# C2.2 Project Deliverable B:

## Problem Definition, Concept Development, Project Plan

Kyle Leonard

Archibald Given

Ashan Dindyal

Jiadong Yu

Alif Adnan Alif

Michael Haddad

February 2, 2023

# Table of Contents

# B.1 – Problem Definition

## 1.1 - Introduction:

The purpose of this deliverable B is to create a problem definition where all client needs will be listed and prioritized. The client's needs will be prioritized utilizing a weight system, with a brief justification for the importance that was attributed to the specific exigency. Based upon this prioritized list, a problem statement will be developed, which will describe the general purpose of the product.

Need-inspired metrics will be listed and benchmarking equivalent products on the market will be conducted. Additionally, various final prototype concepts will be generated for each subsystem, as well as the entirety of the system. Based upon this list of concepts, only a few will be chosen for further refinement and will be combined into a visually represented global concept.

In brief, the focus of this document is to set objectives based on the client's demands, determine different prototypes with their advantages/disadvantages, and finally, to set specific descriptions for each subsystem of the Robotic Arm.

## 1.2 - Client's Needs:

### 1.2.1 - Interpreted Needs:

- Simplistic iPhone app design which allows the client to control and utilize all aspects of the robotic arm with ease.
- Robotic arm is able to move freely around the client's house.
- Robotic arm is able to grab / hold on to everyday items. (specific items include: container, plastic cup, Nintendo switch remotes, T.V remote, door handle, cabinet handle)
- Arm should be able to pickup/putdown items from the floor up to cupboard shelves
- Robotic arm should use a rechargeable battery.
- Robotic arm is sturdy & secure.
- Robotic arm should be maintainable by anyone.

- Complete the project with a budget of 100$ or less.

## 1.2.2 - Prioritized Needs:

| **Client's Needs** | **Importance** | **Justification** |
|---|---|---|
| 1. Simplistic iPhone app used to control and move the arm | 5 | Client is limited with her ability to interface with an app and usually uses her nose, as such a simple-to-use app is crucial for the arm to be useful to the client. |
| 2. Robotic arm can move freely around the client's house | 4 | It would be nice if the arm can move around the house freely, however it is more important that the arm can grasp and moving objects and could potentially be moved around the house by a caregiver. |
| 3. Robotic arm can grab / hold on to everyday items | 5 | Based upon the first client meet, the client's primary use of the arm is to retrieve common household items such as a cup of water or a container of food from hard-to-reach areas such as the floor or a kitchen counter. |
| 4. Arm should be able to pickup/putdown items from the floor up to cupboard shelve | 5 | If the arm pickup/putdown objects but the range is not sufficient then it will not be useful to the client. |
| 5. Robotic arm should use a rechargeable battery | 3 | If the arm is able to move freely around the house then a rechargeable battery would be useful, however if it had to be plugged into the wall and the cord length allowed large range, or if it was stationary then a battery is not as important. |
| 6. Robotic arm is sturdy, secure | 5 | The client is not able to push / move herself around the house on her own; hence it is important that the robotic arm is built with a strong foundation and is consistently able to stay up and in use. |

| | | |
|---|---|---|
| 7. Complete the project with a budget of 100$ or less | 5 | In project description. |
| 8. The arm should be maintainable by anyone | 2 | As long as the arm is sturdy and secure it should breakdown infrequently and maintenance could be done by someone who is a part of the school program. |

* Importance is ranked from 1 (least important) to 5 (most important) *

### 1.2.3 - Unknown Information:

- Distance between front of kitchen counter to front of kitchen cabinet. (Will measure Client Meeting 2).

## 1.3 - Problem Statement:

Create a low-cost, sturdy, and strong robotic arm controlled via a simple and easy-to-use iPhone application for a wheelchair-bound client who has limited mobility. The arm must be able to pick up various household items, be rechargeable, and move freely around her home.

