TEMPLE UNIVERSITY

AD PRIMA CHARTER SCHOOL

Prosthetic Arm Team

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Team Members (from left to right):

Carmen Jenkins, Himma Aklilu, Shabrea' King, Naomi Brooks

Abstract

Our project is to produce a programmable, fully functioning prosthetic arm able to complete specific tasks that demonstrates its strength and adaptability at both a small mass and low cost. We have used the Engineering Design Process - from identifying the problem, researching the problem and possible solutions, to designing and testing prototypes, to redesigning and reevaluating products. The main objective is to work with an amputee that has a below the elbow (transradial) amputation and ensure they can do everyday tasks by using our prosthetic model.

Our motivation is to help advance prosthetics to make them more affordable and accessible to people who cannot afford them. We utilized a 3D printed material claw from Thingverse.com - based on the Vex claw -at a cost of only a few cents per gram. Throughout the project, we overcame various obstacles, made many design changes, and created unique features to address the design challenges.

Our arm is limited by the Vex servo which is slow but makes for a strong claw. We have to perfect our techniques to compensate for the lack of speed. Cutting the Triplewall pipe and poking holes in it was also necessary to decrease mass.All in all, the product of our prosthetic arm cost $23.46.

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Introduction

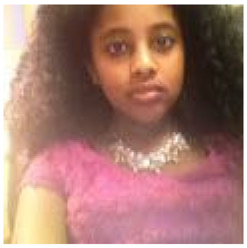
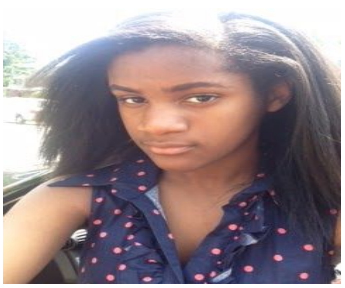
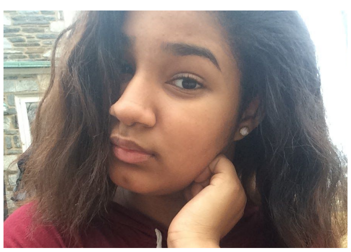
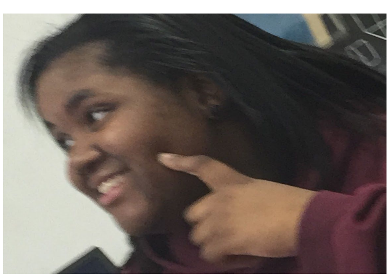
Purpose

Our team's mission is to engineer an efficient, yet low-cost prosthetic arm within a $80 budget. To make the arm as effective as possible, we based our design and trials from the perspective of a hypothetical transradial amputee, which we call Jill. Jill would love to continue to participate in her usual daily activities, such as playing tennis, texting, and tying her shoes, which require high levels of speed, accuracy, and dexterity. To test these, and other features, we ran our prosthetic arm through a series of tests, including distance accuracy and object relocation. We built multiple prototypes of our prosthetic and compared its overall mass with its test performance to ensure optimal efficiency. The idea is to give Jill a prosthetic arm that meets her needs, without being too heavy or bulky to be a nuisance to her. To ensure this arm compensated for Jill's other needs, we decided to undertake further research to acquire a thorough understanding of the human arm's anatomy and physiology.

Background

To certify that we had a strong basis for what we were making, we used BioDigital Human to understand the basic functions of the human arm. Then, we began considering the needs of our hypothetical amputee. By doing this we were able to make a real world connection with what we were building, thus improving our design. We also researched how professionals were building and employing 3D printed prosthetic arms. Initiatives like Project Daniel, which 3D prints prosthetic arms for Sudanese refugees who lost their arm due to civil war, illuminated how relevant prosthesis are. Additionally we observed how this arm could be used for Jill and many other amputees in this predicament. Finally, we investigated a plethora of existing prosthetic arm designs, including “Lego Arm”, “e-NABLE”, and designs from previous MESA competitions.

