The Creation of a Foot Controller for Immersion in Video Games

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***Abstract*—There is a lack of foot controllers. Whether for fun, for users who do not have arms, or for specific controllers designed for immersion, there has been an avoidance of the usage of feet. Giving users the opportunity to try using a part of their body they are not used to using for a specific action, or the opportunity to try a specific action using another body part due to not having the normal body part for it. This would allow the increase of users in the community as they will be able to have access to devices they were unable to access before. Unfortunately with how the prototype resulted, there's still a long way to go for this to become a reality.**

***Index Terms*—foot, feet, controller, immersion, accessibility, VR**

I. Introduction

The foot is the 2nd most dexterous part of the body, aside from the hands. There are therefore many things that feet can do that hands can do as well. Yet feet are often unexplored in the gaming industry. When they are, such as with foot pedals or VR treadmills, they are quite expensive and inaccessible to the general population. We aim to capitalize on this gap in the market by making a foot controller that is affordable and comfortable to use. Additionally, the usage of feet can increase immersion in many games that make use of feet in the game, such as sport simulators, running games, even racing games. We can feel immersion in games with hand controllers through things like haptic feedback and vibration, so that we feel like we are interacting with the game world (such as with guns, bows, etc), but no such thing exists for feet. Immersion is one of the reasons that people love to play games. Based on a U.S survey in gamer interest in immersive gaming in 2021, 53% and males and 44% of females are interested in playing immersive games [1]. Our controller will tap this market, with increasing immersion and allowing for new and interesting ways to play games. Our foot controller is used with two feet; one foot controlling inputs, and the other controller a gyroscope-accelerometer. The gyro is the main focus, and the user will be able to place their foot on it and move it around, with their actions reflected in the game world. In this report, we detail the process we went through in creating our foot controller. First with a literature review on our research, then a progression of our design up to the final prototype, details on each iteration, analysis of a QFD and SUS usability score, and the takeaways we got from this whole process.

II. Literature Review

A. A new interface using image-based foot tracking for motion sensing devices

With the start of using motion sensing input devices such as USB cameras and infrared sensors in controllers. The paper claims that most motion sensors rely on databases that have memorized poses that users must make while playing a game. Moreso, the paper claims that this technique works only when a specific part of the user's body stays within the sight of the infrared sensor. The point of the paper is to propose a new way of motion sensors by using and capturing 3-dimensional skeleton and information for feet. Testing feet allow them to see if would be clear for this new method for motion sensors would work with a skeletal model that would consist of two joints or more. So with the new method, they start with the pre-processing process, in that they detect the foot shape and form image sequences of it. This process focused on a shoe as the center line for the points. As most human foot has an external shape that is asymmetrical, and allow for the reduction of any asymmetry of foot motions. After the collection of data and extracting points between the center line and features that would be able to be used by users, such as ankles and tiptoes. They then determine the projective relationship to the ground through global and local coordination between the camera and the ground plane. After collecting the results, they were able to track free motion. With this new interfacing technique, motion sensors can track feet accurately. This paper concludes that this method would allow for the development of foot-operated video games as it will ease foot control. Even though we don't particularly use camera motion sensors for our controller, learning about how it can be done in others ways is beneficial and allows us to learn, for future developments.

B. A Serious Game for Post-Stroke Motor Rehabilitation

Strokes are the cause of balance loss, partial paralysis, and reduced movement on the side of the body. The paper claims that over the years that there have been many systems implemented and tested for motor rehabilitation, but video games were the most successful and attracted patients of all ages as a therapeutic tool. Since video games were the most successful therapeutic tool, there was an exploration of the concept of serious games for rehabilitation therapies. Since it's a game, the design process followed virtual reality, and the proposal focused on an objective, reaction time, and how it would relate

to motor functionality. The implementation resulted in patients starting an embodiment process as they were getting used to the virtual space. Then later on were able to get used to it, and adapted to perform. The evaluations of tests validated that rehabilitation can occur, as well as confirmed the expected validity of working. The paper proves that with enough interest and enough trial, our foot controller would be able to grow and inspire other foot-focused controllers. Furthermore, we can implement a controller that can help with motor functionality for the limbs.

C. MSI Liberator Foot Pedals

The MSI Liberator is a controller that resembles a drum pedal with three buttons on the pedal. Furthermore, it encloses around the foot to minimize the movement needed to hit the button. Supposedly the MSI Liberator is easy-to-use, and with an 8-degree angle, the MSI is ideal for an ergonomic build. Much with something new, there's a learning curve when using the MSI Liberator especially since it's meant to be used together when using other controllers. Comparing this product to our controller, the intentions are different as we are trying to get our controller to be used alone rather than with the default controllers. However, our controller took some inspiration from the MSI Liberator.

