Design Project 4 – Power in Community:

The Grabber Pro Max

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial T10

Team Fri-08

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Submitted: April 10, 2024

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The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Fahd Zada 400516007

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Keerath Singh 400506284

Keerath Singh

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Jacob Rodrigues 400529286

Jacob Rodrigues

_
(Student Signature) *

Executive Summary

Project 4 involves the integration of extensive levels of computing and modeling applications to challenge the engineers to work together to create a cohesive device design for the client, Tiffany. Tiffany experiences mobility challenges due to her medical condition, Spina Bifida, and struggles to perform various day-to-day tasks in an accessible manner. Specifically, she faces difficulty carrying various objects as well as reaching them from long distances. Thus, the group decided to pursue the innovative idea of creating an automated grabbing device "The Grabber Pro Max", for Tiffany to help her overcome this obstacle. Implementing this automatic grabber device for Tiffany, would allow her to have easier accessibility and better convenience as the device makes it easy to grab onto objects while being portable.

The Grabber Pro Max's design uses a complex interior electronic system that fits inside the handle, rod, and claw. Specifically, it includes an Arduino Nano attached to a servo in a claw that is operated by a push button built into the handle, which activates the claw's movement. This offers greater protection to the electronics as the wires and circuitry system are enclosed, ensuring a long lifespan of the grabber. Moreover, it offers a portable feature with a foldable mechanism in the rod that enables it to fold in half, being supported by magnets so that it stays secure and prevents movement that could result in unwanted damage.

Figure 1. Photo of final prototype

Furthermore, in direct contrast to existing alternatives, the grabber has several advantages. It seamlessly activates its claw with the simple push of a button, in contrast to current grabbers, which need a squeezing motion. With eight claw prongs, the gripper exceeds traditional models, which typically feature only two prongs, particularly excelling in picking up cylindrical objects. Additionally, its portable and collapsible shape allows for simple movement and storage, fitting neatly into small areas like backpacks, purses, and sachets. The grabber also has an ergonomically designed handle with a non-slip grip pattern, allowing users to confidently operate it.

Moving forward, with additional time, resources, and investment, several aspects of the gripper could be improved. The first consideration was the weight of the gripper; while the gripper weighed only 2.4 pounds, adopting materials like carbon fiber might have made it considerably lighter. Secondly, the joint that attached the handle to the shaft was weak, resulting in reduced durability. Given more time and resources to fix this problem, a better solution would have been a custom joint that could support the pressure. Lastly, due to the nature of robotics in the project, it was not suitable for all weather conditions. To fix this the gripper would get coated in a hydrophobic coating along with waterproof wire sheaths.

Background Information

Tiffany has been diagnosed with spina bifida since she was born. Spina bifida is a birth defect that happens when the spinal cord does not completely close in utero, resulting in different levels of physical disabilities. In this case, Tiffany cannot move or feel anything below her waist. She also wears two metallic rods on her back to keep it straight.

Because of disability Tiffany moves around using a power wheelchair which needs specific door widths for accessibility making maneuvering through narrow doorways difficult. In addition, to earn money and support her family, Tiffany works at Walmart most days. Some of the duties she performs involve putting things on shelves, which often requires her to reach out beyond her arm length. However, the grabber she has is not useful at work where she does not employ it.

Understanding Tiffany's medical condition, daily challenges, and personal aspirations is crucial for designing a solution that improves her quality of life, enhances her independence, and addresses her unique needs and preferences.

Problem Framing

The problem statement for project 4 is: Design a device for our client Tiffiany who is in Hamilton, Ontario. That allows her to have easier accessibility grabbing and reaching for items without any assistance. Since tiffany is unable to reach high places because of her medical condition. The device should be easy to grip, portable, and versatile. However, the device cannot exceed a certain weight limit.

Objectives	**Constraints**
User-friendliness (user scale)	Cost ($CAD)
Versatility (user scale)	Weight (g)
Maintenance (user scale)	
Folding mechanism efficiency (s)	
Claw grip weight load (g)	
Reaching Distance (m)	

Conceptual Design

Ideation (Initial Brainstorm Sketches and Morph Chart)

The following images below are two of the group's initial sketches of the collapsible and automatic grabbing device designed for the project. Such additions of a trigger/button to activate the claws automated movement as well as a collapsible feature for portability purposes were the key features that the group persisted with throughout the entire project.