Team Member Profiles:

Himma Aklilu Captain 	Himma is responsible for programming and wiring the arm. She also has been a key leader throughout the engineer and design process.
 Naomi Brooks Designer	Naomi played a pivotal role in designing the arm, made a finished tinkercad model for the prosthetic and helped develop techniques to use with the arm.
 Carmen Jenkins Lead for Engineering Design Notebook	Carmen maintained the creation and finalization of the Engineering Design Notebook. She also aided in the initial prototype construction.
 Shabrea’ King Supporting Technician	Shabrea’ has effectively planned meeting schedules, led brainstorming design & solution sessions.

Discussion

Design Process

For 2016 Regionals we initially used a 3D printed design of a Vex Third Prototype claw and started working on this 4th prototype. Our biggest issue was that this design would not function adequately when the parts were 3D printed. The material for some of the parts required, for structural purposes, that some of the pieces be metal and not plastic. Furthermore, there were 42 individual parts to be assembled, and some of the parts did not fit properly from our analysis. The most unique feature of this particular arm was the ability to adjust its flexible drainpipe for the team's various arm lengths.

Final Design

Our final design is based off of an existing VEX Robotics claw kit. We discovered the kit this website: http://www.vexrobotics.com/276-2212.html. We found it was an improvement over our 3rd prototype, especially because the parts for it required materials we could attain. We are able to mount a servo to our 3D printed claw, and reinforce it with VEX's metal brackets and screws, all while still remaining under budget.

Attending the MESA 2017 Build Day, three weeks before regionals, provided the time and resources required to complete the arm. We were able to reduce the length of wiring, re-solder and test the arduino pro trinket. Unfortunately we did not have ample time to practice our technique but have done so during lunch. Being that it is our second year, understanding the rules has definitely enhanced our preparation.

Self Assessment

To make sure that our final design was complete, we reviewed the team's goal, criteria, and constraints of our prosthetic arm. Our goal to build a functioning transradial prosthetic arm that cost under $80. The prosthetic had to be light but strong at the same time. We used a Triple Wall pipe as the surface arm of the prosthetic. The purpose of using a prosthetic arm is to replace the loss of an original limb. This means that our prosthetic must be able to grip and grasp objects that a real hand would be able to do so. To strengthen grasping ability, we added velcro straps. The problem with our prosthetic resides with the fact that the arm was too heavy for the competition. To resolve the issue we drilled holes in the Triplewall pipe and cut it in half. Now team members are not forced to use upside down.

<u>Comparing our Design to the Human Arm</u>

The motor also acts like the muscles in the hand, it helps the claw move. The Triple Wall pipe that surrounds the arm acts like the arm of the human hand. Our prosthetic, as instructed, can open and close like a real functioning hand. The claw specifically acts like the hand due to it's grip that allows it to pick up objects.

Hardware Integration

Having an experienced programmer on the team allowed us to choose among different chips for automating our claw. The Sparkfun Redboard proved to be durable despite our trials in learning to solder. We also considered the arduino uno that has the same basic functionality. The best selection due to a much smaller size, half the price, and all the capability was the Adafruit Pro Trinket.

Programming the Arm

Our team utilized Arduino’s programming language to code a SparkFun RedBoard, and used add-ons from the Sparkfun kit. To make our prosthetic work we programed a button to make its hand or claw open and close. Before we learned how to program our prosthetic arm to open and close, we had to start with the basics.We started by turning a LED on and off by pushing a button. Once we perfected that,we applied our knowledge to program a servo motor.

Later, in an effort to lower costs & mass of the arm, we switched from the RedBoard to the Adafruit Trinket Pro 5V. It is much smaller than our original board, but still has all the functionality. The Trinket, however, did require additional libraries in order to run. The great thing about it was that it was so small,that it could sit on the wrist of our prototype and add no noticeable weight!