D. Wii Fit Board

The Wii-Foot board was basically a board that looked and worked as a scale. It had Bluetooth technology and contained four pressure sensors. It also was able to be used only on a hard surface. With just four pressure sensors, there was only so much that the controller could have done. Working mostly as a scale, the Wii Foot Board, was a foot in the right direction. Our controller used the Wii Foot Board as inspiration to be able to balance the controller.

III. Methods

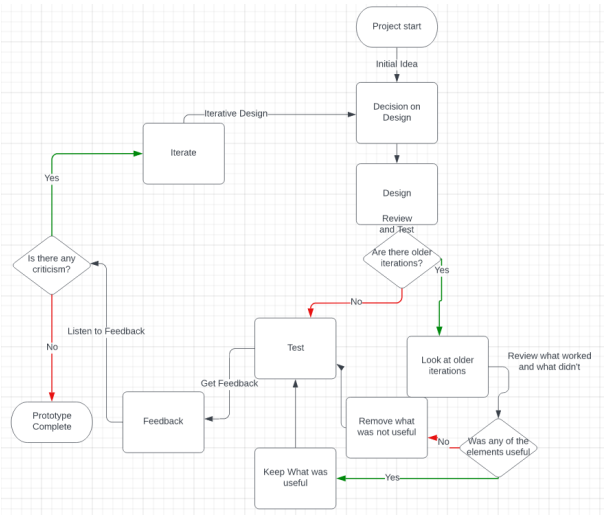

Fig. 1. Workflow and Iterative Design

IV. Results

The QFD shows that the most important functional requirement of our product is its structural integrity and resistance, while against competitors, our product excels in ease of use and functionality (fulfilling requirements of buttons, leds, and actuators). We believe that what requires the most improvement is comfort, as it is important and yet has one of the lowest scores. The SUS score we received is 73, which is a passing score. The responses showed again that our prototype is easy to use and not cumbersome, but some issues are that people were not confident using the system, and that many people did not actually see themselves using such a foot controller. Both the QFD and SUS are available in Appendix A.

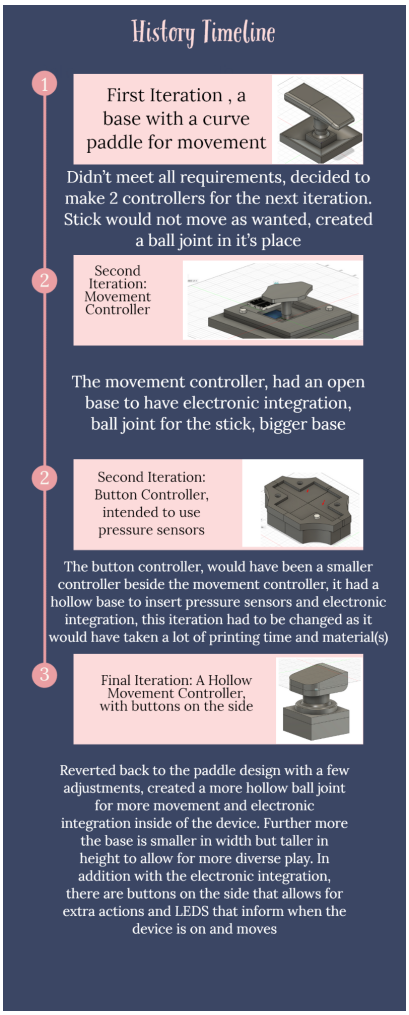

Fig. 2. Prototype Progression

V. Takeaways

Over the course of this process, we have come across many different issues while designing and putting together our prototype; as a result, we have come to the conclusion that there are a multitude of things that would have been done differently. Firstly, we thought that printing our prototype would take only 1-2 attempts, and that we could get it done

within around a week; however, we were sorely mistaken. Issues such as printing errors that caused pieces to merge together, design flaws, spacing issues, etc caused the printing process to take more time than we anticipated. Allocating more time for printing would help us with finding and fixing issues faster. Secondly, if we were to finalize the design of the controller earlier, in particular, deciding whether to do 1 controller or 2, it would provide more time to gather feedback which would allow us to iterate further on our design. Finally, gathering more feedback from both peers and the professor about our controller design would have helped with iterating on our design, allowing for changes to be made to the design that we may have missed when reviewing it internally. From our experience making this controller over the course of the semester, we have learned how important it is to receive feedback on a design, no matter how bad we may think it is, in-order to receive feedback as soon as possible to begin the iteration process. This is because after the iteration process begins, we are able to make adjustments to the design and catch potential issues earlier.