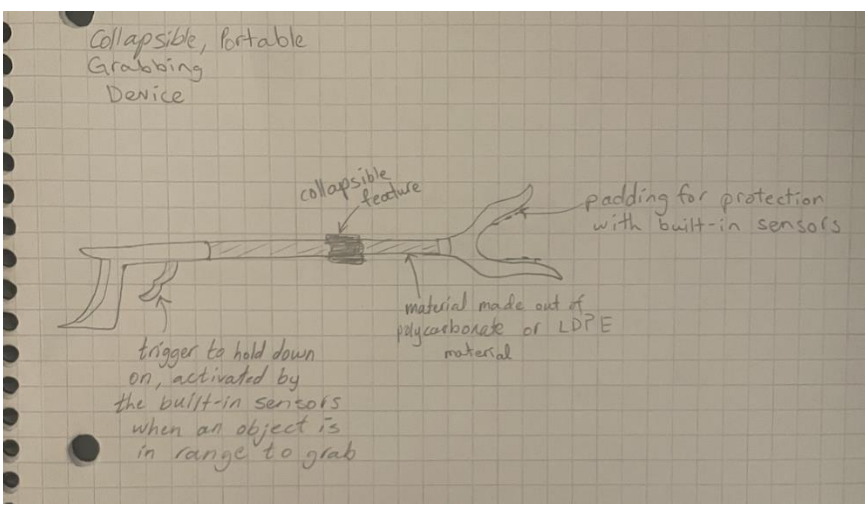


Figure 2. Grabber Device Initial Brainstorm Sketch #1

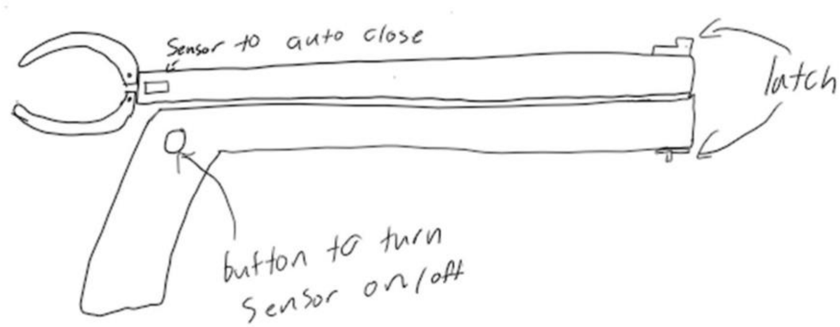


Figure 3. Grabber Device Initial Brainstorm Sketch #2

Function	**Means**					
Collapsibility	Telescoping pole	Folding arm	Scissoring arm	Portable assembly (Take it part)	Spring Loaded system	Screw Mechanism
Arm movement	Linear Actuator	Rotary Motor	Scissor geometry	Linkage system	Pneumatic System	Gear Mechanism
Gripper /Grabber movement	Button	Trigger	Sensor	Slider	String	Switch
Claw/Jaw grasp ability	4 prong claw all in one dimension	4 prong claw all in two dimensions	2 prong claws	Cage design	Flat square design with 4 points of impact	6 prong claws

Figure 4. Morph Chart

Existing Ideas/Solutions (Patents & Commercial Products)

When inventing and developing new tools and devices, patents play a particularly important role in shaping the process in which a design is developed into the final product. Patents serve as checkpoints in innovation which state the current boundaries to innovate further from, and in turn, create better products. In the case of the design for a grabber device that is compact, lightweight, and portable, the existence of patents offers a view of the current state of technology in grabber arms and the innovative mechanisms already in use. With these patents in mind, it would affect the prototype of the new grabber arm based on what already exists on the market.

The first patent describes an object-picking tool for picking objects from a distance and includes an elongated arm with a gripping device of two moveable grippers. It is controlled via a handle at the distal end of the arm and a folding and locking device which is initialized with a button [1]. An image of the patent is shown below:

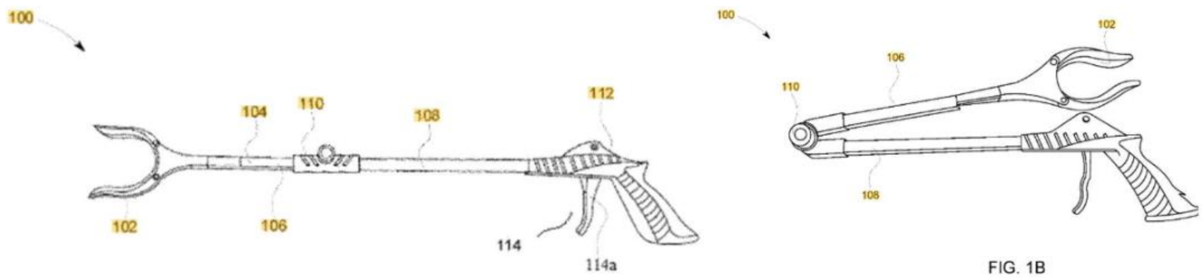


Figure 5. Patent One [1]

The second patent describes an adjustable-length telescoping pole with a gripping mechanism of at least two movable fingers that move together designed to grip objects. The fingers are hinged and at least one of the fingers is attached to a cord which is used to close the gripper. Furthermore, a spring is added to leave the gripper in a naturally open position. The cord is threaded through the telescoping pole to prevent it from becoming tangled [2]. This patent has expired as of February 26th, 2024; thus, it’s mechanisms can be used in the design. An image of the patent is shown below:

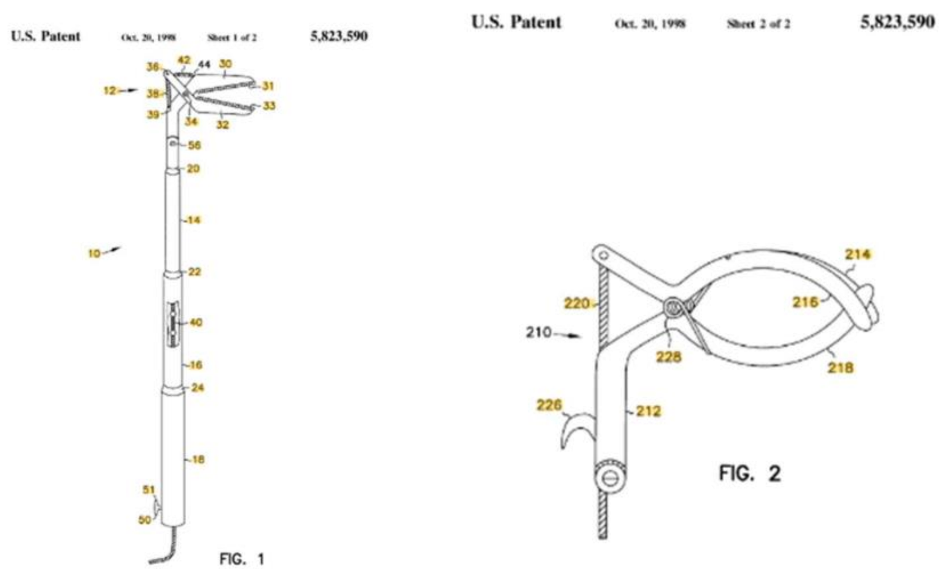


Figure 6. Patent Two [2]

With these patents, some design considerations arise solely due to the patents existing. For the first patent, since it is still active, the group could not use the same fold and lock mechanism with the trigger because it interfered with the existing patent. Instead, the group would still be able to implement a folding gripper that does not use a similar mechanism. However, with the second patent, since it is no longer active, the technology that is found in the patent can be used and improved upon the existing design. Therefore, by implementing unique improvements such as a technologically advanced design than the initial patent, the group would be able to commit to their grabber design without patent interference during the prototyping and finalizing stages of the product.

Decision Matrix

To determine the ultimate features to implement into the final design of the project, a decision matrix was performed. This ensured for the group that these features were feasible and not overcomplicated to put into practical use.

Criteria	Weighting	Folding hinge		Telescoping		Button controlled		Trigger controlled	
		Score	Total	Total	Total	Score	Total	Score	Total
Portability	5	4	20	5	25	1	5	1	5
Simplicity	3	3	9	1	3	4	12	4	12
Durability	4	4	16	2	8	5	20	5	20
Length Extension	5	4	20	3	15	2	10	2	10
Total			**65**		52		47		47

Figure 7. Decision Matrix

Design Alternatives

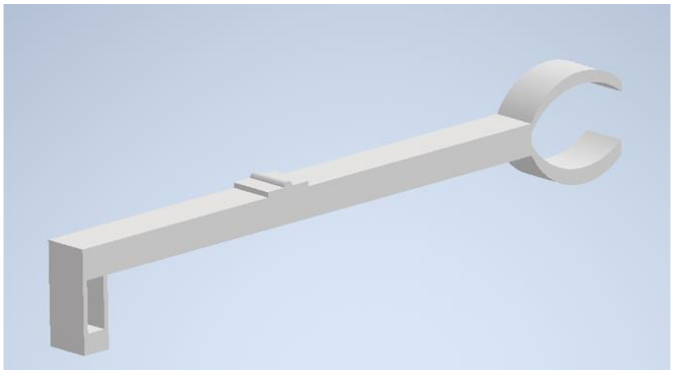


Figure 8. Grabber Device Concept Design #1

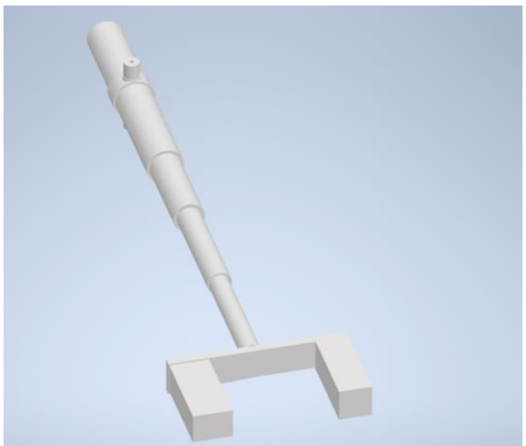


Figure 9. Grabber Device Concept Design #2

Looking at both initial concept sketches, the decision matrix, along the achievability of a final project, the group decided to move forward with concept design #1. The reason for this decision was due to several factors. First, looking at the feasibility and goal of achieving a final project, concept design #1 with the bending arm was more likely to be made. On the other hand, the telescoping arm in concept design #2 seemed to be an overreach, which not only has more moving parts but also a more complex mechanism. Specifically, it involves a series of latches, gears, and a string pully system, which would be difficult to employ in a practical use. Furthermore, concept design #2 is seemingly more time-consuming, but also quite costly as more complex motors and materials are required for the design. Therefore, the decision matrix favored concept design #1, reinforcing and justifying the group's decision to use and commit to concept design #1 for the entirety of the project.