Testing Procedures

The difficulties in constructing the arm directed our research strategies,such as attempting various prototypes which presented different challenges. Each changed the brainstormed design. Completing the arm in order to make the PA MESA Tournament was our most important objective. As a result, we competed with a prototype but had very little data.

STEM Concepts and Analysis

<u>Comparing our Design to the Human Arm</u>

Using Biodigital Human and small models of the fingers, we discovered that the thumb and index finger do most of the gripping and grasping by the hand. The three remaining fingers act as force multipliers. We decide to focus on grabbing objects, so only two fingers are needed.

The metal braces of the flex claw acts like the wrist its function is to connect the hand to the drainpipe.The motor also acts like the nerves in the hand, it helps the fingers and also the hand move. The Triplewall pipe that surrounds the arm acts like an arm of the human hand. Our prosthetic, as instructed, can open and close like that of a real, functioning hand. The claw specifically acts like the hand due to it's grip that allows it to pick up objects. All in all our prosthetic arm illustrates the arm of a human.

Results

Object Relocation Tasks

	Trial Time (sec)	# of Objects Dropped or Broken	# of Objects in Finishing Area
Himma	41	0	5
Shabreá	39	0	5
Naomi	60	0	5
Carmen	45	0	4

Distance Accuracy Tests
Performed by Shabrea'

Trial 1:	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
# of bean bags	0	1	0	2	1
Trial Time (60.00sec)					60.00

Performed by Carmen

Trial 2:	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
# of bean bags	2	1	0	3	1
Trial Time (47.00sec)					47.00

Data Analysis

The arm had random pauses in between the task or even during one. That made for unpredictable performances for both object relocation and distance accuracy. For this malfunction the team had disappointing scores that could have been improved with more precise techniques. Troubleshooting helped us discover that the 9V battery pumped too much juice into the servo despite what was in the specs on the Vex website. Switching back to 4 AA batteries and improving our technique has led to a consistently better performances as shown in the tables.

Conclusion

Since we have a proven design and strict time constraints, our focus has been on small changes to improve functionality of the arm. Enhancements include reducing the amount of wiring, re-soldering and testing the chip, punching more holes in the Triplewall pipe, and practicing our techniques. This has also meant maintaining open lines of communication and working lunches.

Materials Budget

Name	Price	Quantity	Total	
Adafruit Trinket	$ 8.54	1	$ 8.54	Amazon
Vex Claw Kit Screws	$ 0.50	11	$ 2.50	sales@vexrobotics.com 1 903 453 0802
Vex Claw Plastic Washers	$ 0.50	4	$ 2.00	sales@vexrobotics.com 1 903 453 0802
Vex Claw Kit 2"Long Square Bar	$ 0.50	1	$ 0.50	sales@vexrobotics.com Amazon 1 903 453 0802
Vex Claw Kit Metal Components	$ 0.50	2	$ 1.00	sales@vexrobotics.com Amazon 1 903 453 0802

1.75 ABS Filament Smart Reel (3D Printed Claw Parts)(size nine faunt)	$ 0.17	3 meters	$ 0.51	Prosthetic Arm Challenge 2.0 CA Addendum
2 hole Triplewall pipe (4” x 10’)	$ 9.98	1	$ 0.38	HomeDepot
Resistors	$ 0.25	2	$ 0.50	Sparkfun
Battery Holder	$ 2.49	1	$ 2.49	Sparkfun
4 AA Batteries	$ 1.00	1	$ 1.00	DollarTree
Wires	$ 0.07	8	$ 0.56	Sparkfun
Mob Skateboard GripTape	$1.00 per 240 sq in	4.5 sq in	$ 0.01	Amazon
Delta rectangular foam (low density)	$ 0.14	1	$ 0.14	HomeDepot
Side Release Buckle Straps	$28.00 for 15-50	2	$3.33	StrapWorks.com
Final Total			$23.46	

Recommendations

Prepping for the regionals has been very nerve-racking, but it also was very exciting. It was challenging to conjure up new ideas. To make a lighter prosthetic, we replaced the drainpipe with half of a Triple Wall pipe from the previous year. To secure our arms to the prosthetic straps were used. Going forward, it would be a good idea to produce a lightweight but secure housing for the Adafruit trinket. This would prevent damage as well as ensure its proper functioning while yielding a full range of motion and maximize grip at the highest speed available for our servo.

