Deliverable M
Final Report

GNG2101 - Section Z01: Group 1

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Abstract

The SMART Grabber was designed by students at the University of Ottawa to aid people with disabilities and the elderly in picking up items independently. The Agile Design and Design Thinking models were used to create this product. Through these design methodologies information was gathered from interviewing Stephen, a potential client, which was used to define customer needs. The needs were then translated into a problem statement which focused on creating a pick up stick that was simple, versatile and durable. Four prototypes were developed based on the predefined problem statement, to determine the ideal solution. Each prototype was composed of three main parts; including the handle, arm and claw. To contribute to the success of the SMART Grabber, observations were collected from the client along with client's feedback to create the final design. Thus the final design at the end of the course was a motorized pick up stick with touch sensor activation, a double claw, an ergonomic gun grip and of set length.

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1.0 Introduction

People with disabilities and the elderly have trouble doing tasks that most people can complete. This includes picking up items like a phone, glasses, coins, and many other everyday objects. Using assistive devices is a common solution for people with disabilities, with over 80% using at least one assistive device [1]. Tools referred to as “pick up sticks”, “reachers” and “grabbers” are used to pick up different items. Many pick up sticks on the market have either single or double claws, opening and closing manually. A long tube attaches to these claws and on the other end lies the handle. Most handles have a trigger that needs to be continuously pressed to pick up an object. The force applied to the handle by a person’s hand must be significant to successfully pick up items. This can be difficult for those with limited hand motor function.

The purpose of this project was to reinvent the current pick up stick to make it easier for people with disabilities and the elderly to use. To tackle this problem, the team first empathized with their clients, which included Stephen Bay, a patient at at Saint-Vincent Hospital in Ottawa and Bocar N’diaye, a technologist at the same hospital. To do this, the needs of the client were first obtained by interviewing them. Stephen had limited motor skills which makes it difficult for him to reach objects. Stephen and Bocar were asked many open-ended questions and a list of needs were created from this acquired information. Then metrics were created and a list of design criteria and target specifications were set. Benchmarking was also used to analyze competition.

Many ideas were brainstormed, first individually then as a team, and these ideas and concepts were then combined, refined and analyzed. This is an important step in many design processes that is necessary to find the design that best suits the client’s needs while considering different limitations. After this, a flow chart was used to select the best options for each component of the pick up stick for the first prototype. A physical prototype was then created and tested with our client. The feedback received from the client was used to create an improved prototype. This process was done again to form the final solution.

2.0 Need Identification

Design Thinking philosophy states that it is important to empathize with the customer and truly understand their needs before beginning the design process. The customer needs for the reacher are based on feedback given by Stephen and Bocar N'diaye after the first client meeting. Their statements were ranked below from most essential to least.

1. The pick up stick has an ergonomic design that is lightweight and simple to use for a wide range of people
2. The product is capable of handling a variety of objects of different sizes, materials, weights and textures.
3. The product has a reasonable length for various situations, preventing accidental falls and injuries from patients over extending.
4. The stick must be portable, easily accessible and transportable.
5. The reacher is cost effective.
6. The pickup stick must be useable in various settings such as the household, outdoors and in the hospital.
7. The reacher is easy to grab from storage.
8. The reacher is conveniently stored for the patient.
9. The reacher can be used in the dark.

3.0 Product Specification Process

To develop a suitable product that meets the needs of potential customers, multiple steps were taken to ensure such satisfaction. The steps included developing a problem statement, benchmarking with marketed versions, and creating a set of metrics and target specifications.

The first step taken to create the successful SMART Grabber was identifying the problem. There are a significant amount of pick up sticks already on the market. The first step was recognizing what the other pick up sticks were missing. The benchmarking process and creating the problem statement was an interconnected process. Through benchmarking, one general problem was identified: all the pick up sticks were manual and required constant applied force. Since the pick up stick that needed to be designed was supposed to fall into the assistive device sector, a manual pick up stick was not the most ideal option for a solution. After initial meetings with Bocar and Stephen, initial assumptions that a manual pick up stick was not ideal was proven to be correct.

Additional, information from Stephen and Bocar that was converted into customer needs in the previous section helped draw the conclusion that a need existed for a pick up stick that was sufficient in aiding a spectrum of people with different capabilities. These capabilities ranged from range of motion, fine motor skills and functionality of dominant hand. The vision was to create a “smarter” pick up stick that rivals current marketed ones. A problem statement was created that states:

“ There is a need for a smart tool that can pick up a variety of objects that is easy to use, durable and versatile in its given terms. The product also aids in maintaining a sense of independence for the elderly and people with disabilities. “

Following problem identification, a set of metrics were created using benchmarking as a guide and target specifications were created using both the metrics and client interaction as a guide. The following table displays the target specifications and metrics identified at the start of the project along with reasoning for each.

Table A. Metrics and Target Specifications

	Ideal	**Acceptable**	**Reasoning**
Gripping Capacity	> 2 kg	> 1 kg	Acceptable strength in order to be able to carry heavy objects such as a call bell, coffee grains or a water bottle.
Mass of the reacher	< 300 g	< 500 g	A mass that is light enough for the user to hold as well as heavy enough to withstand heavier weights and forces.
Length of the reacher	(70-100) cm	(60-80) cm	This range was chosen so that the reacher can be portable but also extend further than the current reacher on the market.
Opening width	> 15 cm	> 11 cm	Allows for a sturdier grip on the object that is being picked up.
Energy Consumption	<= 2 W	<= 2.5 W	5V and under, with an estimated consumption of 500mA per hour of continuous use.

Battery Capacity	>= 2000 mAh	>= 1500 mAh	A battery size that would support its functions but does not add extra mass. Capacity will allow the reacher to have a long battery life of approx. 3-4 hours of continuous usage.
Cost	<= $75	< $100	The cost of the reacher must be under $100 as it is the budget given in the course

4.0 Conceptual Designs

Through benchmarking, different variations of the design of a common pick up stick was researched. The different design options had their own pros and cons. The following diagram displays the flowchart of the numerous design options with the new possibility of a motorized reacher.

