

# ASSTIVE FEEDING

by Pthahnil Guo & Jichen Zhang

A report submitted in partial fulfillment of  
the requirements for

GNG 2101 Course

Faculty of Engineering  
28 July 2018

## ABSTRACT

The purpose of this report is to explain the results of our real-world product development project. The explanation will be illustrated by the process of how our team approach and finalize the final product. The process involves our design process, solution, research, and assumptions, which will all included in the summarization of the work that had been done in each deliverable to justify our final solution is most appropriate one. Furthermore, there is also a clear description for the plans of how the product will be introduced to marketplace.

## TABLE OF CONTENTS

ABSTRACT .....	2
LIST OF FIGURES AND TABLES .....	2
INTRODUCTION .....	3
Problem Motivation .....	3
User's Requirement .....	3
Design differentiation and Key aspects .....	3
MAIN BODY: SUMMARIZATION OF ALL DELIVERABLES.....	4
Need identification and product specification process .....	5
Targeted clients' needs.....	5
Product specification process .....	5
Conceptual designs .....	8
Design Criteria:.....	8
Visually representation .....	9
Project planning and feasibility study.....	10
Project Planning:.....	10
Feasibility study:.....	11
Prototyping, testing and customer validation.....	12
Prototyping: .....	12
Testing.....	13
Customer Validation: .....	14
Description of final solution and its features .....	15
Business model .....	16
Identification of business model.....	16
Business model canvas .....	17
Economic analysis .....	18
List of costs:.....	18
3-year income statement: .....	19
NPV analysis and Break-even point: .....	19
CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK .....	20
Lessons learned.....	20
Productive avenues for future work.....	20
BIBLIOGRAPHY & APENDICES.....	21
Picture of the device.....	21
Control unit of the device .....	21
Picture of specification of the motor.....	22
Codes for servo motors used.....	22
RobotRun.cpp .....	22
RobotRun.h.....	25

## LIST OF FIGURES AND TABLES

Figure 1	Illustration of Design Thinking Process.....	2
Figure 2	Robotic Arm from Harbin Institute of Technology.....	3
Figure 3	Working Demonstration of Robotic Arm from Japan.....	3
Figure 4	Visually representation of the robotic arm concept.....	6
Figure 5&6	Robotic arm prototype.....	11&21
Figure 7	Validation Board.....	13
Table 1	List of metrics of client A.....	4&21
Table 2	List of metrics of client B.....	4
Table 3	Project Planning.....	7
Table 4	Business Model Canvas.....	16
Table 6	Variable Costs.....	16
Table 7	Direct Costs.....	17
Table 8	Indirect Costs.....	17
Table 9	Fixed Costs.....	17
Table 10	3-year income statement.....	18
Table 11	NPV analysis.....	18
Table 12	Break-even point.....	19

## INTRODUCTION

### Problem Motivation

Assistive feeding devices are designed for people with disabilities. It can be as simple as a spoon, a fork but it could also be complicated equipment which is the integration of the most advanced technologies.

Both of our clients are from Saint-Vincent Hospital, one of them is an adult lady on a motorized wheelchair, she has a limit arm movement and have difficulties eating and drinking by herself. Another client is a senior lady who is constrained in her bed and her arms have a minimum range of movements, also her strength is too small to hold any type of utensils even the lightest plastic spoon or a straw. Both of them need assistant when they are eating.

Our mission is to design an assistive feeding device with whose help the clients can eat on their own or replace the person who help them eat.

### User's Requirement

During our visit to our clients, they expressed some expectations to the function of the device. Our first client, the lady in her wheelchair, not only wanted the device to help her with eating but also, she needed the device to help her live more independently. She has three main requirements, first the device must make her eating process easier. Second, she wanted the device also help her turn the pages of a book or a magazine. Third, she wanted the device to help her reach something that is far away from her, for example, help her push the button of the elevator or help her change the channel.

The second client, the senior lady, her requirement was more basic compared to the other client. She simply wanted the device the help her eating and drinking but the weight of the device is important since she could not handle any weight even if a straw.

### Design differentiation and Key aspects

The device is made of four servo motors, an Arduino board and a few LED indicators. The bottom motor has a rotating angle of 360 degrees, all the other motors have 180 rotating angles. There are some existing assistive feeding devices in the market but what makes our product unique is its low cost and its great potential of being a multi-function device by loading more complicated codes into the device. The device can be using as a machine that helps the clients turning pages by simply adding another set of coding onto it. Also, our device has a controller which has a few buttons and two joysticks. The client could use the joysticks to control the robot arm which could give them a large range of movement, a normal assistive feeding device cannot achieve this. Other

key aspect includes high quality frame material, the frame of the device is made of aluminum, the lost cost to replace the broken parts.

## MAIN BODY: SUMMARIZATION OF ALL DELIVERABLES

In order to enable our team to keep our tack and be more effective to develop and finalize the product, our group decide to choose design thinking as the appropriate design process to follow due to the following reasons: our project requires to have empathy with clients in the purpose of getting both their needs and feedbacks, it is essential to discuss and prioritize the needs and decisions with clients before add new or eliminate old functionalities to/from the prototype, each modification require the generation of new ideas and then use the prototype to establish these priorities with the clients, and finally iterate the proceeds to constantly refine our prototype to the final product.