## 1.4 - Benchmarking:

https://assistive.kinovarobotics.com/product/jaco-robotic-arm
https://www.assistive-innovations.com/en/robotic-arms/iarm

### 1.4.1 - Benchmarking table based upon other products:

| Product Name: | Jaco Robotic Arm | iARM |
|---|---|---|
| Company Name: | Kinova Robotics | Assistive Innovations |
| Weight of Arm | 5.2 kg / 11.5 lbs | 9 kg / 19.8 lbs |
| Maximum payload of arm | 1.3-1.6 kg / 2.9-3.5 lbs | 1.5 kg / 3.3 lbs |
| Maximum reach of arm | 900 mm / 2.95 ft | 900 mm / 35.4 in |
| Power Consumption (Average) | 25 W (5 W on standby) | Less than 24 W |
| Method of controlling the arm | Joystick in addition to an optional OLED display | Joystick in addition to a 5x7 in LCD display |
| Maximum opening of gripper | N/A | 9 cm |

## 1.4.2 - Benchmarking table based upon our own measurements of household objects:

| Object Name | Weight (g) |
|---|---|
| Basic Containers:<br> <br> | Container on the right: 28 g<br>Container on the left: 41 g<br>Container on the right with cookies inside: 104 g |
| Plastic Cup of water (similar dimensions to the cup used by the client)<br> <br> | Empty cup on the left: 75 g<br>Cup full of water on the right: 576 g |

| | |
|---|---|
| Plastic Water bottle:<br> <br> <br> | Empty water bottle in the top left: 192 g<br>Water bottle in the top right (500ml): 704 g<br>Water bottle in the bottom left (24oz or 710ml): 898 g |

## 1.5 – Metrics and Units

| **Metric #** | **Need #** | **Metric** | **Imp** | **Unit** |
|---|---|---|---|---|
| 1 | 3,6 | Maximum payload weight | 5 | g |
| 2 | 3 | Maximum payload width | 5 | mm |
| 3 | 3 | Maximum payload depth | 5 | mm |
| 4 | 4 | Minimum arm range (height) | 5 | mm |
| 5 | 4 | Maximum arm range (height) | 5 | mm |
| 6 | 4 | Maximum arm range (depth) | 5 | mm |
| 7 | 3 | Maximum opening of gripper | 5 | mm |
| 8 | 7 | Cost | 5 | $$ |
| 9 | 5 | Uses battery | 4 | Boolean |
| 10 | 5 | Battery life | 3 | Min |
| 11 | 5 | Power Consumption | 2 | W |
| 12 | 2 | Can move freely around house | 4 | Boolean |
| 13 | 1 | How to interface with app | 5 | Appendage |
| 14 | 8 | Training required to fix/maintain | 2 | Capability |
| 15 | 2 | Speed of locomotion | 2 | mm/s |

## 1.6 – Target Specifications (Marginal and Ideal Values):

| **Metric #** | **Metric** | **Unit** | **Marginal value** | **Ideal value** |
|---|---|---|---|---|
| 1 | Maximum payload weight | g | 500-1000 | 1000 |
| 2 | Maximum payload width | mm | 100 | 200 |
| 3 | Maximum payload depth | mm | 100 | 200 |
| 4 | Lowest arm range (height) | mm | 500 | 0 |
| 5 | Tallest arm range (height) | mm | 1000 | 2000 |
| 6 | Maximum arm horizontal distance | mm | 300 | 600 |
| 7 | Cost | $$ | <=150 | <=100 |
| 8 | Uses battery | Boolean | False | True |
| 9 | Battery life | Min | 300 | 600 |
| 10 | Power Consumption | W | <25 | <20 |
| 11 | Can move freely around house | Boolean | False | True |
| 12 | How to interface with app | Appendage | Fingers | Nose |
| 13 | Training required to fix/maintain | Capability | Student of GNG2101 | Anyone |
| 14 | Speed of locomotion (wheeled platform) | mm/s | 50 | 150 |

| **Metric #** | **Justification** |
|---|---|
| 1 | Ideal: A value of 1000g would allow the client to pick up / hold onto items slightly heavier than her typical items (plastic water cup, cookie jar).<br>Marginal: A value between 500-1000g may not allow for heavier items but can still maintain needed objects used in her daily lifestyle. |
| 2 | Ideal: allows the arm to grasp large containers.<br>Marginal: the arm cannot grasp large containers but can still grasp cups and smaller objects |
| 3 | Ideal: allows the arm to grasp large containers. |