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APPENDIX

Results
QFD:
SUS:
Technical Drawings and Bill of Materials

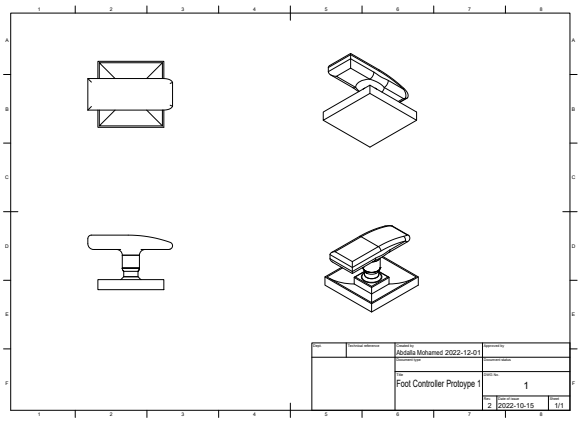


Fig. 3. Foot Controller Prototype 1 Technical Drawing

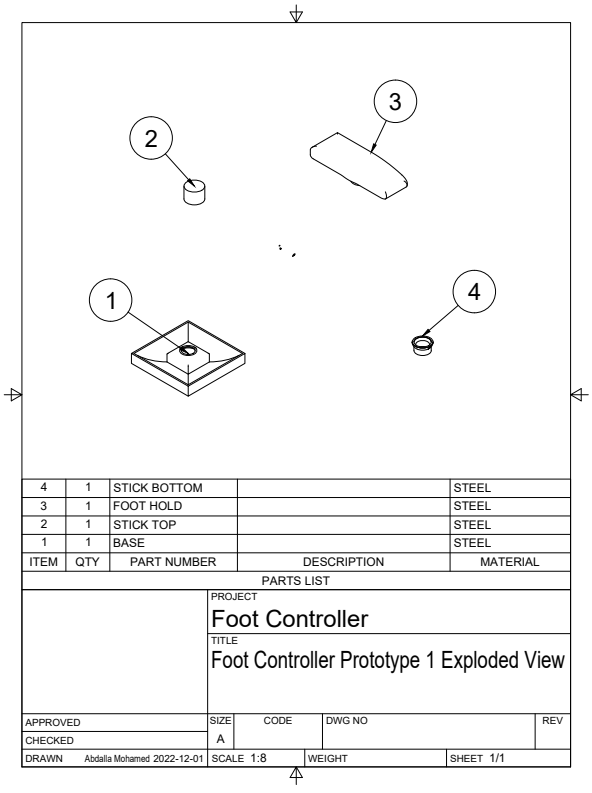


Fig. 4. Foot Controller Prototype 1 Exploded View

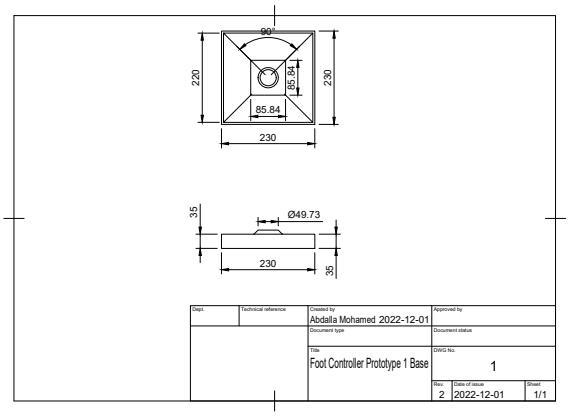


Fig. 5. Foot Controller Prototype 1 Base Technical Drawing

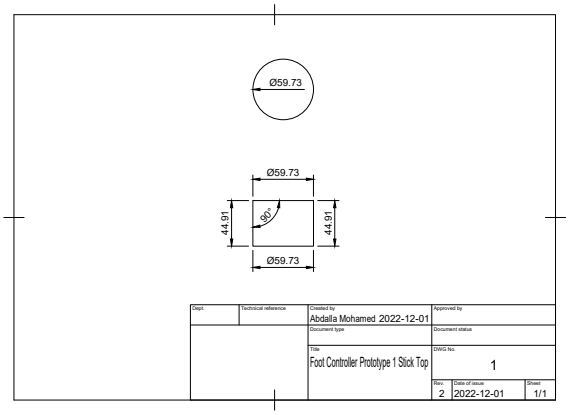


Fig. 6. Foot Controller Prototype 1 Top Stick Technical Drawing

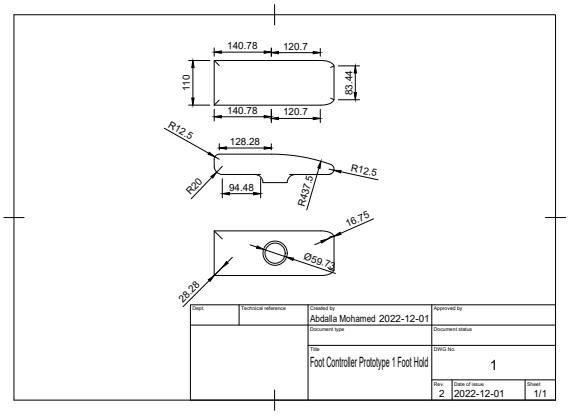