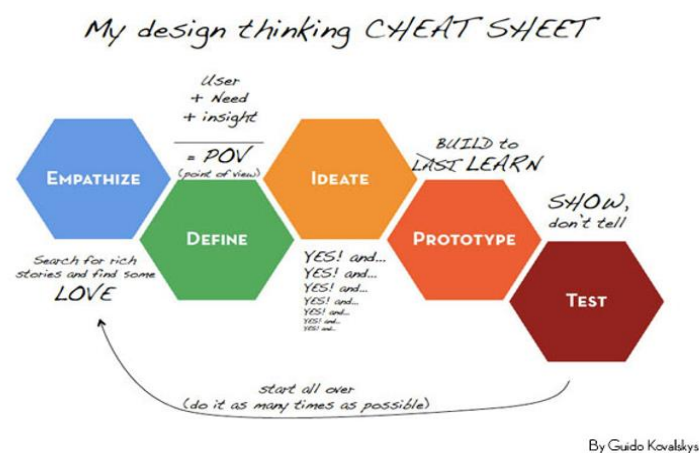


Figure 1 Illustration of Design Thinking Process.

The following subsets will present our critical components during the design process. Not only is to illustrate how we approach our final product step by step, but also justify that our final solution is the most appropriate one.

Need identification and product specification process

Targeted clients' needs

- 1) The robotic arm must assist clients to feeding themselves and should take actions in a smooth way.
- 2) The product must be easily and comfortably operated by applying a few of strength by clients.
- 3) The product can do actions in unlimited angles, especially can scoop.
- 4) The product need to have the ability to be fixed in certain places and is also removeable to other places.
- 5) The product can help client to do daily things such as turn page, push the elevator button, and picking up.

The appearance of the product will either in blue or pink.

Product specification process

1. Problem statement:

Design an assistive feeding product with simple operations, less strength requirement, and fixed position to assist elder people who are incapable of looking after themselves.

2. Benchmarking:

a) From Harbin Institute of Technology:

Using voice control technology, through the computer software in advance, the master's voice into the robot's internal chip, robot remember the owner's voice, master. When using the microphone to give instructions, the robot receives instructions and rotates plates or feeding according to requirements.



Figure 2 Robotic Arm from Harbin Institute of Technology.

b) From Japan:

The rod can be operated on the arm of the robot by using the position of the jaw or shoulder. The front end of the robot arm is equipped with a fork and a spoon, which can automatically clip the food and send it to the operator's mouth. The soft food can be scooped directly with a spoon, the upper fork will be retracted, the paralyzed patients under the neck and the inconvenient old man can also eat on its own.



Figure 3 Working Demonstration of Robotic Arm from Japan

3. List of metrics:

a) Client A:

Metrics (Each need it address) ◦	Imp ◦	Units ◦
Weight of the control unit (For picking up) ◦	1 ◦	g ◦
Length of the control arm (Different body size of clients) ◦	1 ◦	CM ◦
Height of the entire device above the tray (Easy to operate) ◦	2 ◦	CM ◦
Total mass (Easy to operate with few applying strength) ◦	1 ◦	g ◦
Moving rage of the device (Area) (Comfortably to operate) ◦	2 ◦	CM <sup>2</sup> ◦
Moving speed (Moving smoothly) ◦	2 ◦	m/s ◦
Power of the motor (Provide enough strength) ◦	3 ◦	Kw ◦
Rebooting time ◦	4 ◦	<u>ms</u> ◦
Maximum tip rotating angle ◦	2 ◦	degree ◦
Maximum arm rotating angle ◦	3 ◦	degree ◦

Table 1 List of metrics of client A

b) Client B:

Metrics (Each need it address) ◦	Imp ◦	Units ◦
Weight of the control unit (For picking up) ◦	2 ◦	g ◦
Length of the control arm (Different body size of clients) ◦	2 ◦	CM ◦
Height of the entire device above the tray (Easy to operate) ◦	2 ◦	CM ◦
Total mass (Easy to operate with few applying strength) ◦	5 ◦	g ◦
Moving rage of the device (Area) (Comfortably to operate) ◦	1 ◦	CM <sup>2</sup> ◦
Moving speed (Moving smoothly) ◦	3 ◦	m/s ◦
Power of the motor (Provide enough strength) ◦	3 ◦	Kw ◦
Rebooting time ◦	5 ◦	<u>ms</u> ◦
Maximum tip rotating angle ◦	1 ◦	degree ◦
Maximum arm rotating angle ◦	1 ◦	degree ◦

Table 2 List of metrics of client B



4. Target specification:

1) Weight of the control unit:

Marginally: < 100g, Ideally: < 50g

**Reason:**

The control unit is a small device our client will use to control the entire. Including picking up food, rotating the dish and grab the utensil etc. During our interview with our client A, she expressed her concern about the maximum weight she can hold in her hand, even a plastic strew can sometimes add burden to her hand and arm. Thus, the weight of the control unit is critical for her. We want to design something that she can use easily without adding pressure to her hand. On the hand, our client B can hold much heavier things than our client A.

2) Length of the control arm:

Marginally < 50 cm, Ideally: Between 30 cm to 50 cm and adjustable

**Reason:**

Both of our client A and B use a tray when they are eating. The distance from the tray to their mouth is roughly about 30 cm to 50 cm. However, the body size of client A is much smaller than client B, which means client A has a shorter distance to reach the food then client B. So, we want to design something that is adjustable so that it can fit both of our client.