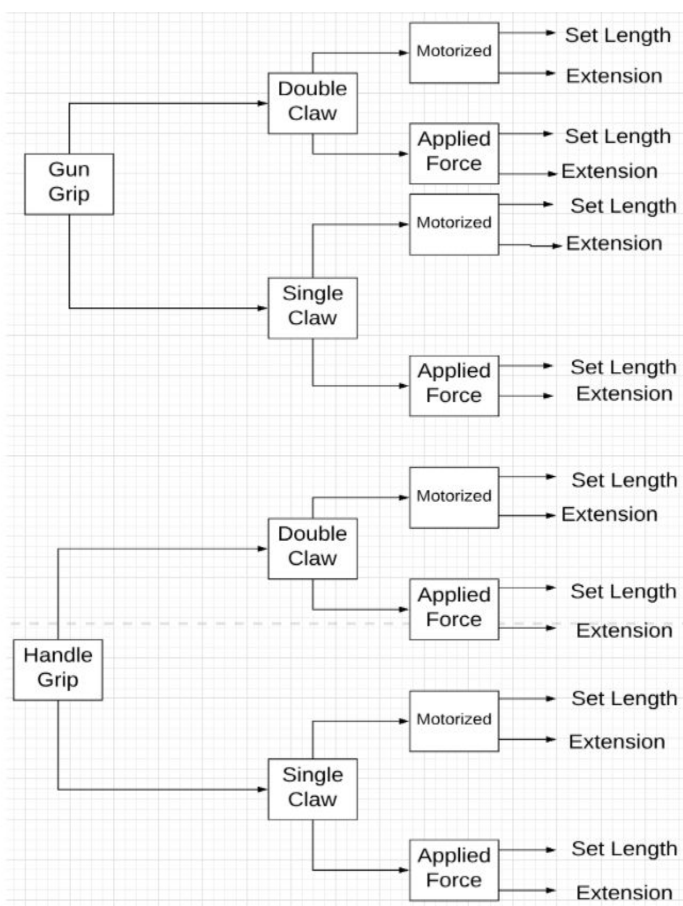


Fig 1. Flow Diagram of Conceptual Designs

The conceptual design as seen in the Flow Diagram is a four step decision process. The four step flow chart was developed to reflect the four categories of our design: grip, claw, activation and length.The initial conceptual design chosen was a motorized pick up stick with a gun grip, set length, and a double claw. The conceptual design was decided through group discussion and a ranking system of each option in a category against each other.

The gun grip was the appropriate design option in consideration of the assistive device acceptability of creating a new product. The gun grip would operate with less hand mobility and capabilities, making the grip more accessible to a wider range of users. Patients with arthritis, hand injuries or weaker strength would have potentially struggled more with a handle grip in comparison to the gun grip. Although, the gun grip was the heavier option, the difference in weight was concluded to be negligible in comparison to the overall support given to the clients.

The double claw was thought to be the most efficient design due to the hypothesis that the double claw would allow the client to grab the object from any angle, increasing flexibility. The double claw would also have a stronger and more secure grip on the object by having two acting forces on the object.

Motorization of the pick up stick was concluded to be the defining aspect of a future pick up stick. A motorized pick up stick would be the factor that would allow the SMART Grabber to be known as “revolutionary” and be competitive in a potential factor. Additionally, the motorization would remove the burden of the straining force to close and maintaining the close position of claws as seen on manually applied force pick up sticks.

An extendable arm was ranked as the most beneficial option for the design of the product.. Although by a unanimous group discussion, the decision was made to create the product with a set length due to the complexity and weight of an extendable arm. With consideration of Bocar N’diaye’s opinion, the decision was reversed and a extendable length was added to the conceptual design. Along the course of the project, the conceptual design of the product was gun grip, double claw, motorized and extendable length.

5.0 Project Planning and Feasibility Study

To organize the project effectively, tasks were given to team members and were listed in Table B where it shows the duration of tasks, the people that have to complete them and any dependencies. It was also important to analyze the uncertainty and risk (Table D) for this project and to go over the TELOS factors to assure feasibility of the project.

Table B: Scheduling

The above table is the deliverable deadlines post the start of the course. The dates are subject to change based on obstacles or new developments.

Deliverable A: Team formation and contract	May 13, 2018
Deliverable B: Need identification + product specifications	May 20, 2018
Deliverable C: Conceptual Design	May 27, 2018
Deliverable D: Project plan and Feasibility study	June 3, 2018
Deliverable E: Prototype 1 (customer meeting prep)	June 10, 2018
Deliverable F: Customer Validation/Next Steps presentation	June 15, 2018
Deliverable G: Business model	June 22, 2018
Deliverable H: Economics report + video pitch	June 29, 2018
Deliverable I: Prototype 2	July 8, 2018
Deliverable J: Intellectual Property	July 15, 2018
Deliverable K: Design Showcase	July 20, 2018

Table C: Project Planning Table

A-All, Su-Susan Peters, T-Tenner Cheung, J-Joongho Kim, R-Rachael Awotundun, Sa-Sarah Kobeissi

#	Task	Duration (days)	Person	Dependency
1	Research other pick-up sticks, materials and how to build prototypes	7	A	
2	Brainstorm Ideas	4	A	1
3	Choose best ideas to develop further	1	A	2
4	Complete Solidworks design for each subsystem	4	Su	3
5	Complete Prototype I	3	A	4
6	Test Prototype I	1	A	5
7	Review Prototype I and make changes (based on client meeting too)	1	A	6
8	Buy all the materials and make materials list	2	T, J	4
9	3D printing parts from Solidworks	7	J, Su	4
10	Develop code	2	T, Sa, Su	4
11	Develop circuits	4	T, J	4, 8
12	Complete Prototype II	7	A	7
13	Test Prototype II	1	A	12
14	Review Prototype II and make changes	4	A	13
15	Complete Prototype III	4	A	14
16	Test Prototype III	1	A	15

Milestones

Below is a list of milestones that our team completed to successfully create and present the SMART Grabber:

- Finalizing the design
- Finishing Prototype I
- Client Meeting I
- Alterations to Prototype based on Client preferences
- Finishing Prototype II
- Client meeting II
- Finishing Prototype III
- Client Meeting III
- Design Day