Design Evaluation

1st Design Review Comments:

- TA advised to ensure that the battery source of the grabber does not cause any issues. Possible solutions to overcome this would be covering it with plastic or placing it inside the handle for protection
- TA said to consider the cost of sensors and other electronic equipment

Impact on Design Process:

- The comments received regarding the battery impacted the group's overall design as challenges surfaced to fit the battery inside the handle to increase protection to the electronic components of the grabber device.
- Moreover, the comments regarding the cost of electronic equipment posed a further challenge as it needed to be taken into consideration in the budget along with the costs of other parts used in the product

2nd Design Review Comments:

- TA agreed with design choice to proceed with less complicated mechanism
- TA mentioned that telescoping would also increase the cost of the project
- TA motioned using materials such as PVC or Acrylic for rods in grabber
- TA advised and showed concern to coding complexity and mentioned that if the idea is proceeded with, then coding and designing processes must start as soon as possible

Impact on Design Process:

- The comment regarding a less complicated mechanism allowed the group to opt for an automatic grabber that does not include an ultrasonic sensor, but an easy-to-use button for better convenience
- The comment about the telescoping portable feature reinforced the decision to stick with the folding mechanism
- The comment regarding using materials like PVC or Acrylic for the rod of the grabber device made the group commit to a rod made of aluminum alloy due to it being lightweight and cheap
- The comment regarding the coding and design complexity made the group work on the project from early on to have enough time to troubleshoot and fix problems that appear along the process

Final Design Review Comments:

- Complete testing plan by next week and try to use around 10 objects of different shapes and sizes for testing
- Try to use grabbing device on objects consecutively next to each other to see if it grabs one object at a time

Impact on Design Process:

- The comment regarding the testing plan’s completion and grabbing objects next to each other enabled the group to try various sized objects with different shapes to simulate real-life usage by a client
- This also allowed for the group to identify what the grabber device can carry and cannot carry allowed the group to make changes for a claw with a servo motor with sufficient torque to carry objects

Final Proposed Design

The final design is an automated grabbing device named “The Grabber Pro Max.” It is activated with the push of a button which automatically closes the servo claw with virtually no effort. The grabber also has a foldable design which enhances its portability, allowing for easy transportation in something as compact as a backpack. This feature not only increases its mobility but also ensures convenient usage on the go. The grabber functions from an Arduino nano fitted inside the handle connected to a button via a small breadboard inside the handle which controls the movement of the claw the whole electronic system is also controlled by a simple and easy-to-change 9V battery which fits seamlessly into the handle. The Arduino is run with some simple code to open and close the servo when the button is pressed, the code is given below:

SercoPushButtonTest §

```
int angle =90;    // initial angle  for servo
int angleStep =10;
const int minAngle = 0;
const int maxAngle = 180;

int buttonPushed =0;

void setup() {
  // Servo button demo by Robojax.com
  Serial.begin(9600);          //  setup serial
  myservo.attach(servoPin);  // attaches the servo on pin 3 to the servo object
  pinMode(pushButtonPin,INPUT_PULLUP);
   Serial.println("Robojax Servo Button ");
}

void loop() {
  if(digitalRead(pushButtonPin) == LOW){
    buttonPushed = 1;
  }
   if( buttonPushed ){
  // change the angle for next time through the loop:
  angle = angle + angleStep;

    // reverse the direction of the moving at the ends of the angle:
    if (angle <= minAngle || angle >= maxAngle) {
      angleStep = -angleStep;
       buttonPushed = 0;
    }
    myservo.write(angle); // move the servo to desired angle
      Serial.print("Moved to: ");
      Serial.print(angle);   // print the angle
      Serial.println(" degree");
  delay(100); // waits for the servo to get there
   }


}
```

Figure 10. Screenshot of Code from Arduino IDE

Overall, the grabber is 65cm long and has a gripping force of 8kg.cm coming from the high torque servo motor and can hold an item with a weight of up to 700g. When folded in half the grabber is only 33cm long and weighs only 2.4 pounds increasing the portability greatly.

Through the testing in milestone 5, the grabber was updated and now passes all four objectives of portability, ease of use, lifting capability, and maintenance all these objectives were tested thoroughly. For portability, the test was if it was able to fit into a backpack the capabilities were tested by checking if the grabber fits into four different backpacks. The ease of use was tested by asking 10 random people to use the grabber without instruction and see if they knew how to use it. The lifting capability was tested by using various objects of different sizes shapes and weights and checking if the gripper could pick them up finally, the maintenance was tested by taking apart and reassembling the grabber.