3) Height of the device from above the tray:

Marginally: < 50cm, Ideally: < 40cm

**Reason:**

The reason for this is that the maximum height of the device should not higher than the clients' forehead so that they don't have to look up when they are using the device. The height from their mouth to the tray is about 30cm to 40 cm.

4) Moving rage of the device (Area):

Marginally: 40CM~50CM (In diameter), Ideally: 50CM (In diameter)

**Reason:**

The moving rage of the device should be the same width of the tray and covers every single point in the tray in order that the clients can put their food wherever they want on the tray. Ideally, the moving rage should be slight bigger then the area of the tray.

5) Moving speed of the device:

Marginally: < 0.025 m/s, Ideally: 0 ~ 0.025 m/s

***Reason:***

A major issue caused failure from last team was that they used a servo motor but could not control the rotating speed of the motor. Thus, we would like to make a knob or add a potentiometer for controlling the speed of movement. From 0 to 0.025 m/s, as the client preferred.

6) Power of the motor:

Marginally: enough to hold a stainless-steel spoon, ideally: powerful enough to hold a cup filled with water

***Reason:***

A major issue caused failure from last team was that Their device cannot handle the weight of a spoon with food in it. Thus, we would like to design a device that is strong enough to hold a spoon with any kind of food in it. Preferably, the device could handle the heavy things like a book or a glass of water.

7) Total mass of the device:

Marginally: < 500g, Ideally: between 0~500g

***Reason:***

During our interview, we noticed clients sometimes put bible or magazine on their tray. So, it is important for them to be able to take the assistive device off by themselves and make more room for other stuffs. Since our client A cannot lift very heavy things. The total mass of the device should be under half a kilo.

Conceptual designs

Design Criteria:

- 1) The robotic arm must be easy to operate (turn-on or turn-off) does not require extra strength provided by client.
- 2) The moving speed of robotic arm must be smoothly which is in the range of 0 ~ 0.025 m/s.
- 3) The power of motor must be sufficient enough that can easily to finish the action of scooping.
- 4) The position of robotic arm must be easily change and fix (mass of product need to in the range of 3.0~5.0 kg), and the postures of arm should be convertible/changeable to corresponding with client's position.
- 5) The robotic arm should automatically feed clients after it got set up.
- 6) The height of robotic arm should not over 50 cm and the length of arm will be in the range of 30~50 cm.

- 7) The robotic arm may help clients to pick up/turning pages and the weight of the control unit should less than 100 g.