Gantt Diagram

Task Name	Start Date	End Date	Duration (Days)
Research other pick-up sticks, materials and how to	2018-05-16	2018-05-23	7
Brainstorm Ideas	2018-05-23	2018-05-27	4
Choose best ideas to develop further	2018-05-27	2018-05-28	1
Complete Solidworks design for each subsystem	2018-05-28	2018-06-01	4
Complete Prototype I	2018-06-07	2018-06-10	3
Test Prototype I	2018-06-15	2018-06-16	1
Review Prototype I and make changes (based on cl	2018-06-15	2018-06-16	1
Buy all the materials and make materials list	2018-06-01	2018-06-03	2
3D printing parts from Solidworks	2018-06-13	2018-06-20	7
Develop code	2018-06-13	2018-06-15	2
Develop circuits	2018-06-15	2018-06-19	4
Complete Prototype II	2018-06-15	2018-06-22	7
Test Prototype II	2018-06-22	2018-06-23	1
Review Prototype II and make changes	2018-06-23	2018-06-27	4
Complete Prototype III	2018-07-04	2018-07-08	4
Test Prototype III	2018-07-09	2018-07-10	1

Figure 2. Gantt Diagram Data

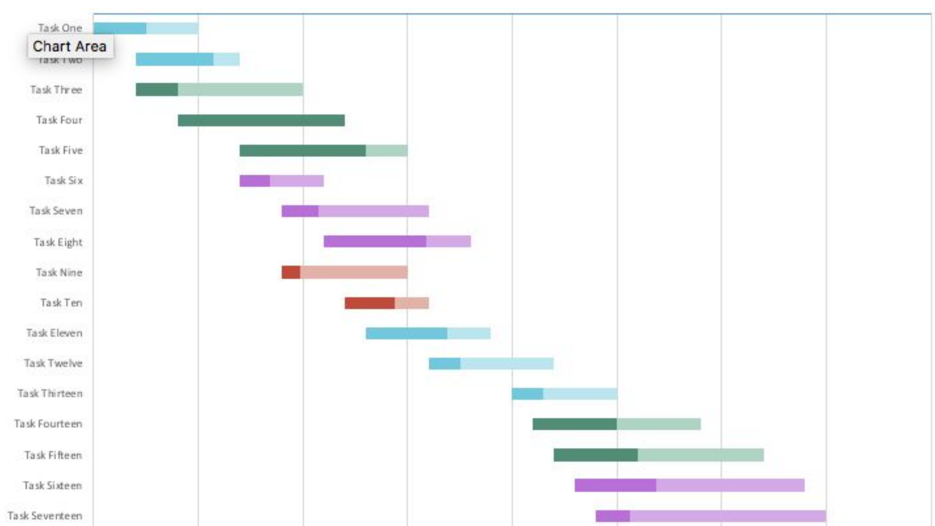


Figure 3. Gantt Diagram Chart

Table D: Uncertainties and Risks

Uncertainty / Risk	Mitigation / Contingency plan
A short lifespan	To avoid this, we go through use well known parts that will function as we need them to. Small heatsinks can be placed on the potentially high temp electronics such as the DC-DC converter.
The servo mount and or grip connector can break when holding heavy weight	The servo mount, grip+cover, claws can be printed with 100% infill
Frequent exposure to moisture or liquid contact, which can cause short circuits	Exposed metal surfaces can either be heat shrunk, covered by UV solder mask or by electrical tape
Construction is not stable	To ensure that the pickup stick does not fall apart we will use reliable parts from reputable sellers. In addition we will benchmark the specs of the items with those of similar purpose. Wiring can be optimized to allow less tangling and potential disconnections and/or shorts.

TELOS Factors

Technical: *Does your team have enough expertise and technical resources?*

Our team is comprised of a variety of different disciplines. Our project can be supported and seen in different perspectives. The electrical and computer engineering members are able to cover the basis of the electrical and software components. The mechanical and civil members can visualize the risks and weaknesses of the design and the CAD would be developed by them too. The chemical engineering member is knowledge in overall system designs and technical report writing. They are able to oversee the entire project and direct the the other members to create the pickup stick.

Economic: *Can the cost of your project be reasonable?*

The project has many economical factors. As a result, the bill of materials can range from $50-$100. The materials will cost less if we use cheaper retailers such as Aliexpress or eBay, where the components come straight from factories. If we are to buy in bulk, it would make the cost to be more economically reasonable. If we buy locally, we will not have to pay for express shipping but the base of prices of the items might be higher. The cost could potentially be higher if during our testing the products that we choose to buy could potentially fail or not be up to par with what we would expect. Therefore as a result there would be the need to buy replacement parts to improve those possibly lackluster choices.

Legal: *Are there any legal issues with releasing your solution to the public?*

Before any medical device can be released, it has to have Class II certification from the Canadian Nuclear Safety Commission (CNSC). The certification is required to sell the pickup stick in Canada or change any aspect of it.

The biggest legal issue regarding the pick up stick is the misuse of it. If the stick is used to pick up items that are too heavy, slippery or fragile this may result in damage of property or physical injuries.

When the object becomes available on MakerPro, it can be opened by anyone and modified to become a weapon.

Operational: *Are there any organizational constraints that will prevent your success?*

Potential organizational constraints that will prevent our success is available production methods. Ideally, our product would be more durable with a metal frame and structure. Since, Brunsfield is inaccessible, majority of the parts of the pick up stick will be made out of the plastic, PLA, used in 3D printers. The 3D printer parts will be manageable but would not have the same life span and strength as metal. An additional constraint is our budget, as a low budget production team we do not have the luxury of purchasing high quality motors and electronics. This will hinder the ability of the claw to function at its highest ability. The team is capable of creating a highly functional product with our available options but the constraints may become evident as we start building prototypes.