In the creation of the grabber, many materials were considered, in the final design the grabber was made of an aluminum pole taken from a conventional gripper which is lightweight and durable, the handle is made of a soft rubber material which makes grabber ergonomic and easy to use and finally, the claw itself is a mix of aluminum and 3D printed plastic. The price of the materials used and the electronics inside are listed below.

<u>Bill of materials:</u>

Claw: $29
Handle: $6
Gripper (used for pole): $13
Breadboard: $2
Arduino Nano: borrowed (if not borrowed $20)
Servo: lending library (if not borrowed $15)
Wires and button: borrowed. (if not borrowed < $10)

The insights gained from the current testing plan results helped guide iterative enhancements to the design. Having instant feedback from test users helped the final design in ensuring its effectiveness and usability. For a future testing plan with a longer amount of time, the battery life and the life of the servo motor could be tested. This would give an accurate lifespan of the grabber and also give a recommended time for repair and replacement of the servo. Another test that could be conducted would be a durability test, this could be done on both the electronics and the other materials that the grabber is made from.

Conclusions

Steps that the group would take to improve the device are to add a sensor that would eliminate the button required to grab things and instead do everything automatically. There would still be a switch that would turn the gripper on and off. Adding to that, using a material that is light would make it easier for Tiffany to use and handle. The final test plan altered future refinements made by testing the initial 3D printed claw, but after some tests, the group noticed that it could not pick anything due to its small power and torque, therefore the group changed the claw to a servo motor claw instead that had a greater torque and could hold heavier objects of various shapes and sizes.

Looking back, this project provided significant insights into both the design process and team dynamics. Firstly, a project's design process is very complicated and often isn't linear. The group went back and forth between concepts and prototypes. Secondly, regarding team dynamics, effective communication, trust, and having defined responsibilities is essential. As the slightest miscommunication can have major implications. If this team were to work again, the only change would be to have better-defined project goals.

References

[1] J. Fleming, "US10500715B1 - foldable Reacher grabber tool," Google Patents, https://patents.google.com/patent/US10500715B1/en

[2] B. Forrest and J. Hubbard, "US5823590A - adjustable length grabber," Google Patents, https://patents.google.com/patent/US5823590A/en

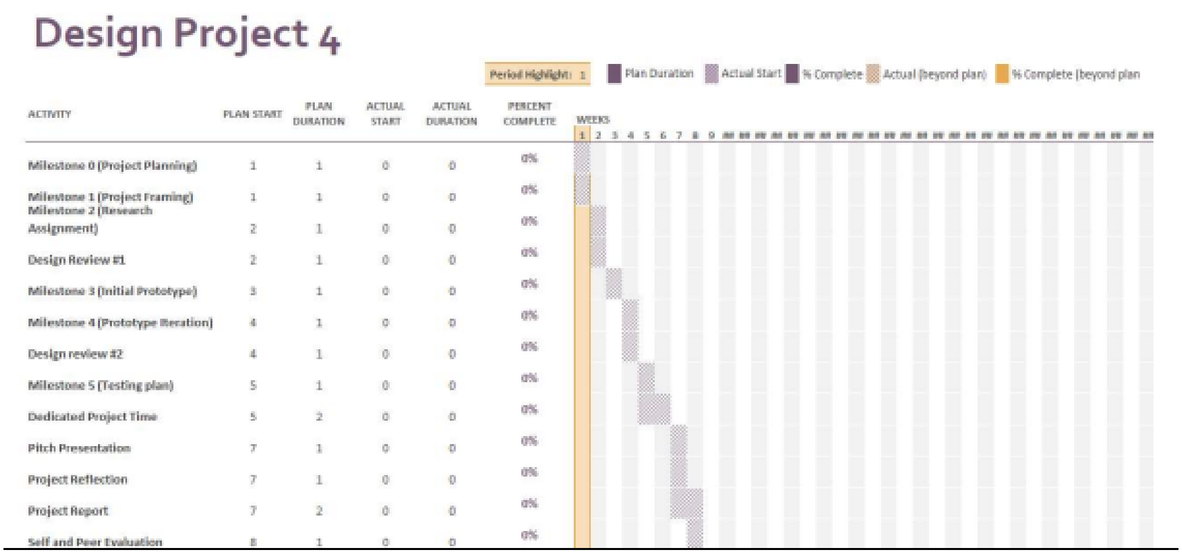
[3] "Amazon.ca: Low Prices – Fast Shipping – Millions of Items," *Amazon.ca*, 2024. https://www.amazon.ca/?tag=hydcaabkg-20&hvadid=677796472754&hvpos=&hvnetw=g&hvrand=8618287644759197759&hvpone=&hvptwo=&hvqmt=e&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9000875&hvtargid=kwd-31636821&ref=pd_sl_2gqjnc4wf3_e&hydadcr=11828_13481604&gad_source=1.