### Visually representation

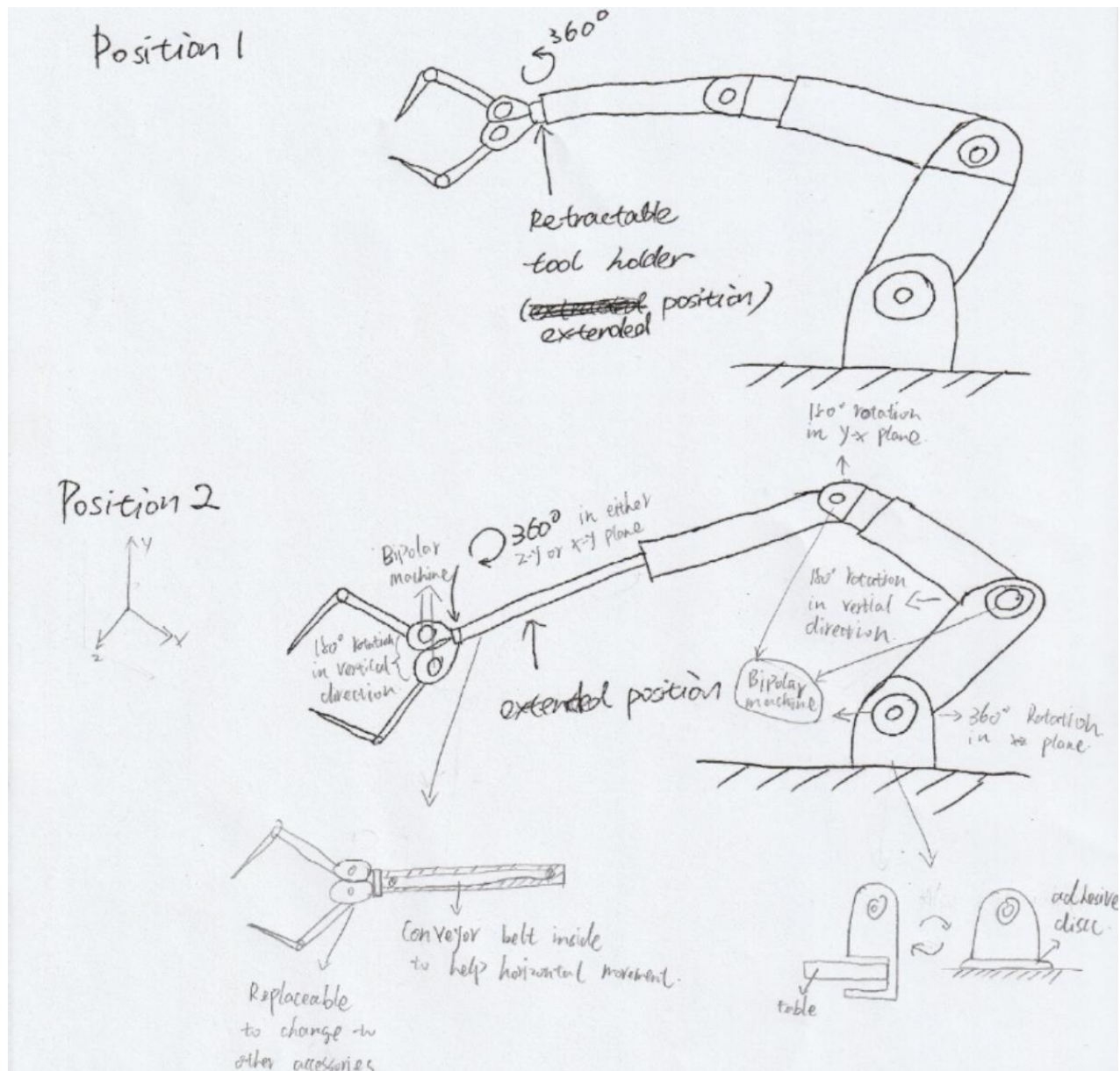


Figure 3 Visually representation of the robotic arm concept

## Project planning and feasibility study

### Project Planning:

Tasks↵	Responsible Team Member↵	Estimated Duration↵	Dependencies↵
Re-analysis of Clients' needs ↵	Pthahnil Guo↵	Jun 5~Jun 6↵	↵
Analysis of product's difficulties↵	Mohit Kapur & Pthahnil Guo↵	Jun 6~Jun 8↵	↵
Separation of individual technical deficiencies↵	Leo Tan & Qi Qin↵	Jun 6~Jun 8↵	↵
Material research↵	Zhang Jichen↵	Jun 5~Jun 7↵	↵
Constrains research↵	Qi Qin↵	Jun 5~Jun 6↵	↵
Develop proper solutions↵	All team members↵	Jun 6~Jun 8↵	↵
Appearance design ↵	Zhang Jichen↵	Jun 8~Jun 15↵	↵
Structural design ↵	Pthahnil Guo & Mohit Kapur↵	Jun 8~Jun 15↵	↵
Software design↵	Qi Qin & Leo Tan↵	Jun 8~Jun 15↵	↵
Circuit design↵	Zhang Jichen↵	Jun 8~Jun 15↵	↵
Robotic arm System module development↵	Pthahnil Guo↵	Jun 15~Jun 23↵	↵
Remote system module development	Leo Tan & Qi Qin↵	Jun 15~Jun 23↵	↵
Servo motor system development↵	Mohit Kapur↵	Jun 15~Jun 23↵	↵
Power supplement system development ↵	Zhang Jichen↵	Jun 15~Jun 23↵	↵
Integrating system module development	All team members↵	Jun 23~Jun 25↵	↵
Porotype system testing ↵	All team members↵	Jun 25~Jun 26↵	↵
Issues identification and document ↵	Qi Qin & Leo Tan↵	Jun 26~Jun 27↵	↵
Issues correction ↵	Pthahnil Guo & Mohit Kapur↵	Jun 27~Jun 28↵	↵
Product refinement↵	All team members↵	Jun 28~July 5↵	↵

Table 3 Project Planning

### Feasibility study:

#### a) Technical:

Our team does have enough expertise and technical resources for our project. Since our project idea to create a robotic arm, it is technically possible for us to make our project come to life. From what we have discussed, we'll require several alumni supports, servo motors, Arduino Nano, Handle, AC Power Adaptor, and electronics to control the speed of the motors. According to these items, our team can easily purchase them through online customer design. The main technical problem that will inhabit our design process is how to programming the list of actions and enable the actions perform on the robotic arm as expected.

#### b) Economic:

In general, our project could be done in the range of given budgets. However, there are several things that will affect the cost of project. For examples, both the materials of our alumni support and servo motors are required to reach the needs of clients, easy operation with less strength requirement, which may occupy a big percentage of our budgets. Besides this, we definitely will require the usage of 3D printing, and the quality of the printing may not satisfy our expected standard; or if there is a design changing or physical damage that requires re-printing. All the situation that mentioned above will cause our final cost increases. Therefore, our costs may beyond the given budgets, but all of the costs are reasonable and will be documented with the prove of receipts.

#### c) Legal:

Overall, robotic arm is an extreme hot topic with many technical knowledges involved. Thus, we do need to consider many intellectual properties such as patent and industrial design in order to make our product illegally functional that not offense others' rights.

1) Patent 2744162- Bluetooth Networking

2) Patent 2739727- Portable Robotic Arm

3) Industrial design: Educational Robot-Registration number: 174793

#### d) Operational:

Essentially, everything about this project is fairly straightforward: build a device to assist with feeding. When it comes to actually developing the product, that's where we could potentially run into some issues. The biggest constraints that would prevent our success would be a lack of knowledge when it comes to

certain topics and having too little or the wrong materials. Both of the situations listed would prevent our group from achieving success.

e) Scheduling:

Ourselves tasks deadlines are determined by the whole team, and mainly depend on the types of works we need to done. For example, the re-analysis of Clients' needs and the analysis of product difficulties on due on June 6 and June 8 respectively, the duration of each task is among one or two days. However, for the deadlines of software design and structural design are on June 25, that the duration is much longer due to the amount of the works of these tasks have and the high level of difficulty compared to the analysis section. Thus, most of our deadline and duration of each task are accord with their difficulties and the amount of works. In addition, some tasks' deadline may vary depend on the Personal condition of responsible team member of each task. The deadline of the final product is among the end of July, it is pretty possible for us to execute the final deliverable to our clients, although we may need to catch up a little bit.