6.0 Prototyping, Testing and Customer Validation

6.1 Prototype 00

Table E: Materials for Prototype "00"

● Cardboard ● Tape ● 3D printed gear (2) ● Hot glue ● 170 pin breadboard (2) ● Digital usb voltmeter/ammeter	● Jumper wires (male-to-male, male to female) ● 0.96" OLED yellow-blue screen ● Arduino nano v3 ● 5V unipolar stepper motor ● Tactile button

● Usb to breadboard cable	● ULN2003 Driver Board ● Anker 5200mAh power bank

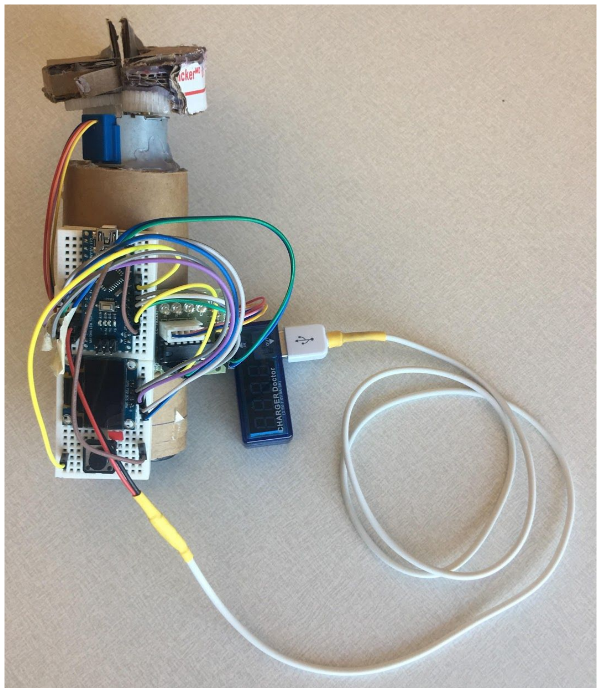


Fig 4. Full View of Prototype “00”

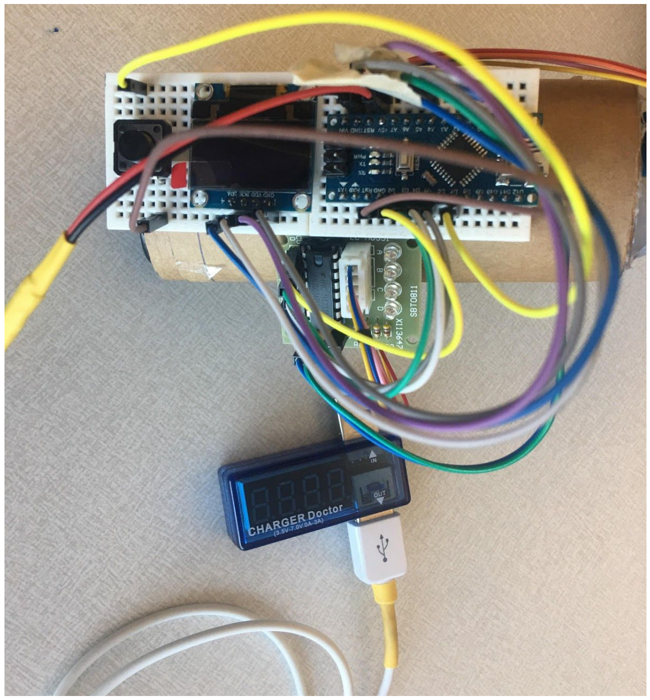


Fig 5. Circuitry view of Prototype “00”

Purpose: Since “00” was our first prototype, there was not much concrete data for us to develop it. Our main purpose for this revision was to fulfill the guidelines given to us in the course, combined with the data we had previously collected from our first client meeting. This prototype is simply meant to be a low fidelity prototype, to physically communicate the concept to the client. The device we created had to be able to pick up items, be easy to handle (in terms of weight and ergonomics), have an intuitive user-experience and have a fairly stable build. These statements all hold true in relation to what our client had told us and what had been expected of us.

Function: When the USB cable is plugged into the power bank which is wrapped in cardboard (and acts like a grip), the device turns on. At this moment, the OLED screen on the lower breadboard scrolls a welcome greeting for the user to present a safe and friendly environment. For every odd press the user applies on the tactile button below the OLED screen, the arduino nano gives a digital signal to the motor driver board to turn the stepper motor clockwise to open the claws. At this point, since the claws are open, the screen is updated to confirm this with “Claw mode: -OPEN-” shown on screen. In the same manner, even presses close the claws due to the counterclockwise motion and the screen shows “Claw mode: -CLOSED-”. The included blue *Charger Doctor* module attached to the USB-A cable is used to get an estimate of how much current is being drawn during real-time use while the voltage on the module shows us whether 5V is enough for our circuit or not, so we may modify our design to properly support these power requirements in the future.

Testing: The testing process for this prototype involved repeated use to ensure functionality of all the parts. During the testing process the team realized that the stepper motors draw too much power and do not output enough torque. The team also understood from the beginning that the length of this prototype is not adequate, however that was not it's purpose.

6.2 Prototype 01

Table F: Materials for Prototype "01"

● 3D printed claw (2), dual servo mount, "gun grip" ● Towerpro SG90 Servo (2) ● Elastic band (3) ● Flex pipe ● Jumper wires (male-to-male, male to female)	● 170 pin breadboard (2) ● USB-A male ● 750 mAh Li-po battery ● 5V step-up boost module ● Tactile button ● Arduino nano v3

Fig 6. Servos and Claw of Prototype "01"

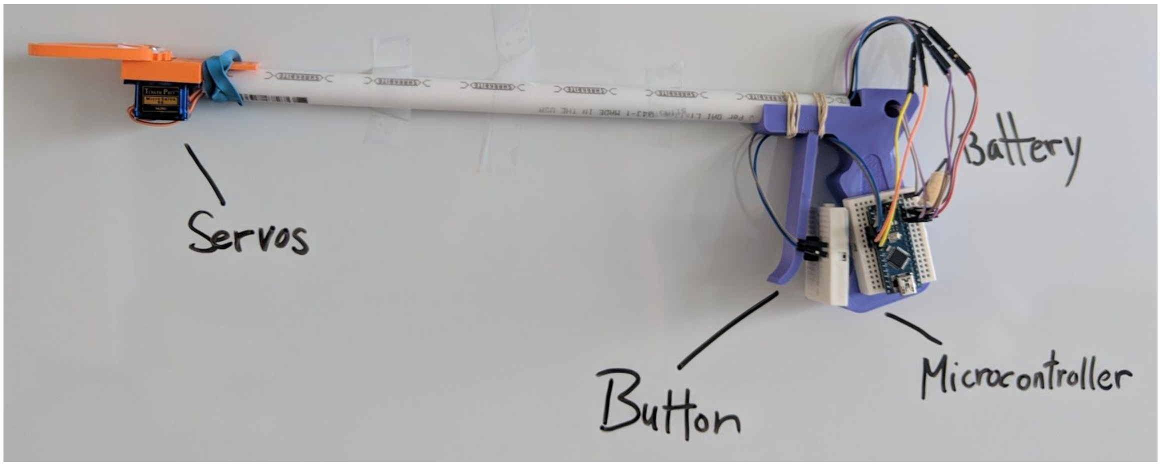


Fig 7. Full view of Prototype “01”