Fig. 7. Foot Controller Prototype 1 Foot Hold Technical Drawing

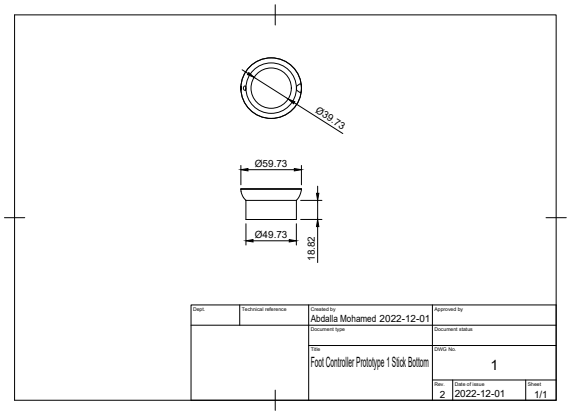


Fig. 8. Foot Controller Prototype 1 Bottom Stick Technical Drawing

	Parts List			
Item	Qty	Part Number	Description	Material
1	1	Base	The base of the controller	PLA
2	1	Stick Top	The top side of the stick would allow for movement for the foot hold	PLA
3	1	Foot Hold	Where the foot would be placed on, so the controller moves around	PLA
4	1	Stick Bottom	The bottom side of the stick would connect to the base so it can handle the weight of a foot	PLA