Prototyping, testing and customer validation

Prototyping:

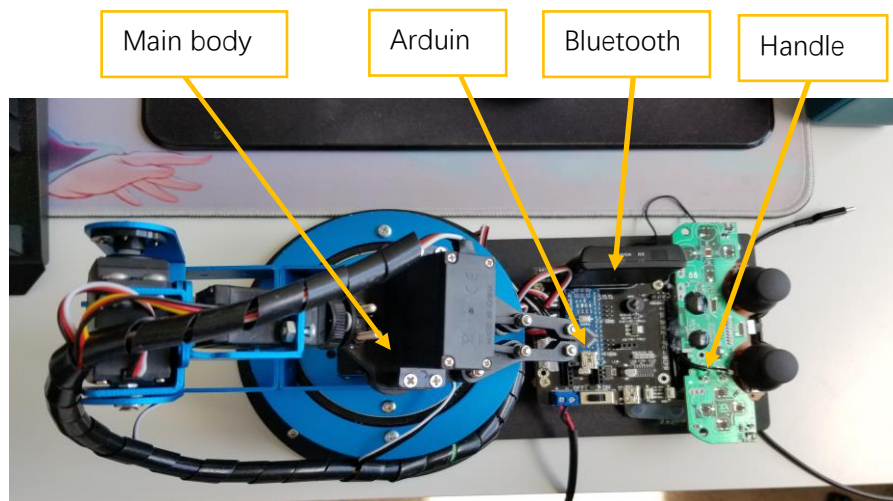


Figure 5 Robotic arm prototype

The basic plan to achieve assistive feeding is letting plier to hold a scoop and program a list of actions that enable the arm to finish scope and deliver foods in certain fixed areas by using a handle via Bluetooth.

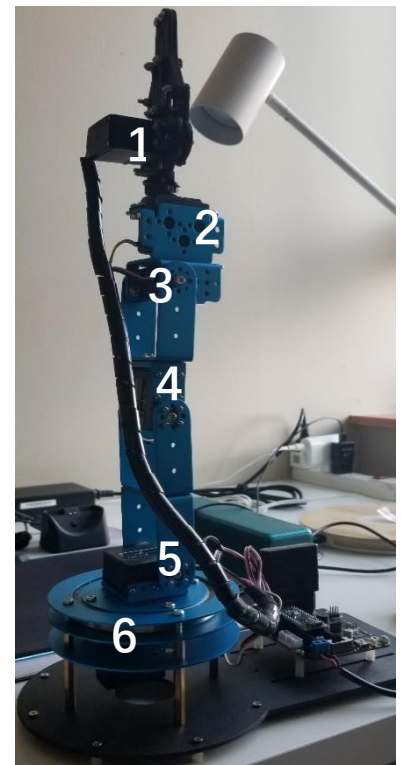


Figure 6 Robotic arm prototype

## Testing

### 1. Test Define process:

#### 1) Dimension measurements test

Upon the finishing of prototype using cardboards, we measured the height, length, width, etc. of the prototype to make sure the height is perfect for our customer and the finishing equipment will fit on the little table that our client eats on.

#### 2) Strength test

We put several light to heavy material on the rotating surface and the conveyor belt part of the prototype to make sure that the equipment is strong enough to hold the weight of the food. The test result came out well since the prototype is made of cardboard. Once the final product is made, the conveyor belt and rotating table will be able to hold more weight because different material will be used to build the final project.

#### 3) Appearance test

Each our group member gave opinions of the appearance since one of our client has special need for the appearance and color of the project. We took a picture of the prototype and use a mobile phone app to put color on the prototype. By doing this, we can determine the possible ways to improve the appearance of our product.

#### 4) Durability test

Since we want to build a durable and reliable product for our clients so we did a few test on the durability of different material. The rotating mechanism part of the product tends to have more technical failure so find the best material for the rotating wheel is critical for the success of the final product. We built this part with different material that we could find in the maker lab.

### 2. Problems identified in testing:

#### a) Defuncting of one motor:



- The first thing we could think of is coding error, in order to find out if this is caused by the coding error, we and PMS checked coding but everything seems fine.
- The second possibility is the mechanical failure of the motor, in order to confirm if there's mechanical problem, we exchange this motor with different motors.
- The third thing could be something happened to the mother board. To test this, we connected this motor to the other outputs on the motor board, and it works perfectly. Thus, we came to conclusion there is nothing wrong with the board.

b) Losing of blue tooth connection:

After the uploading of the new codes to Arduino, we lose the RX output which is used for Bluetooth connection. We try to solve it replace the Arduino Nano with same codes inside, but the result is same. In addition, the low voltage alarm is still ring, which we conclude that the problem may occurs on AC adaptor or is still due to Arduino board. However, we run out of both materials and time, and these two problems have to leave for next team to fix.