[4] "The Home Depot Canada," *Homedepot.ca*, 2020. https://www.homedepot.ca/en/home.html.

[5] Y. FILLY, "YouTube," *YouTube*. 2024. [YouTube Video]. Available: https://www.youtube.com/.

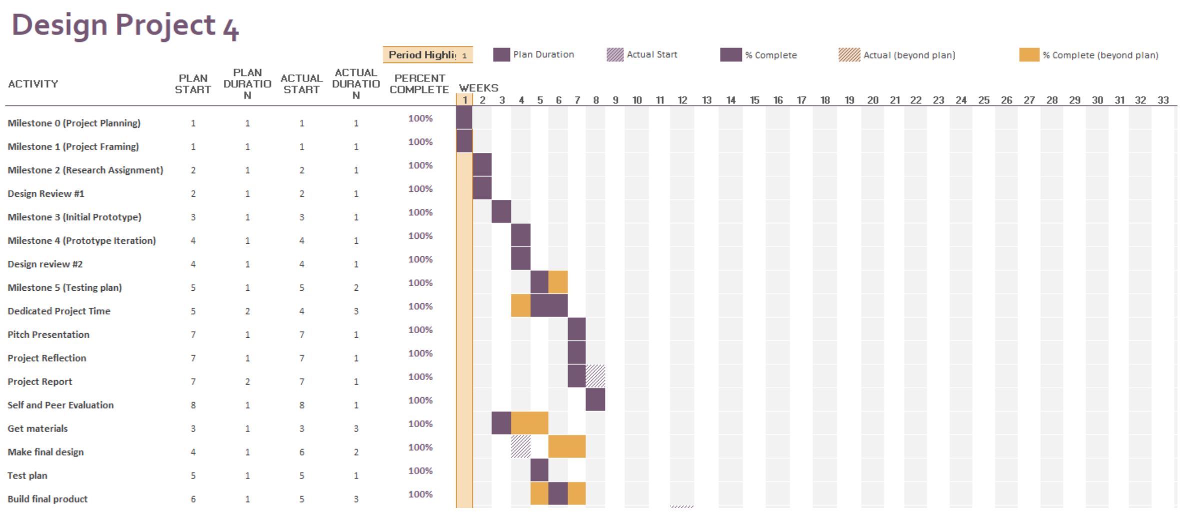
Appendices

Appendix A: Project Schedule



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Project Planning)	1	1	0	0	0%
Milestone 1 (Project Framing)	1	1	0	0	0%
Milestone 2 (Research Assignment)	2	1	0	0	0%
Design Review #1	2	1	0	0	0%
Milestone 3 (Initial Prototype)	3	1	0	0	0%
Milestone 4 (Prototype Iteration)	4	1	0	0	0%
Design review #2	4	1	0	0	0%
Milestone 5 (Testing plan)	5	1	0	0	0%
Dedicated Project Time	5	2	0	0	0%
Pitch Presentation	7	1	0	0	0%
Project Reflection	7	1	0	0	0%
Project Report	7	2	0	0	0%
Self and Peer Evaluation	8	1	0	0	0%

Figure 11: Preliminary Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Project Planning)	1	1	1	1	100%
Milestone 1 (Project Framing)	1	1	1	1	100%
Milestone 2 (Research Assignment)	2	1	2	1	100%
Design Review #1	2	1	2	1	100%
Milestone 3 (Initial Prototype)	3	1	3	1	100%
Milestone 4 (Prototype Iteration)	4	1	4	1	100%
Design review #2	4	1	4	1	100%
Milestone 5 (Testing plan)	5	1	5	2	100%
Dedicated Project Time	5	2	4	3	100%
Pitch Presentation	7	1	7	1	100%
Project Reflection	7	1	7	1	100%
Project Report	7	2	7	1	100%
Self and Peer Evaluation	8	1	8	1	100%
Get materials	3	1	3	3	100%
Make final design	4	1	6	2	100%
Test plan	5	1	5	1	100%
Build final product	6	1	5	3	100%

Figure 12: Final Gantt Chart

Logbook of additional meetings and discussions:

Sunday, March 10, 3:30PM to 6:30PM

Work: Ahmed and Fahd go to Home Depot and find suitable aluminum material to use for a rod with a sizeable diameter

Wednesday, March 13, 5:00PM to 6:00PM

Work: Fahd cuts the aluminum rod in half to be used in the design

Sunday, March 17, 5:00PM to 7:00PM

Work: Keerath works on Arduino code to implement for the use of an Arduino Nano in the circuit of the grabber device and tests it on the ultrasonic sensor

Tuesday, March 19, 12:00PM to 2:00PM

Work: Ahmed, Keerath, and Jacob go to Home Depot to purchase copper brushings to attach the aluminum rods and magnets used for the foldable feature of the grabber device