Fig. 9. Foot Controller Prototype 1 Bill of Materials

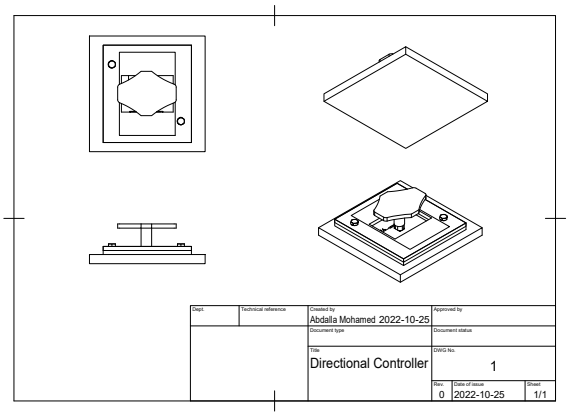


Fig. 10. Directional Controller Technical Drawing and BOM

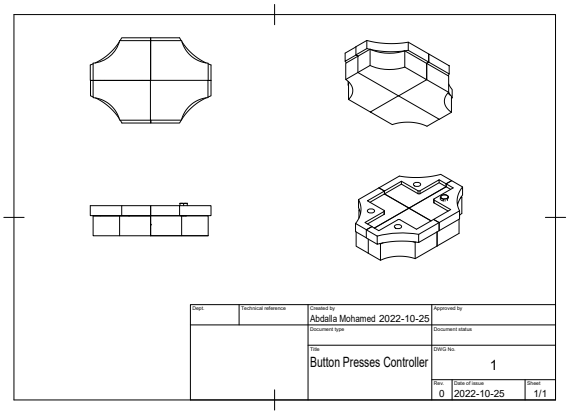


Fig. 11. Button Presses Controller Technical Drawing and BOM

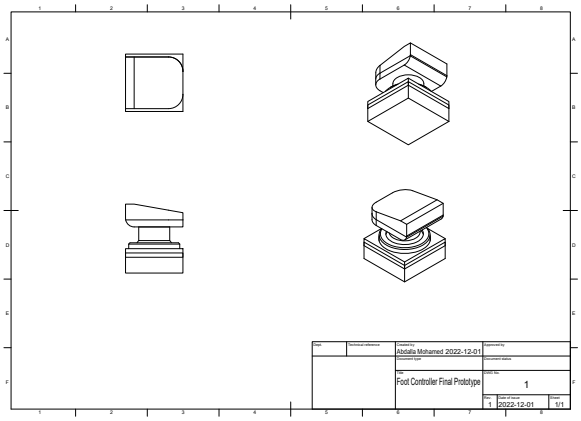
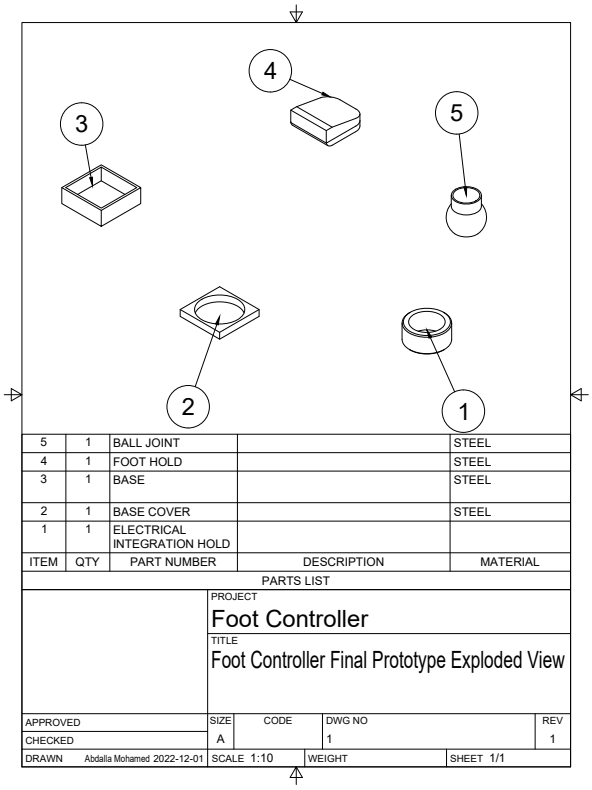


Fig. 12. Foot Controller Final Prototype Technical Drawing



ITEM	QTY	PART NUMBER	DESCRIPTION	MATERIAL
5	1	BALL JOINT		STEEL
4	1	FOOT HOLD		STEEL
3	1	BASE		STEEL
2	1	BASE COVER		STEEL
1	1	ELECTRICAL INTEGRATION HOLD		

PARTS LIST

PROJECT: Foot Controller

TITLE: Foot Controller Final Prototype Exploded View

APPROVED	SIZE	CODE	DWG NO	REV
CHECKED	A		1	1
DRAWN Abdalla Mohamed 2022-12-01	SCALE 1:10	WEIGHT	SHEET 1/1	

Fig. 13. Foot Controller Final Prototype Exploded View

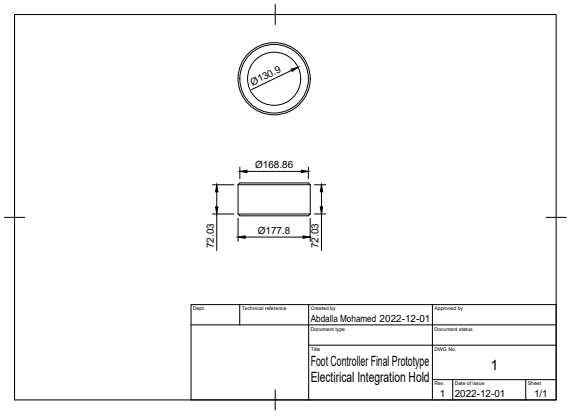


Fig. 14. Foot Controller Final Prototype Elecrtical Integration Hold Technical Drawing