Customer Validation:

Validation Board					
Track Pivots		Start	1st Pivot	2nd Pivot	3rd Pivot
Customer Hypothesis		Conveyor belt failure	Rotating table failure	The food will fall off from the belt	
Problem Hypothesis		Too much friction on conveyor belt on the motor side caused	Due to the mechanical failure, the turntable won't work.	Due to the smooth surface of the belt. The food won't stay on	
Solution Hypothesis		Design a conveyor belt from scratch. Or use a roller conveyor belt system	Get a similar mechanical system for robots toy like a toy car, then convert it into turn table	Make a small plate on the conveyor belt, so the food sits in it.	
Design Experiment		<p><b>Riskiest Assumption</b></p> <p>The conveyor belt will detach and break.</p> <p><b>Method</b></p> <p>Observing and testing.</p> <p><b>Success</b></p> <p>The roller conveyor belt works well at first on transfer food.</p>			
<p><b>Design Experiment</b></p> <p>The conveyor belt can hold weight of food on it and will not detach on it own.</p> <p>The turntable can turn to the left and right without friction and resistance is good.</p> <p>Make different shape of plate on the conveyor belt, see if the food can sit in it.</p>		<p><b>Results</b></p> <p><b>GET OUT OF THE BLDG</b></p> <p><b>Invalidated</b></p> <p>1. Only eat the food and the food will not stay on the belt.</p> <p>2. Only eat the food and the food will not stay on the belt.</p> <p>3. Only eat the food and the food will not stay on the belt.</p> <p>4. Only eat the food and the food will not stay on the belt.</p> <p>5. Only eat the food and the food will not stay on the belt.</p> <p>6. Only eat the food and the food will not stay on the belt.</p> <p><b>Validated</b></p> <p>1. Have a table find similar system.</p> <p>2. Have a table find similar system.</p> <p>3. Have a table find similar system.</p> <p>4. Have a table find similar system.</p> <p>5. Have a table find similar system.</p> <p>6. Have a table find similar system.</p>			

Figure 7 Validation Board



## Description of final solution and its features

1. Using online customer design service to gather the components of robotic arm.
  - Due to the constraints of time and labor, the rest of group decide to use the online design service to get all materials required. Although it increases the budgets, it definitely will make the final prototype more effective and saving the time for us to focus on other problems.
2. Flexible arms and base which can rotate 180 degrees (base) and 90 degrees (joints) respectively.
  - According to figure 5 & 6, the main body of robotic arm will take actions by the rotations of servo motors from ID 2-5 in certain degrees. The ID 6 motor will cause main body to rotate in y-axis in the range of 180 degree. The ID 1 motor will control the plier to hold or release staff.
3. A solid frame which will not bend easily due to the weight of some heavy food and must be able to handle unexpected vibration and hitting, for example dropping on the floor by accident.
  - Achieving the goal by using aluminum as the frim material so that the frame is not easily bend or destroyed, and the main body will combine together by the servo motors.
4. A special scoop to be attached on the tip of the robot arm so that the food can be picked up easily.
  - Since the tip of the arm only rotates 180 degrees in the horizontal direction, so we will bend the spoon to make the area that holds the food is vertical to the bar. This is the easiest solution without adding a new joint to the entire system.
5. The equipment can be controlled by a bundle.
  - We use a PS2 handle as a controller so that clients can either using the rockers to control the robotic arm to do expected action or pressing the button on the handle to stimulate programmed actions.
  - We define a button on the as reset button. Once this button is pressed, the equipment will go back to its initial position which can be set up based on the clients' preference.

6. Every single movement of the equipment should be at a relative low speed in case the food spills off the scoop.
  - Achieving this goal by using delay function while programming the servo motor in the arm, and also extend the time period of excitation for each action.
7. Additional functions
  - Except the main function, assistive feeding action, we do add other functions such as pushing elevator buttons, picking up, and turning book pages to satisfy clients' needs, and help them to look after themselves with minimum helps from others.

## Business model

### Identification of business model

“Razor-blade” business model is the one of the most suitable types of business model to commercialize our product. We sell products at separate prices and deal with part of the same product at a low price. For example, if the consumer buys a razor, the beautiful knife rack is sold at a very low price, but the price of the disposable blade is very high. The owner of the tool holder must continue to buy a specific blade to make the manufacturer make a lot of money. In the similar methodology, we will sell our assistive feeding machine with all accessories in it at a relatively cheaper price, and we will sell those accessories which need to be replaced after a period of time at a higher price. In addition, the product owners have to buy those accessories in order to continue to use the product. Thus, we can control the prices and gain profit effectively.

## Business model canvas

<b>Key Partners</b>  - University of Ottawa - Saint Vincent Hospital	<b>Key Activities</b>  - Provide a way to allow people who require assistance to be able to eat on their own	<b>Value Propositions</b>  - Helping to feed humans and potentially animals	<b>Customer Relationships</b>  - Help customers daily life - Provide a product to satisfy customers	<b>Customer Segments</b>  - Disabled people - Weakened people - Disordere d people
	<b>Key Resources</b>  - Algorithm for motor rotation speed - Angular rotation algorithm		<b>Channels</b>  - Website - Amazon - Mobile App - In store(s)	
<b>Cost Structure</b>  - Web hosting - Marketing - Product development - General and administrative			<b>Revenue Streams</b>  - User purchase - Investors	

Table 4 Business Model Canvas

## Economic analysis

### List of costs:

#### 1. Variable costs:

<b>Item</b>	<b>Price for Buying One piece</b>
Alumni Supports	\$25
Motor	\$30
Arduino	\$20
Cable	\$15
3D-print material	\$10

Table 6      Variable Costs

#### 2. Direct cost:

<b>Item</b>	<b>Costs per year</b>
Printer maintenance	\$20

Table 7      Direct Costs

#### 3. Indirect cost:

<b>Item</b>	<b>Costs per year</b>
Depreciation	\$33
General & administrative (G&A) expenses	\$100