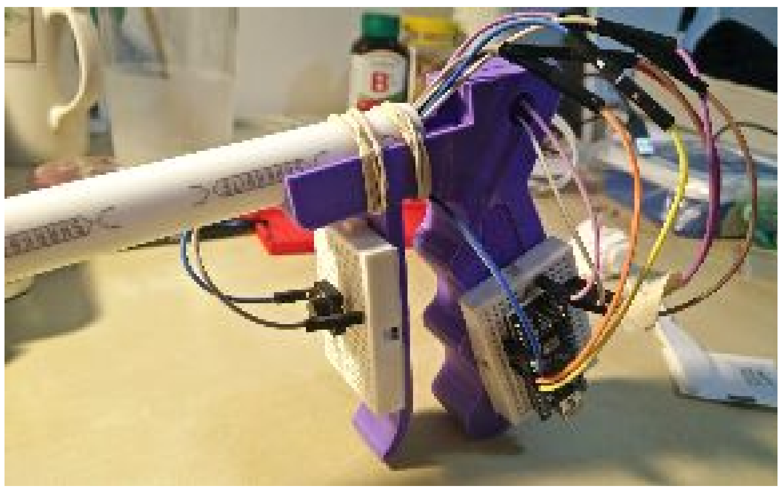


Fig 8. Circuit-view of Prototype “01”

Purpose: The main purpose of “01” is to be a low-medium fidelity prototype to communicate to the client how their feedback from prototype 00 can be implemented to suit their needs and preferences. The motors now make use of 3D printed parts rather than cardboard, meaning a variety of objects of different structures and sizes can be handled by the prototype.The improved grip was created to replicate the current reacher the client is using, since a familiar feel provides for ease of use in the long run. The stepper motor was replaced with servos, as we found in testing that stepper motors do not output the necessary torque and draw an unnecessary amount of power. The longer length of the whole tool is to let the client pick up objects further away from them and not only objects in close proximity like “00”.

Function: Once powered on, the reacher can open its claws when every even number of button presses at the grip (due to a position initialization in the servos). While the reacher closes its claws to grab said objects every odd number of presses on the trigger button excluding the first press. The servo motors are constantly attached while closing due to the force providing torque to hold objects, but it is detached when the claws open to save power.

Testing: The testing process for this prototype involved repeated use with a variety of objects and reading data from the serial monitor to ensure correct functionality. In future revisions, the claw's constant attaching may run on a condition to wear the servos and the battery less. These cases can also be on a timed average due to data from client meetings or testing. Furthermore, the servo could possibly attach until it reaches the original position. Concerns about the wear of the button trigger was also raised, as the button had been worn down considerably by the end of the testing period.

6.3 Prototype 02

Table G: Materials for Prototype "02"

• 3D printed claw (2), dual servo mount, "gun grip" • MG996R Servos (2) • Aluminum curtain rod • Jumper wires (male-to-male, male to female)	• M3 screws • 2000 mAh Li-po battery • 5V step-up boost module • Tactile button • Arduino nano v3 • Magnetic Micro-USB charging cable

Fig 9. "Gun-grip" of Prototype "02"

Fig 10. Servos and Claw of Prototype “02”

Fig 11. Full side view of Prototype “02”

Purpose: The main purpose of “02” is to approach a more finalized design with full large scale parts, less exposed wiring, enclosure for the circuitry, and a more sophisticated button trigger design. The servos were also replaced with high torque servos with metal gearing so the reacher is capable of picking up larger and heavier objects. In addition to this, a servo holder was designed so the servos and claws can be sturdily attached to the body of the reacher, in contrast to the previous prototype, where the servos were attached with elastic bands.

Function: The main function is almost identical to that of the previous prototype, just at a larger scale and a more sophisticated design. One small change was the addition of power switch, which allows to user to power on or off the prototype.

Testing: As the main function of this prototype is almost identical to that of the previous one, testing was done to ensure that the larger scale reacher is capable of picking up objects from a further distance. Testing was also done to discover that the prototype is capable of picking up approximately 650 grams before concerns were raised about its structural integrity. Repeated testing also revealed that the grip was uncomfortable and adding unnecessary strain on the wrist, so a grip redesign was necessary.

6.4 Customer Validation

When prototype 00 was presented to Bocar N'diaye and Stephen Bay, overall, they were both satisfied with this low fidelity prototype. However, N'diaye suggested to create a motorized extending arm for the pick up stick and to to have electrical and motorized components packaged inside the handle to look more aesthetically pleasing and easy to use. Bay liked the double claw, gun grip and the activating button to easily open and close the claws but he thought that the arm length was too short and the handle could be larger and therefore more comfortable. Furthermore, the claws were weak and consequently could not pick up a large variety of items. This feedback was used to create the next prototype.

Prototype 01 was then presented to the clients. When Stephen Bay tested the pick up stick, he pushed the activation button repeatedly to make the claw move faster, however, this did not work. The code was modified so that repeated button pushing would not confuse the claws. The vice claw idea was also also removed as Bay preferred the simpler double claw. The client also suggested to create a longer pick up stick that was light in weight. The motorized arm extension was therefore removed and the PVC arm was changed to a metal one. The grip was also lacking in comfort so it was made bigger with rounded edged. In all, the client's feedback was very helpful and played a large role in the success of the final prototype.

7.0 Final Solution and Features

Through all the stages of iterative design our first prototype had undergone, we decided on implementation of the features included in our final prototype. This model consisted of a smart grabber which was capable of lifting up objects up to one pound in mass when the claw was closed onto it. It featured qualities consisting but not limited to: magnetic charging, touch-enabled operation (claws), an ergonomic handle, length of 30", charging indication, and battery-level indication.