Thursday, March 21, 8:00PM to 10:00PM

Work: All members put together all the parts gathered (aluminum rods, copper brushings, magnets, Arduino Nano, wires, boat hinge, and 3D printed claw) into a feasible design and initial prototype

Tuesday, March 26, 12:00PM to 5:00PM

Work: All members go to Thode makerspace to cut holes in the bike handle and attach aluminum alloy rods to the handle to create space to insert wires and other electronic components for the design

Thursday, March 28, 11:30AM to 3:00PM

Work: All members go to Thode makerspace to incorporate the new servo motor claw with higher torque than the 3D printed claw and test the coding program on it

Thursday, April 4, 11:00AM to 5:00PM

Work: All members go to Thode makerspace and work on the product presentation, attaching new parts, fitting in electrical components inside the handle, troubleshooting code, and soldering the push button

Appendix B: Scheduled Weekly Meetings

ENGINEER 1P13
MEETING WITH TEAM Fri-08 – FRIDAY MAR 1, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Jacob Rodrigues**	**rodrij51**	**Yes**
Administrator	**Keerath Singh**	**singhk24**	**Yes**
Coordinator	**Ahmed Yassin**	**yassia8**	**Yes**
Subject Matter Expert	**Fahd Zada**	**zadaf**	**Yes**
Guest			

AGENDA ITEMS

1. Attendance and updates
2. Check for completion of initial designs.
3. Anything to change with designs.
4. Compare designs.

MEETING MINUTES

1. Attendance and updates
   a.
2. Check for completion of initial designs.
   a.
3. Anything to change with designs.
   a.
4. Compare designs.
   a.

POST-MEETING ACTION ITEMS

1. Think of specific material to use
2. Power soure in handle
3. 3D print first iteration
4. Locking mechanism for folding arm
5. Look for what sensors and motors we need.

1

ENGINEER 1P13
MEETING WITH TEAM Fri-08 – FRIDAY MAR 1, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Jacob Rodrigues**	**rodrij51**	Yes
Administrator	**Keerath Singh**	**singhk24**	Yes
Coordinator	**Ahmed Yassin**	**yassia8**	Yes
Subject Matter Expert	**Fahd Zada**	**zadaf**	Yes
Guest			

AGENDA ITEMS

1. Attendance and updates
2. Look at prototype ideas
3. Think about what we need to do to further create our prototype
4. Questions about prototype

MEETING MINUTES

1. Attendance and updates
2. Check for completion of prototype
3. Anything to change with designs.
4. Start thinking about final iteration for our prototype

POST-MEETING ACTION ITEMS

- Focus on software component
- Think about 3d printing/laser cutting
- Finish prototype
- Gather parts

1

ENGINEER 1P13
MEETING WITH TEAM Fri-08 – FRIDAY MAR 15, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Jacob Rodrigues**	**rodrij51**	**Yes**
Administrator	**Keerath Singh**	**singhk24**	**Yes**
Coordinator	**Ahmed Yassin**	**yassia8**	**Yes**
Subject Matter Expert	**Fahd Zada**	**zadaf**	**No**
Guest			

AGENDA ITEMS

1. Attendance and updates
2. Look at final prototype
3. Think about what we need to do to start making final design
4. Questions about prototype

MEETING MINUTES

1. Attendance and updates
2. Check for completion of prototype
3. Anything to change with designs.
4. Start thinking about building final design

POST-MEETING ACTION ITEMS

- Weight limitations
- Create testing plan (different items around grocery store, 10 objects)
- 3D print claw
-

ENGINEER 1P13

MEETING WITH TEAM Fri-08 – FRIDAY MAR 22, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Jacob Rodrigues**	**rodrij51**	**Yes**
Administrator	**Keerath Singh**	**singhk24**	**Yes**
Coordinator	**Ahmed Yassin**	**yassia8**	**Yes**
Subject Matter Expert	**Fahd Zada**	**zadaf**	**Yes**
Guest			

AGENDA ITEMS

1. Attendance and updates
2. Look at final testing plan
3. Think about what we need to do to finish final design
4. Questions about final design

MEETING MINUTES

1. Attendance and updates
2. Check for completion of testing plan
3. Anything to change with final design
4. Start thinking about presentation and final product

POST-MEETING ACTION ITEMS

- Motor is too weak, try to fix
- Complete testing plan and make changes to design
- Decide between telescoping and folding rod through testing
-

Appendix C: Comprehensive List of Sources

[1] "Autodesk Inventor Professional 2021." Autodesk, San Rafael, CA, 2021.