Recommendations for the arm itself?

Although the arm is innovative, it is not aesthetically pleasing. Using biodigital we were able to get the basics to what our hypothetical client Jill would need in an arm to use on a day to day basis. The team seemed to overlook the aesthetic qualities and hence developed a prosthetic that most probably would not be worn by Jill. Perhaps we could interview someone with a prosthetic to gain insight on what can be done to make a person wearing our prosthetic less noticeable.

Acknowledgements

The team thanks Mr.Snell, our coach, for getting us into this. We are very proud of our work! Hopefully the judges will be also.

We would like to thank our parents for their support and contribution towards the team’s goal.

Thank you Dr.Jamie Bracey, Al Thielben, Spencer Thomas, Gina Bloise, David A. Buckholtz, and Myisha of the Mesa Program at Temple University College of Engineering and it’s I.T. team.

The team would also like to thank Billy G. and Jessica Bowen of Home Depot for donating much of the team's supplies.

Thank you Mr.Gifford of ,Ad Prima Charter School, and the maintenance staff for allowing us to use for their power tools.

We would also thank the past robotics team of G.W Carver H.S of Engineering and Science for their advice and encouragement.

The team would like to thank the adorable third grader, Sistina Whittingham, for her help in making the prosthetic arm much lighter. She drilled four holes in the prosthetic with the guidance from the team.

We would like to give a big thanks to Roberra Aklilu (Himma’s brother) for taking the time to edit the technical paper and assisting with arduino programming.

The team is really grateful for breakfast before school from Mrs. Brooks and after school snacks.

Bibliography

https://www.youtube.com/watch?v=SDYFMgrjeLg&nohtml5=False Identifying the Need, Real World Connection.

https://www.youtube.com/watch?v=qybUFnY7Y8w - Gave the team useful information on Rube Goldberg machines and it allowed us to better understand the engineering design process.

https://www.youtube.com/watch?v=fxJWin195kU&nohtml5=False Exploring Design Process

http://www.vanderbilt.edu/exploration/pdf/index.php?action=view_story_pdf&story_id=314 Researching Arm Design

http://www.thingiverse.com/thing:1275967/#files Researching the design and printing the Vex Claw, that is incorporated on the prosthetic arm.

https://www.tinkercad.com/ Designing Prototypes.

https://www.youtube.com/watch?v=Yvev6shNvSg - 2 Liter Bottle Prosthetic Arm first Prototype.

https://learn.sparkfun.com/tutorials/redboard-vs-uno Source for Sparkfun Redboard.

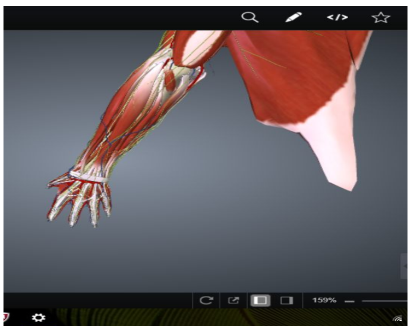
https://human.biodigital.com/index.html- Anatomy of the Forearm.

Lego Mindstorms EV3 Education 45544_ robot arm.pdf- Source for second prototype.

https://docs.google.com/presentation/d/1ID_h9aIfDFcbWawxWJ-nY7YpEISW90qZldhTMt1d8ec/edit#slide=id.g1113077263_0_217 - The presentation board helped us organize our ideas for the technical paper and the poster.