Fig 12. Final Design Full View

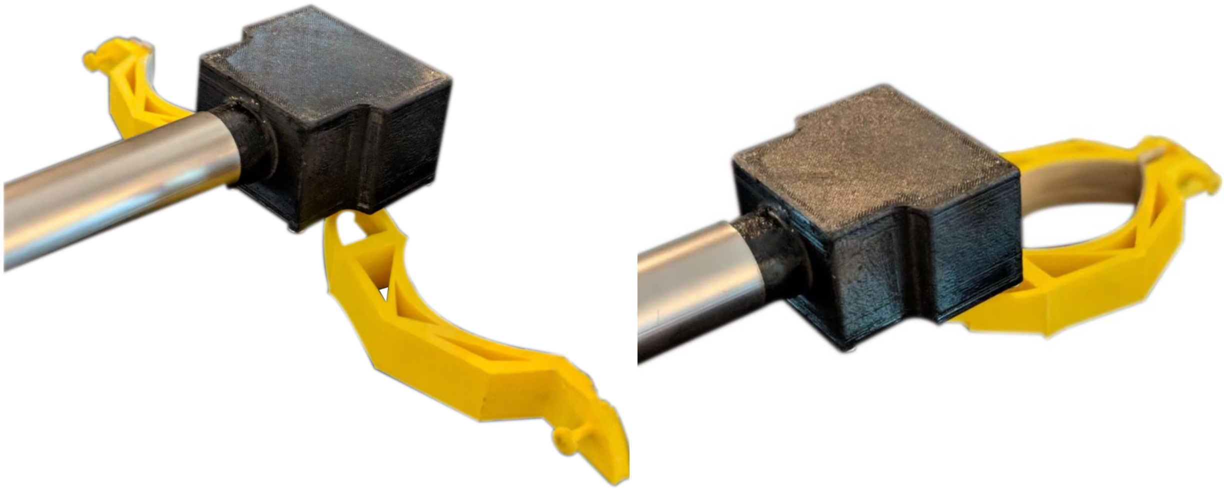


Fig 13. Final Design Claw

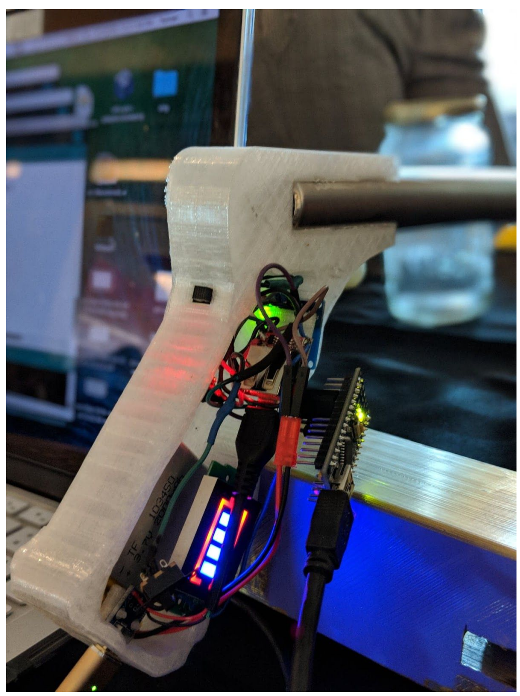


Fig 14. Final Design Grip and Internals

8.0 Business Model

The manufacturer business model was chosen for developing and selling the SMART Grabber. The model involved the “creator” making physical assets which would be sold directly to consumers [2]. This business model suited the SMART Grabber because of the empathetic design used to discover Stephen’s needs to build a physical and viable product. Considering the design of the product was based off of client interaction and experience concerning how they felt and the restraints they have encountered, building personal relationships with clients led to the conclusion the product will be sold to our customers directly. The manufacturer model was also the best model for the pick-up stick because it would increase profit margins as the team did not use distribution channels to sell the product and the model created more brand building.