Table 8      Indirect Costs

#### 4. Fixed costs:

<b>Item</b>	<b>Cost per year</b>
Rent	\$0
labor	\$0
General & administrative (G&A) expenses	\$100
Marketing Expense	\$33

Table 9      Fixed Costs

3-year income statement:

Table 10 3-year income statement

<b>Income Statement:</b>	<b>1<sup>st</sup> year</b>	<b>2<sup>nd</sup> year</b>	<b>3<sup>rd</sup> year</b>
Total Revenue	\$1,140	\$1,900	\$2,660
Cost of Goods Sold	\$ 900	\$1500	\$2,100
Gross Profit	\$ 240	\$400	\$560
<b>Operating Expenses:</b>			
General & administrative (G&A) expenses	\$100	\$100	\$100
Utilities	\$67	\$67	\$67
Depreciation	\$33	\$33	\$33
General & administrative (G&A) expenses	\$33	\$33	\$33
<b>Total Operating Expenses</b>	<b>\$233</b>	<b>\$233</b>	<b>\$233</b>
<b>Operating Income (EBIT)</b>	<b>\$7</b>	<b>\$167</b>	<b>\$327</b>
<b>Interest Expense</b>	-	-	-
<b>Earnings before tax (EBT)</b>	<b>\$7</b>	<b>\$167</b>	<b>\$327</b>
<b>Taxes</b>	-	-	-
<b>Net Income</b>	<b>\$7</b>	<b>\$167</b>	<b>\$327</b>

NPV analysis and Break-even point:

<b>Year</b>	<b>Cash Flow</b>	<b>Discount Factor (at 10% nominal interest rate)</b>	<b>Present value</b>
1	\$500	0.909	\$455
2	\$500	0.826	\$413
3	\$500	0.734	\$376
		Net Present Value	\$1244

Table 11 NPV analysis

<b>Year</b>	<b>Fixed costs</b>	<b>Price per unit</b>	<b>Total variable costs</b>	<b>break-even point</b>
1	\$233	\$150	\$360	0.971
2	\$233	\$200	\$600	0.583
3	\$233	\$200	\$840	0.416

Table 12 Break-even point

## CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

### Lessons learned

The most important lesson learned from this project is how to integrate mechanical devices, for example servo motors, to the programming part. We had no experience on how to program a motor before we made this project during which we tried different ways and types code to control the motor.

Soldering is another good example of lesson learned from the project. During our test on of the motor broke down so we need to replace it. However, the new motor had a very short outlet wire, we have to solder some extra wire onto it. As we never used a soldering iron before, it is very challenging at first.

Other lesson learned are timing management ability, having everything done step by step and on time is a key part of this project. Communication skills, how to communicate with groupmates and how to deal with conflicts within the group.

### Productive avenues for future work

The future work includes modifying the code, appearance and integrate additional functions.

At the current stage, the device is only made for grabbing the hard, big pieces food which means the device had a constrain on the type of food. In the future, some work and change could be done to make this device be suitable for all kinds of food, regardless solid or liquid even some stinky food like cheese cake.

Some other feature like recognising hand gesture and voice control can add more value on the project. Using voice control can help reducing the complicity of the control unit, which can bring down the cost.

A box can be added to put all the microcontroller circuit and wire inside so that not only to make the device has a better appearance but also can add water proof function to the device, which is very importance to an assistive feeding device and can also give the equipment a longer life time.

## BIBLIOGRAPHY & APENDICES

Picture of the device

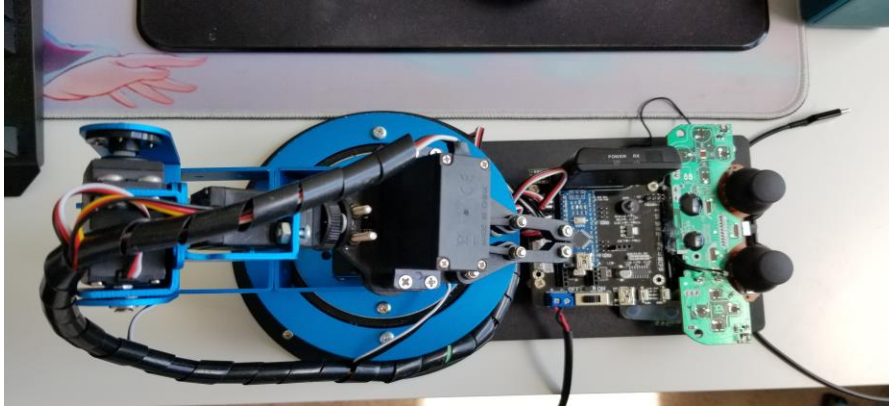


Figure 5 Robotic arm prototype

Control unit of the device

Metrics (Each need it address) ◊	Imp ◊	Units ◊
Weight of the control unit (For picking up) ◊	1 ◊	g ◊
Length of the control arm (Different body size of clients) ◊	1 ◊	CM ◊
Height of the entire device above the tray (Easy to operate) ◊	2 ◊	CM ◊
Total mass (Easy to operate with few applying strength) ◊	1 ◊	g ◊
Moving rage of the device (Area) (Comfortably to operate) ◊	2 ◊	CM <sup>2</sup> ◊
Moving speed (Moving smoothly) ◊	2 ◊	m/s ◊
Power of the motor (Provide enough strength) ◊	3 ◊	Kw ◊
Rebooting time ◊	4 ◊	<u>ms</u> ◊
Maximum tip rotating angle ◊	2 ◊	degree ◊
Maximum arm rotating angle ◊	3 ◊	degree ◊