Appendix

Below are pictures of resources we used during research to compare a human arm and the vision of our prosthetic arm.



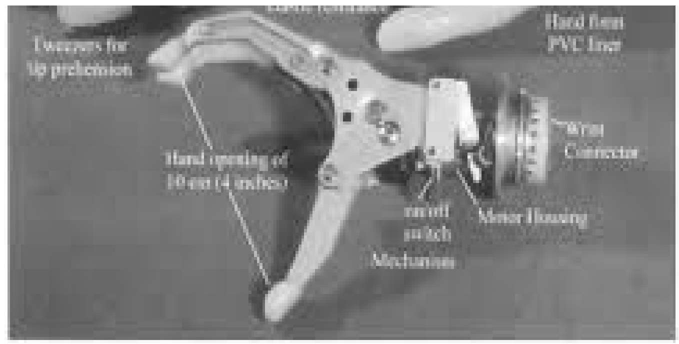


Fig1: Anatomy of Lower Arm **Fig2: 3 pronged claw**

Our Initial Design

Fig3: 2 Liter Water Bottles

Second Prototype

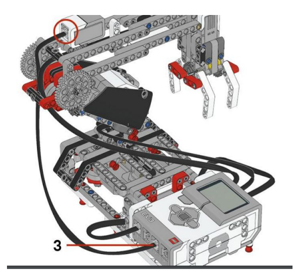
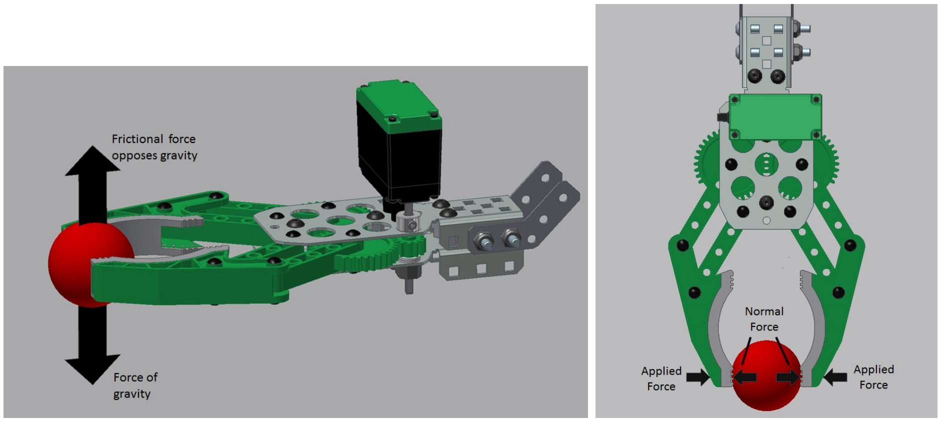


Fig4: Lego Robot Arm Investigation of Claw Mechanics

Fig5:Third Prototype with Vex Claw



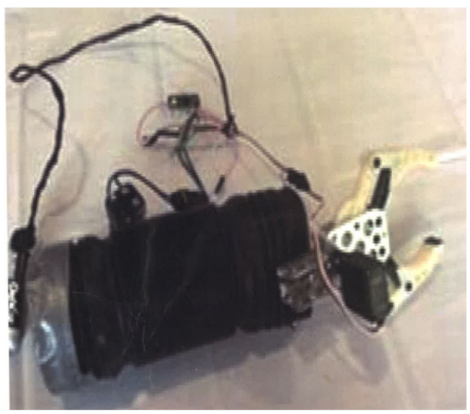
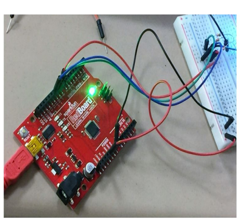