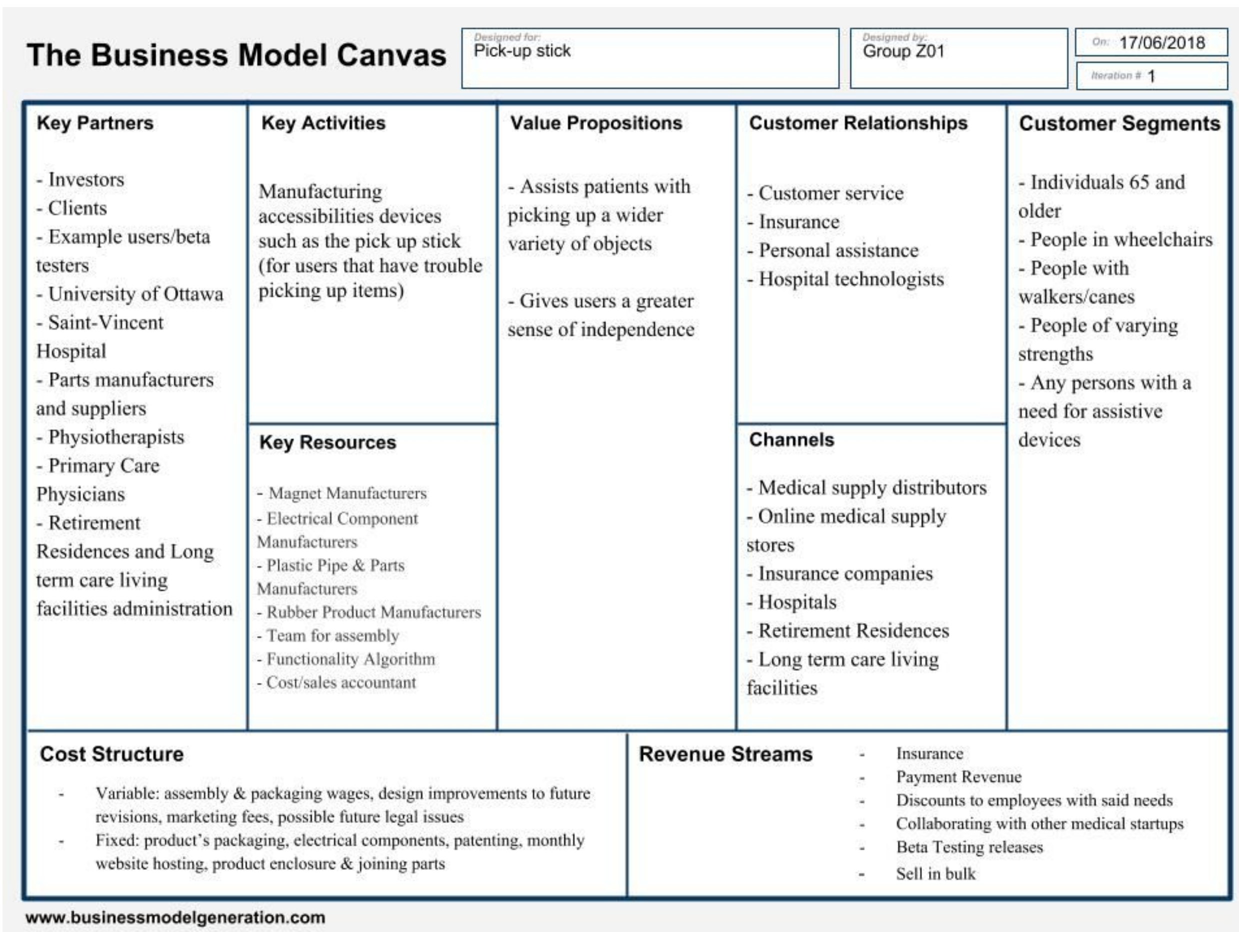


Fig 15. Business Model Canvas

9.0 Economic Analysis

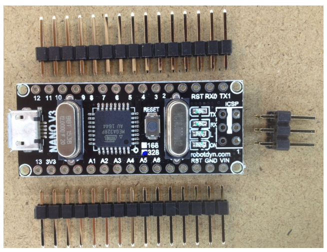
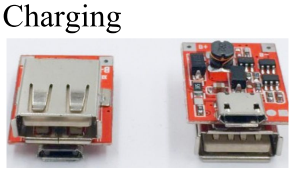
Costs (prices in CAD $)

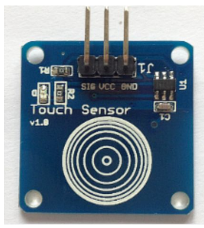
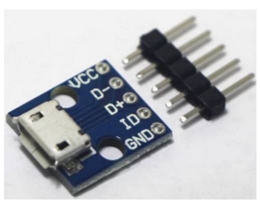
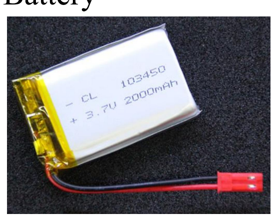
Table H: Costs and Cost Type

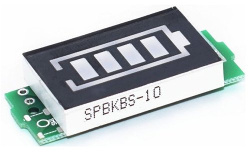
Cost	Type
Battery <= 2.77/pc (Taobao) Shower rod <= 11.27/ft (Walmart) Copper wire <= 3.17/16 ft., 3,168.00/640 25 ft rolls (to produce 1000 units) (rp electronics) Microcontroller/circuit substitute <= 5.50/ea (A2D electronics) Magnetic charging cabling and receiver <= 3.99/set (Amazon) Micro USB breakout <= 0.41/pc (Taobao) Touch sensor <= 0.38/pc (Taobao) Voltage step-up & charging module <= 1.52/pc (Taobao) Battery indicator <= 1.05/pc (Aliexpress) Servo motor <= 4.70/pc (Aliexpress) Micro USB Male connector <= 0.85/10pcs (Aliexpress) Hot Glue <= 4.99/15 sticks (Amazon) Slide switch <= 1150.45/1000pcs (Digi-key) Tin Solder <= 6.90/tube (Amazon) M3 bolts <= 8.64/100pcs (Amazon)	variable
Website hosting fees >= $9.99/mo. (Web Hosting Canada) Website domain fees = $9.99/yr (Web Hosting Canada) Office building rental >= $249/mo (listed on Spacelist for 15 Allstate Pkwy at 200 ft^2)	fixed
Rate wages (management, accounting, marketing, sales, support, design team, etc.) >= $14/hr (Ontario) Equipment <= $2000/yr 1 (servers, main computer, printers, main tv monitor), $500/yr after (with assumption employees bring laptops)	direct
Hydro >= $30 (Hydro One)	indirect

Internet >= $49.99 (at basic bundling with phone plan) (Rogers) Phone bill >= $10/mo (at basic bundling with internet plan) (Rogers) Taxes = vary based on location	

Table I: Bill of Materials

Product	Quantity	Price (CAD $)	Justification
Arduino Nano Micro USB clone  https://bit.ly/2NFW5Wk	1	(5.00 + 0.50 packaging & handling fee) = 5.50	- microcontroller to manage functions of electronics through flashed code - micro usb connector allows for greater convenience due to mini usb being less of a norm
Magnetic Micro USB cable  https://amzn.to/2mHxO70	1	3.99	- cable for charging power source - magnetic quality to ensure easier charging process for client due to less forceful plugging and unplugging which could even in turn cause wear to the connector Cons: Only good if dock made for it is well made and functional 90% of the time
5V Step-up Module with Charging  https://bit.ly/2LMmTni	1	(0.74 + 0.78 shipping) = 1.52	Pros: Gives system 5V of power at 1A and includes port for charging battery through micro-usb at 1A Cons: May on board components

			get hot during intensive current draw/rigorous use
MG996R Servo Motor  https://bit.ly/2ObgGTo (to mobile app listing)	2	(3.96*2 + (0.74*2) shipping) = 9.40 (if each piece is bought in separate orders to avoid higher combined shipping cost)	-energy efficient and high torque motors to move the left and right jaws of the claw
Touch sensor  https://bit.ly/2LJicul	1	(0.07 + 0.31 shipping) = 0.38 [shipping is 0.31 (halved), if bought with micro usb breakout]	-used in order to trigger open and close states of the claw's jaws without any manual force being applied other than touching of the pad
Micro USB Breakout  https://bit.ly/2uMCLQ3	1	(0.10 + 0.31 shipping) = 0.41 [shipping is 0.31 (halved), if bought with touch sensor]	-to extend charging port of the DC-DC converter to a convenient place where the magnetic receiver resides for the charging dock
3.7V 2000mAh Lipo Battery  https://bit.ly/2tifm8r	1	2.77	-to power all electrical components since max voltage requirement are 5V Cons: Requires DC-DC converter/DC step-up module
24 AWG Solid Wire (copper) 	1 (approx. 16 ft. required)	(5.50 + 6.00 shipping) = 11.50 (net 7.36/build)	-connects electronics to each other