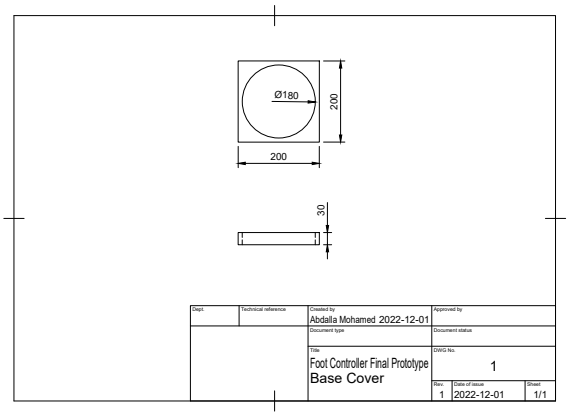


Fig. 15. Foot Controller Final Prototype Base Cover Technical Drawing

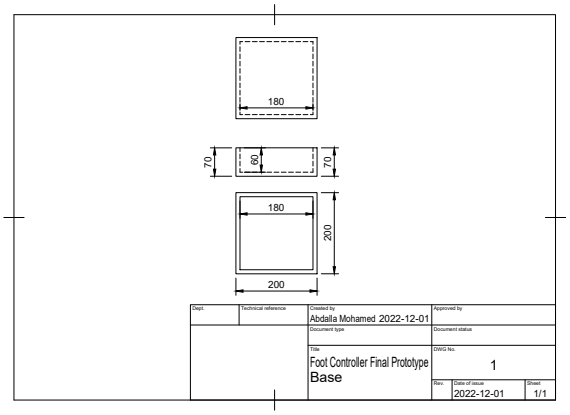


Fig. 16. Foot Controller Final Prototype Base Technical Drawing

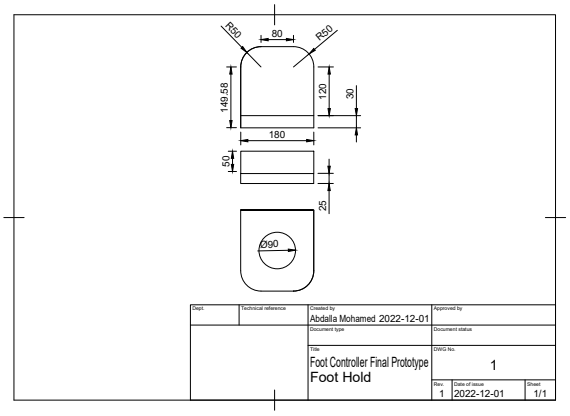


Fig. 17. Foot Controller Final Prototype Foot Hold Technical Drawing

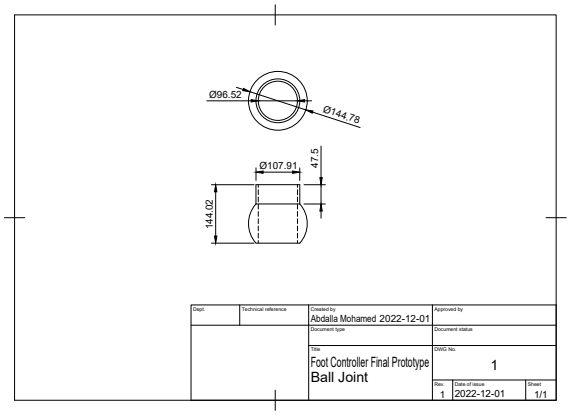


Fig. 18. Foot Controller Final Prototype Ball Joint Technical Drawing

	Parts List			
Item	Qty	Part Number	Description	Material
1	1	Electrical Integration Hold	A space inside the controller to add electronics and integrate the circuits	PLA
2	1	Base Cover	Covers the base, and protects the base and electronics	PLA
3	1	Base	The base of the controller	PLA
4	1	Foot Hold	Where the foot would be placed on, so the controller moves around	PLA
5	1	Ball Joint	This allows for smooth movement from the foot hold	PLA

Fig. 19. Foot Controller Final Prototype Bill of Materials

Electrical Schematics

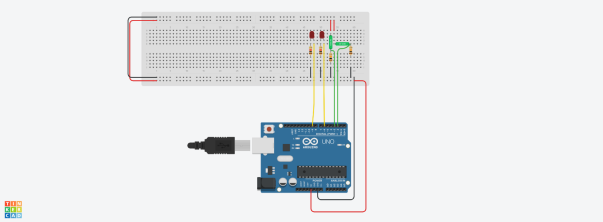


Fig. 20. MPU6050 gyro part simulation schematic

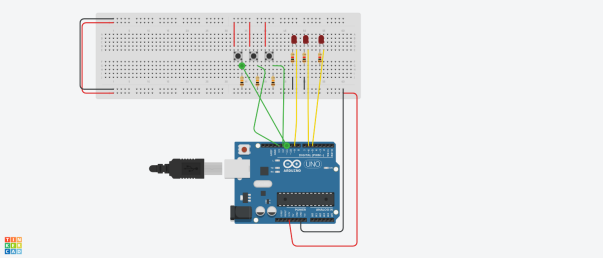


Fig. 21. Buttons and LEDs