Fig 6: Arm at PA MESA Tournament 2016

Final Design



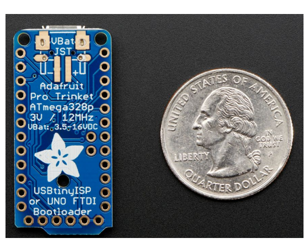


Fig8: Size of AdaFruit Trinket

Fig7: Programming Sparkfun Redboard

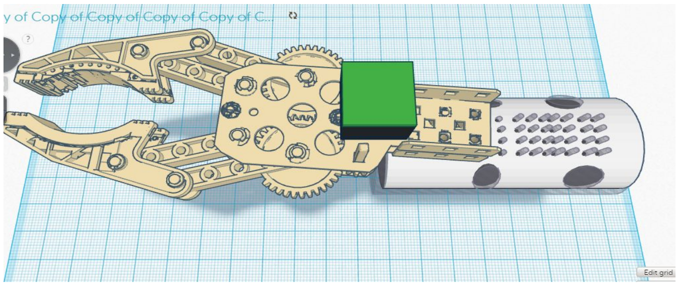


Fig9: This is the side view of our design,it was made on tinkercad.

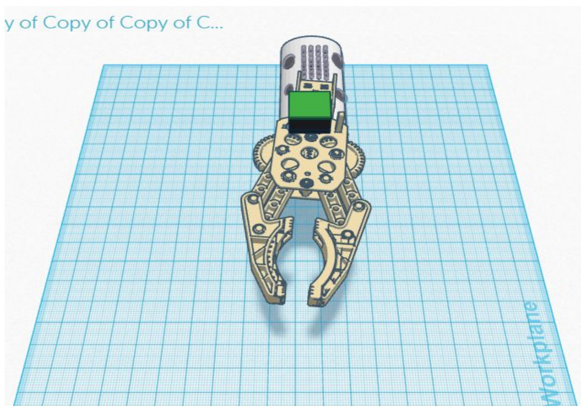


Fig 10: This is the top view of the prosthetic arm design

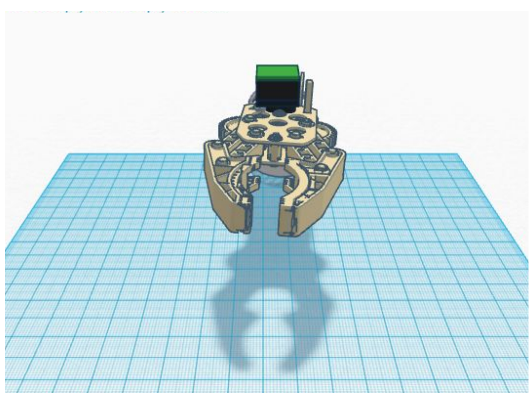


Fig11:Front View

Wiring Diagram: Momentary Button Activated Using an AdaFruit Trinket Pro 5V

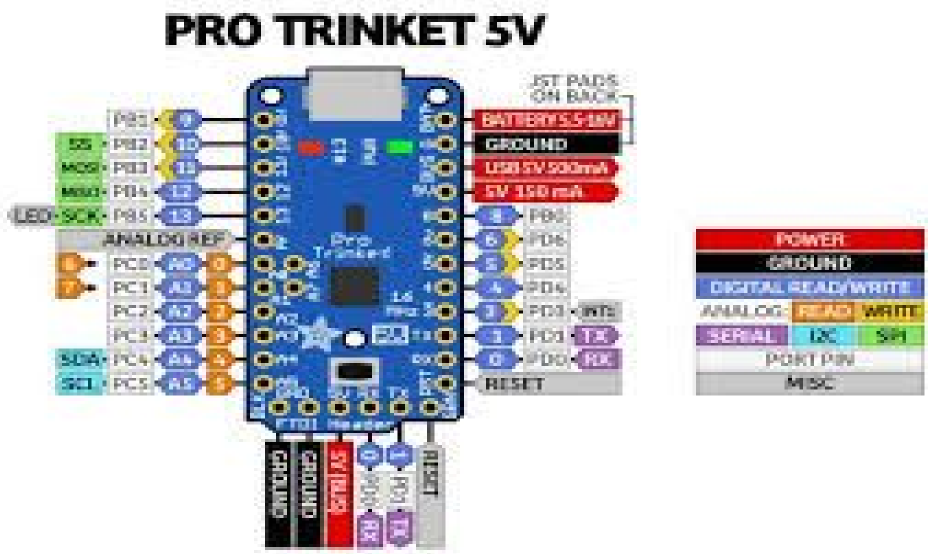


Fig12: Layout of Pro Trinket 5V

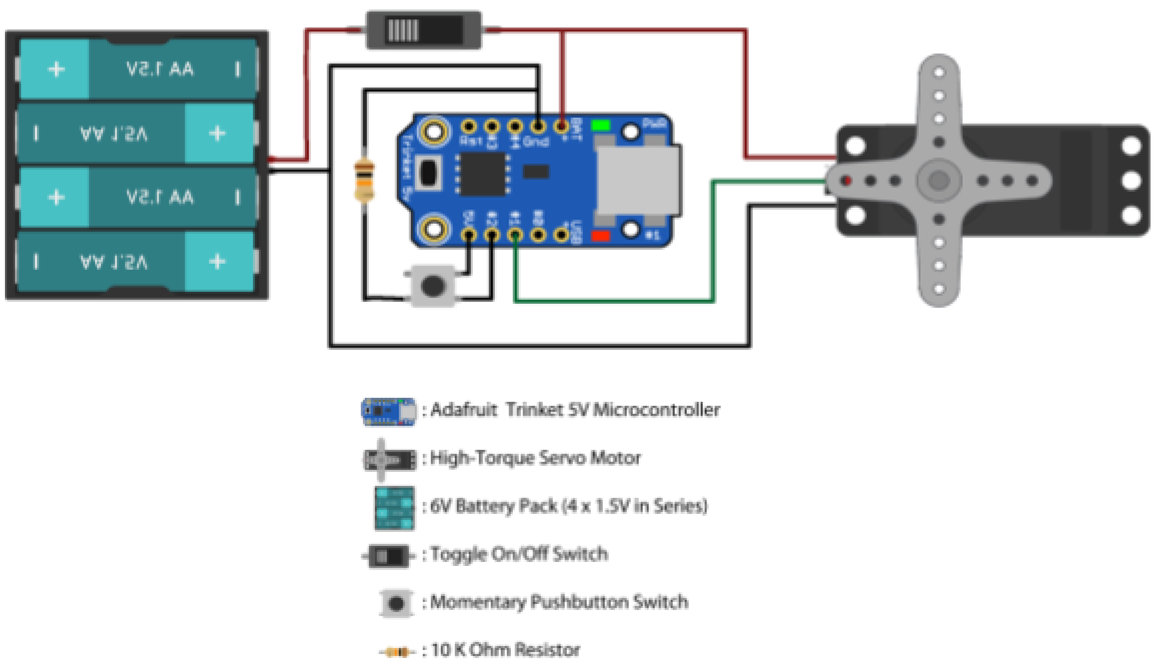


Fig 13: Wiring Diagram

Fig 14:<u>Programming the Arm with Adafruit Pro Trinket & Wiring Setup</u>

Servo control line (orange) on Trinket Pin #0

```
Servo myServo1;

const int buttonPin = 6;     // variable to store the number of the pushbutton pin
int buttonState = 0;         // variable for reading the pushbutton status

void setup() {
pinMode(buttonPin, INPUT);    // initialize the pushbutton pin as an input:
digitalWrite(6, LOW);         // enable pullups to make pin high
myServo1.attach(SERVO1PIN);
}
void loop()  {
buttonState = digitalRead(buttonPin);
if (buttonState == HIGH) {
myServo1.write(170);             // tell servo to go to position in variable 'pos'
}
```