this system frequently	I found the system unnecessarily complex	I thought the system was easy to use	I think that I would need the support of a te	I found the	I thought t	I would im	I found the	I felt very c	I needed t	Score
1	3	2	4	3	4	1	5	4	4	2	70
2	4	1	5	1	4	1	5	1	4	2	90
3	2	1	5	1	4	1	5	2	4	1	85
4	4	1	5	1	4	1	5	3	4	2	85
5	3	1	4	2	4	1	5	2	4	1	82.5
6	4	1	5	1	5	1	5	2	4	1	92.5
7	2	2	5	3	4	2	4	3	4	2	70
8	2	1	2	3	3	1	3	4	2	3	52.5
q1	I think that I would like to use this system frequently										
q2	I found the system unnecessarily complex										
q3	I thought the system was easy to use										
q4	I think that I would need the support of a technical person to be able to use this system										
q5	I found the various functions in this system were well integrated										
q6	I thought there was too much inconsistency in this system										
q7	I would imagine that most people would learn to use this system very quickly										
q8	I found the system very cumbersome to use									average	78.4375
q9	I felt very confident using the system										
q10	I needed to learn a lot of things before I could get going with this system										



REFERENCES

[1] "Accessibility in gaming report." Scope, www.scope.org.uk/campaigns/research-policy/accessibility-in-gaming/About-our-research.

[2] M. LeBlanc, "Give Hope - Give a Hand - The LN-4 Prosthetic Hand," November 2008. [Online]. Available: https://web.stanford.edu/class/engr110/2011/LeBlanc-03a.pdf.

[3] J. Park and J. Kim, "Development of foot devices for virtual reality," 2018 18th International Conference on Control, Automation and Systems (ICCAS), 2018, pp. 1784-1787.

[4] C. Carmichael, M. V. Balderas, B. Ko, A. Nova, A. Tabafunda and A. Uribe-Quevedo, "Spring Stepper: A seated VR locomotion controller," 2020 22nd Symposium on Virtual and Augmented Reality (SVR), 2020, pp. 346-350, doi: 10.1109/SVR51698.2020.00058.

[5] Bonora, V., Chesnais, S., Leclercq, S., amp; Fromy, E. (2015). "U.S. Patent No. 20170185168". Washington, DC: U.S. Patent and Trademark Office.