| | |
|---|---|
| | Marginal: the arm cannot grasp large containers but can still grasp cups and smaller objects |
| 4 | Ideal: arm can grab objects on the floor<br>Marginal: arm is limited to objects on tables or higher |
| 5 | Ideal: arm can grab objects on the top cupboard shelf<br>Marginal: arm is limited to objects on the countertop or lower |
| 6 | Ideal: arm can grab items on the back of the countertop/cupboard and middle of tables<br>Marginal: arm is limited to objects on the front half of the counter/edges of the table |
| 7 | Ideal: project description says cost should be capped at $100<br>Marginal: if cost needs to increase to better fulfil needs it might be ok |
| 8 | Ideal: would be best if the arm operates by battery<br>Marginal: if it can use a battery being plugged into the wall is ok |
| 9 | Ideal: would last an entire day of use<br>Marginal: would have to recharge throughout the day, but still get good amount of use from 1 charge |
| 10 | Ideal: The ideal value would be 20 W or less, as this lower value would help further limit the negative effect on the wheelchair battery<br>Marginal: Based upon benchmarking data, the average arm uses about 25 W through the wheelchair battery which would make it decently power efficient |
| 11 | Ideal: client would like the arm to be able to move around the house freely<br>Marginal: if it can't move, it could be placed in a room by caregiver where it has the range to access items of need |

| | |
|---|---|
| 12 | Ideal: this is the way the client usually interfaces with apps and their best means of control<br>Marginal: the client has less fine control with fingers so this is less ideal |
| 13 | Ideal: Would be best if the arm could be fixed / maintained by anyone as it would allow for caregivers to help quickly without much commotion.<br>Marginal: A student of level GNG2101 or higher would be okay, however less ideal as arm may be out of use for a period of time (until someone can get there). |
| 14 | Ideal: A speed of 150mm/s would allow for quicker/faster use.<br>Marginal: A speed of 50mm/s would be justifiable and would mostly guarantee the sturdiness and strength of the arm. |

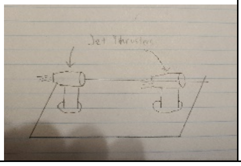
# B.2 – Concept Development

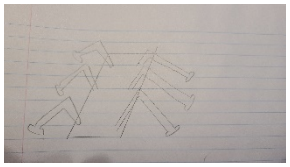
## 2.1 - Sub-System Development

### 2.1.1 - Method of Locomotion

Subsystem Description: One of the aspects of the arm that client mentioned was for it move separately from the actual wheelchair on the floor. Therefore, the possibility of how exactly the arm will move when on the floor will be explored through various existing concepts of locomotion.

Concepts:

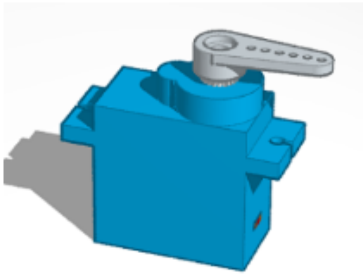
| **System** | Maintainability/Reliability: | Ability to move freely: | Speed of locomotion: |
|---|---|---|---|
| Wheels | Eval: Wheels will be the simplest mechanism to maintain and will prove to be reliable. Can be maintained by caregivers. | Eval: A wheeled platform may struggle with manoeuvrability (large turning circle) around the house and may be difficult to control should it get stuck. However, it still satisfies the requirement of moving freely. | Eval: A wheeled platform will meet the ideal speed value as specified as being 150 mm/s. |
| Tracks | Eval: A tracked platform has a greater number of complex parts involved, therefore it may be prone to issues with reliability. Can be maintained by caregivers. | Eval: A tracked platform has the benefit of offering the greatest and most precise manoeuvrability as it can neutral steer and has lower ground pressure than the other options. | Eval: A tracked platform may not be able to achieve the ideal speed value, due to the steering and increased friction. A tracked platform will satisfy the marginal value of 50 mm/s. |
| Jet Thrust  | Eval: A jet engine will prove to be the most unreliable due to the vast increase in mechanical | Eval: A jet-powered platform will be difficult to control and will not satisfy the requirement of | Eval: A jet-powered platform will mostly likely exceed the ideal speed of 150 mm/s. |

| | | | |
|---|---|---|---|
| | complexity. Cannot be maintained by caregivers. | moving freely around the house. | |
| Spider Legs  | Eval: Spider legs on the platform will also not satisfy the requirement of being maintained by caregivers due to the greater complexity of parts. | Eval: Spider legs will not satisfy the requirement of moving freely, due to the increased chance of getting stuck on objects around the floor (turning a corner). | Eval: A spider leg platform will struggle to meet the marginal value for speed. As it is limited by the mechanical movement of each leg. |

## 2.1.2 - Method of Arm Motion

Subsystem Description: This subsystem involves the actual movement of the arm and will incorporate movement within the X, Y and Z axes.