Table 1 List of metrics of client A

Picture of specification of the motor

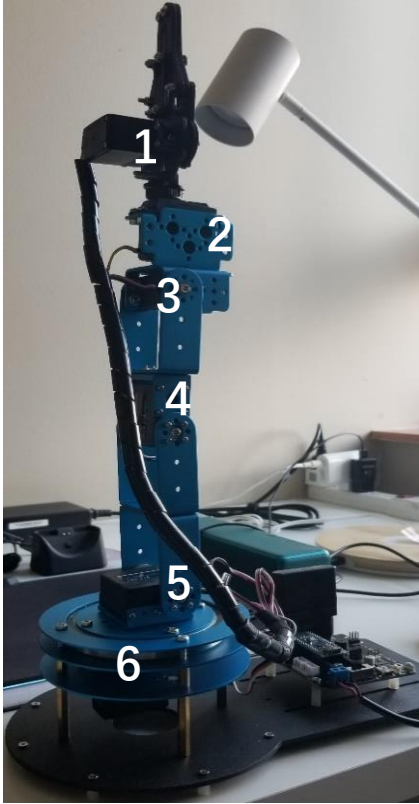


Figure 6 Robotic arm prototype

Codes for servo motors used

#### RobotRun.cpp

```
#include "include.h"
```

```
bool fRobotRun = FALSE;
```

```
uint8 ActFullNum = 0;
```

```
uint32 ActFullRunTimesSum = 1;
```

```
uint32 ActFullRunTimes = 0;
```

```
uint32 TimeActionRunTotal = 0;
```

```
bool fFrameRunFinish = TRUE;
```

```
uint8 FrameIndexSum = 0;
```

```
uint8 FrameIndex = 0;
```

```
void FullActRun(uint32 actFullnum,uint32 times)
```

```
{
```

```
uint8 frameIndexSum;
```



```

FlashRead(MEM_FRAME_INDEX_SUM_BASE + actFullnum,1,
&frameIndexSum);
UART1SendDataPacket(&frameIndexSum,1);
if(frameIndexSum > 0)
{
    FrameIndexSum = frameIndexSum;
    if(ActFullNum != actFullnum)
    {
        if(actFullnum == 0)
        {
            fRobotRun = FALSE;
            ActFullRunTimes = 0;
            fFrameRunFinish = TRUE;
        }
    }
    else
    {
        ActFullRunTimesSum = times;
    }

    if(FALSE == fRobotRun)
    {
        ActFullNum = actFullnum;
        ActFullRunTimesSum = times;
        FrameIndex = 0;
        ActFullRunTimes = 0;
        fRobotRun = TRUE;
        TimeActionRunTotal = gSystemTickCount;
    }
}
}

void FullActStop(void)
{
    fRobotRun = FALSE;
    ActFullRunTimes = 0;
    fFrameRunFinish = TRUE;
    FrameIndex = 0;
}

uint16 ActSubFrameRun(uint8 fullActNum,uint8 frameIndex)
{
    uint32 i = 0;

    // uint16 frameSumSum = 0;

    uint8 frame[ACT_SUB_FRAME_SIZE];
    uint8 servoCount;
    uint32 time;
    uint8 id;

```

```

uint16 pos;

FlashRead((MEM_ACT_FULL_BASE) + (fullActNum * ACT_FULL_SIZE)
+ (frameIndex * ACT_SUB_FRAME_SIZE)
,ACT_SUB_FRAME_SIZE,frame);

servoCount = frame[0];
time = frame[1] + (frame[2]<<8);

if(servoCount > 8)
{
    FullActStop();
    return 0;
}
for(i = 0; i < servoCount; i++)
{
    id = frame[3 + i * 3];
    pos = frame[4 + i * 3] + (frame[5 + i * 3]<<8);
    ServoSetPluseAndTime(id,pos,time);
}
return time;
}

void TaskRobotRun(void)
{
    if(fRobotRun)
    {
        if(TRUE == fFrameRunFinish)
        {
            fFrameRunFinish = FALSE;
            TimeActionRunTotal +=
ActSubFrameRun(ActFullNum,FrameIndex);
        }
        else
        {
            if(gSystemTickCount >= TimeActionRunTotal)
            {
                fFrameRunFinish = TRUE;
                if(++FrameIndex >= FrameIndexSum)
                {
                    FrameIndex = 0;
                    if(ActFullRunTimesSum != 0)
                    {
                        if(++ActFullRunTimes >= ActFullRunTimesSum)
                        {
                            fRobotRun = FALSE;
                        }
                    }
                }
            }
        }
    }
}

```

```

}
else
{
    FrameIndex = 0;
    ActFullRunTimes = 0;
    fFrameRunFinish = TRUE;
    TimeActionRunTotal = gSystemTickCount;

}
}

```

### RobotRun.h

```

#ifndef _ROBOT_RUN_H_
#define _ROBOT_RUN_H_

void TaskRobotRun(void);

void FullActRun(uint32 actFullnum,uint32 times);
void FullActStop(void);

#endif

```