https://bit.ly/2JNEv0l			
Shower/Closet Rod  https://bit.ly/2JQGHnR	1	(9.97+1.30 tax) = 11.27	-connects servos in their mount to grip
3.7V Battery indicator  https://bit.ly/2LCuJTA (to mobile app listing)	1	1.05	-shows battery level of power source
Micro USB Male connector  https://bit.ly/2NWzCFv	1	(0.67+ 0.18 shipping) = 0.85 (net 0.09/build)	-to connect breakout board to charging port of DC-DC converter
Slide Switch  https://bit.ly/2mqxIAt	1	(1.60 + 8.00 shipping) = 9.60	-to turn on system from the grip
Hot Glue  https://amzn.to/2JU4tPT	1 (one mini or standard stick)	4.99 (net 1.33/build)	-to attach shower rod and servo mount to grip
Tin solder	1	6.90 (net 1.73/build)	-to connect wires to

 https://amzn.to/2LPJaAP	(1.5-2ft)		electrical components
M3 bolts  https://amzn.to/2LnDXnu	1 (21 bolts)	8.64 (net 1.81/build)	-to fasten servo mount cover to servo mount base, secure servos in mount, fasten claws to servos, secure lid of grip onto grip base
Total amount: =		78.77, (net single build cost = 62.63 without bulk buys)	

Income Statement
[price per pc at purchase of materials for 1000 units = 2.77+11.27+(3.17)+5.5+3.99+0.17+0.74+1.05+4.7+0.09+0.01+(4.99*(4/15))+(1150.45/1000)+(6.9/4)+(8.64*(21/100)) = $39.48] (in order of appearance on variable costs list)

	2018	**2019**	**2020**
Sale Revenue (incl. tax)	18,359.68 (250 pcs)	26,437.93 (360 pcs)	36,719.35 (500 pcs)
Costs of Goods Sold	9870	14,212.8	19,740
Gross Profit	8,489.68	12,225.13	16,979.35
Operating Expenses:			
Equipment	2000	500	500
Rent	2988	2988	2988
Utilities	948	948	948
Online fees (1st month free to host)	119.88	129.87	129.87
Salaries *(3 people at 8 hrs/week)*	12,702	12,702	12,702
Total Operating Expenses	18,757.88	17,267.87	17,267.87
Operating Income	-10,268.2	-5,042.74	-288.52

Break Even Point

Total fixed costs: $17,757.88
Variable costs per unit: $39.48
Sale price per unit: $73.45 (incl. tax)

Break Even Point = Total fixed costs/(unit sale price-variable unit cost)

The break even point happens after 523 units are sold:

*523 units * (33.97 net profit/pc) = $17,766.31*

Table J: NPV Analysis
Discount Rate: 10%

Year	Cash Flow	Present Value
0	-$28,627.88 + $8,489.68 (est. 250pcs sold) = -$20,138.20	-$28,627.88 + 8,489.68 = -$20,138.20
1	-$17,267.87 + $12,225.13 (est. 360pcs sold) = -$5,042.74	-$24,722.51
2	-$17,267.87 + $16,979.35 (est. 500pcs sold) = -$288.52	-$24484.06
3	-$17,267.87+ $21,740.80 (est. 640pcs sold) = $4,472.93	-$21115.97
4	-$17,267.87+ $27,176 (est. 800pcs sold) = $9,908.13	-$14,348.58
5	-$17,267.87 + $32,271.50 (est. 950 pcs sold) = $15,003.63	-$5032.51
6	-$17,267.87 + $33970 (est.	$4395.41

	1000 pcs sold) = $16,702.13	

NPV = -$20,138.20 + (-$5,042.74/1.1) + (-$288.52/1.1^2) + ($4,472.93/1.1^3) + ($9,908.13/1.1^4) + ($15,003.63/1.1^5) + ($16,702.13/1.1^6)

= *$4395.41*

Therefore the break-even point will occur in the sixth year of business.

Assumptions when Developing Economics Report

During the development of the economics report several assumptions were made. First, since we all live in Canada, we assumed that the company is to be based in Canada. Thus, the rate wages are based on Canadian minimum wage numbers. The cost of equipment and parts were based on the assumption that the equipment and parts used are of reasonable quality, while being purchased at a discounted wholesale price. We also assumed that yearly in salary there are 21 days of vacation days and 50 holiday days. The number of units sold with increase per year by about 100-150 units and eventually plateau at only 50-100 after 6 years due to it being time past its initial release. Another assumption made is that there are no deposits required and that our total fixed costs are only applied annually.

10.0 Future Work

In the future, the iterative process will continue and new modifications will be added to the SMART Grabber. To create a more polished design, materials like rubber will be used instead of PLA. The extension feature will be reintroduced and ways to incorporate it without compromising the weight of the stick will be explored. If the extension does not work, the length of the handle will be increased to make it more useable. To make the stick more accessible to a wider variety of people, adding customizable handles will be considered. To improve the overall weight of the handle, the servos will be pushed to the back. Another alternative to reducing the weight would be using lighter servos.

11.0 Conclusion

In conclusion, the goal of this project was to reinvent and improve the current pick up stick to better the lives of the elderly and disabled. In order to achieve this goal, the team underwent an ideation process, and ideas, concepts and possible solutions were generated. These ideas were analyzed and refined with careful consideration of our client, Stephen's, needs and wants, and were then set into motion using careful physical prototyping methods to communicate these concepts to Stephent. Using feedback from Stephen and our own testing methods, the product went under three different hardware prototyping revisions before the design was finalized. In the end, the "SMART Grabber" was produced, featuring motorized claws actuated from a capacitive touch sensor. The motorized claw will allow it's user to pick up a variety of larger objects that were impossible with previous reachers, and the touch sensor allow for ease of use, allowing the users to reclaim a sense of independence in their lives.

Bibliography

[1]"A profile of persons with disabilities among Canadians aged 15 years or older, 2012", *Statistics Canada*, 2012. [Online]. Available: https://www150.statcan.gc.ca/n1/pub/89-654-x/89-654-x2015001-eng.htm#a6. [Accessed: 29- Jul- 2018].

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