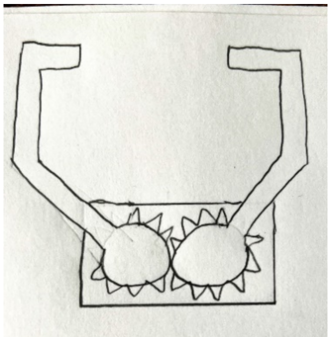
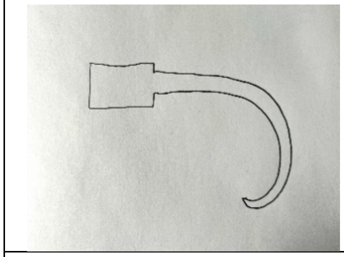
Concepts:

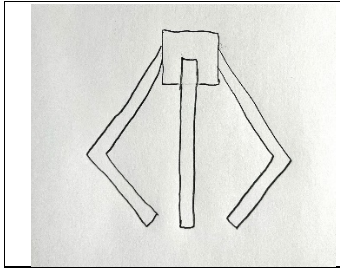
| **System** | **Performance:** | **Reliability:** |
|---|---|---|
| Pneumatic | Eval: Pneumatic system operates with very less resources. Compressed air can retain its pressure over long time.<br>However, it has potential noise during the operation. It is hard to control and to perform very precise motions, which will not satisfy the requirement of grabbing item precisely. | Eval: Less Operating and maintenance cost. |
| Servo motor  | Eval: Servo motors are easy to install and use. They have fast response with accurate controls, providing the precise grabbing concept.<br>The drawback is that the servo motors may not have the required torque to lift heavy things at distance. | Eval: No high technical requirements and low maintenance cost |

| | | |
|---|---|---|
| | Calculations needed to decide. | |
| Pulley System | Eval: Pulley system require other system to control and can only perform one direction movement. It requires large space for install and operate. With applying pulley on the lifting mechanism, less force required for heavy lifting, | Eval: Require regular check-up for belts/cable and rollers. |

## 2.1.3 - Hand Mechanism

Concepts:

| System | Max Payload Width (mm) | Max Payload Depth (mm) |
|---|---|---|
| Dual Gear Claw  | >= 1000 | >= 1000 |
| | Eval: can grasp objects of width and depth that meet the target specs. Grasps objects from the front so requires less vertical clearance and may be easier to precisely control. May suffer when grasping smaller objects, may be able to open clients' doors. | |
| Hook  | N/A | N/A |
| | Eval: the hook would be useful to pick up articles of clothing however it would struggle with holding onto cups/containers and other rigid objects. | |
| Arcade Claw | >= 1000 | >= 1000 |
| | Eval: can grasp objects of width and depth that meet the target specs. The arcade claw must grasp objects from above and so requires more vertical clearance may be harder to precisely control, also will not be able to open doors. | |