(https://www.autodesk.com/)

[2] "Power in Community" P4 Project Module, pp. 3–44, class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[3] "P4 Testing Plan," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[4] "Client Notes from Lecture," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

Appendix D: Additional Documentation

Section 1:

Client Notes:

Client name: Tiffany

Condition: Struggles with spina bifida and hydrocephalus

Current needs: Wheelchair, Reacher Grabber, Back scratcher, Muscle massager

Struggles/issues:

- **Wheelchair belt buckle**
  - Could snap in half
- **Sidewalks in winter**
  - Slippery due to ice
- **Reaching**
  - Hard to reach items that are high and a difficult shape
  - Currently uses Reacher grabber
    - Pointy and not very portable

        - Squeeze to grab
- **Battery**
    - Can degrade in winter
    - Expensive to replace battery
    - Overnight charge
    - No cover on battery
- **Doors**
    - Hard to enter and exit doors
- **Cross walk button**
    - Accessible button
    - Lowering button
    - Time is not long enough

- **Surgery**
    - Due to her condition, she had two metal rods placed in her back
    - In the winter her back can freeze
- **Shower**
    - Has a shower chair
    - Still needs assistant though due to chair not being sturdy
- **Hand Mobility**
    - One hand has full mobility
    - Other is a challenge to open and close fingers

Section 2:

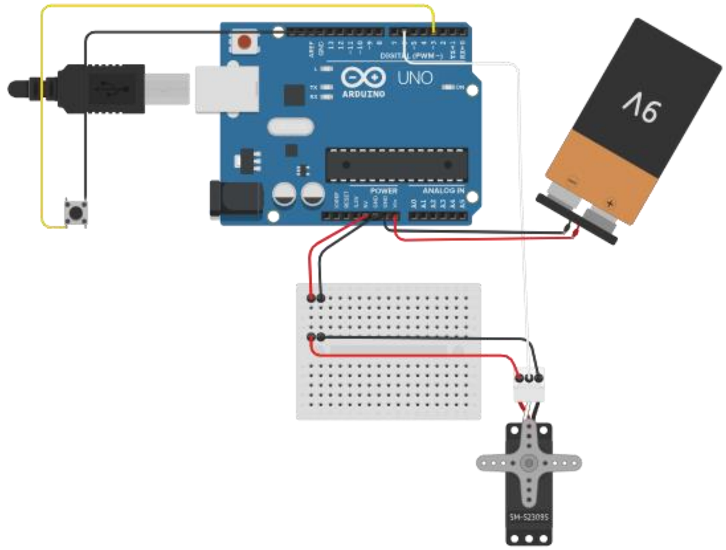


Figure 13. Model of Cricut made on TinkerCAD

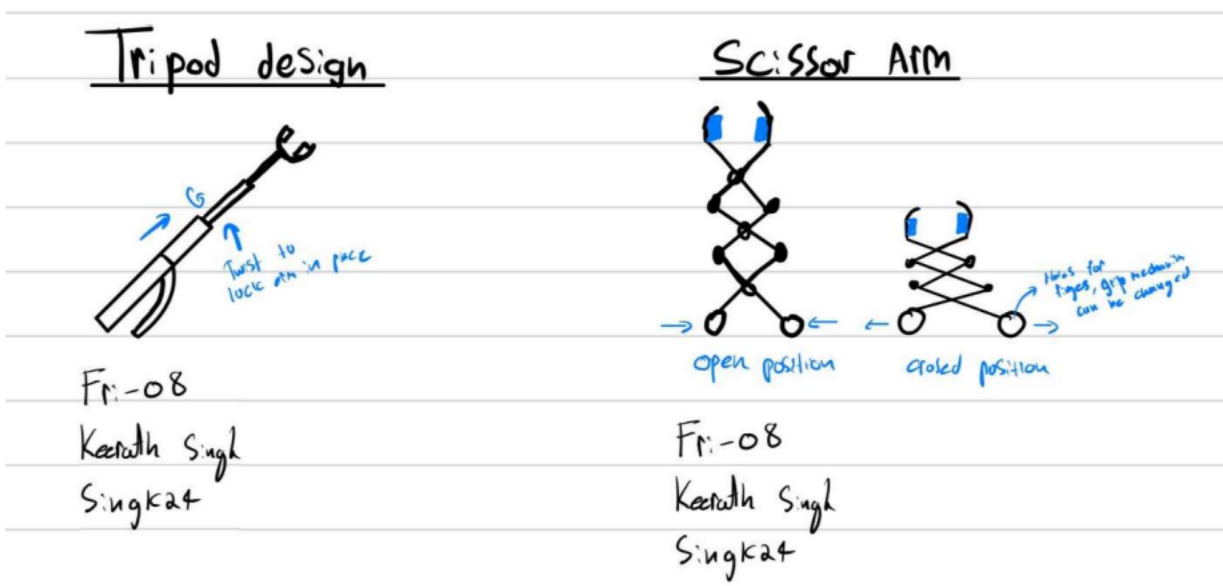


Figure 14. Initial brainstorm sketches

Figure 15. Initial Prototype

Section 3

Figure 16. Final Design Folded and held by magnets

Figure 17. Final Design in use

Appendix E: Design Studio Worksheets