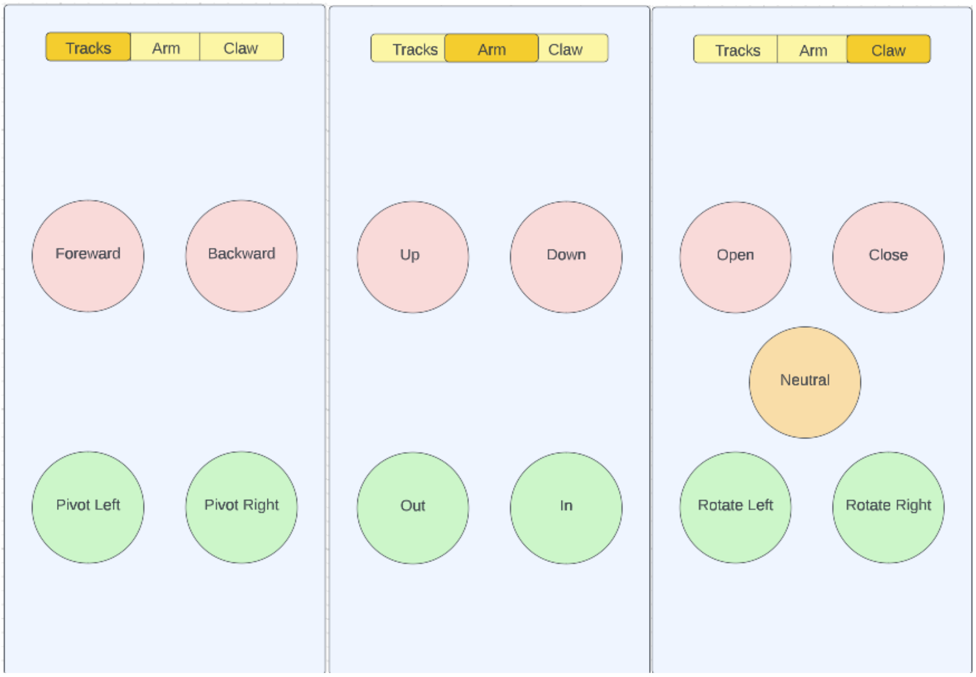
| | |
|---|---|
|  | |

## 2.1.4 - App Interface

Concepts:

- MIT app inventor

MIT app inventor will be used to make the devices app controller. Below is a proposed app layout. This layout uses 3 separate interfaces for the movement control, the arm motion control, and the motion of the hand mechanism. The interfaces are chosen such that they can be easily controlled with only input from the nose.



## 2.1.5 – Controller

Subsystem Description: This subsystem builds the connection between the App and the arm. It controls all the mechanical movements of the arm with user interactions from the software.

Concepts:

- Arduino

Arduino controller will be used to connect the arm with user interactions. The Arduino board will build communication with the phone and be connected to all the mechanical control systems. The codes for control are easy to learn and use. With the MIT app inventor, the movement control, the arm motion control, and the motion of the hand mechanism can be implemented.

## 2.2 - Promising Concepts

List of promising concepts from the above subsystems:

### 2.2.1 – Method of Locomotion:

Wheels: A wheeled platform is known to be the cheapest option pricewise, which may help in keeping the cost below the $100 budget. Additionally, it is the most reliable and maintainable system which allows it to be maintained by support staff. An issue with this concept was the limited slow-speed mobility, however if this concept is further developed, then four-wheel steering can be implemented which will aid in resolving this issue.

Tracks: A tracked platform is known to offer the greatest capability of the concepts. It combines great mobility and good speed which is needed to effectively pick up objects in different spots. The only drawback would be its reliability, however if it is developed, less parts can be used which can used to negate the potential reliability issues.

### 2.2.2 – Method of Arm Motion:

Servo Motor: The cheapest option for controlling possible system.  It has the fastest response speed and can perform accurate controls, providing the precise grabbing concept. It does not require high technology and has great reliability. The only potential issue could be the lack of torque and force for lifting the heavy things at distance. However, with proper development and calculation, the issue can be avoided.

Pulley System: The system is the simple solution for one direction movements, such as moving vertically. With other controlling motors, it can save the force required for lifting heavy items. Although, the pulley or belt may need regular check-up, it has a good reliability with proper design.

### 2.2.3 – Hand Mechanism:

Dual gear claw: is able to hold up to the largest objects (the containers) and also smaller objects. Operates easily needing only 1 servo motor. Can easily grasp objects from the front.

### 2.2.4 – App Interface:

The interface suggested will have to be configured a bit depending on which concepts are used for the other sub-systems, but the general layout is easy to interface with using just your nose and should be able to be made in MIT inventor.

### 2.2.5 – Controller:

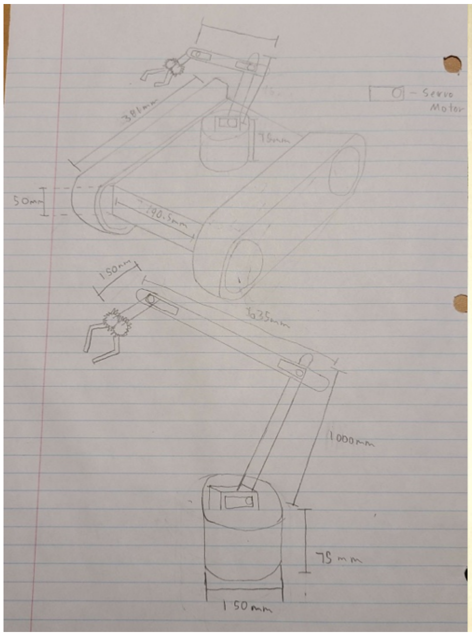
The Arduino board is capable for controlling motors and other moving systems. The code is simple and easy to learn, and the board itself can performs connection between mechanical movement with software interactions from user.

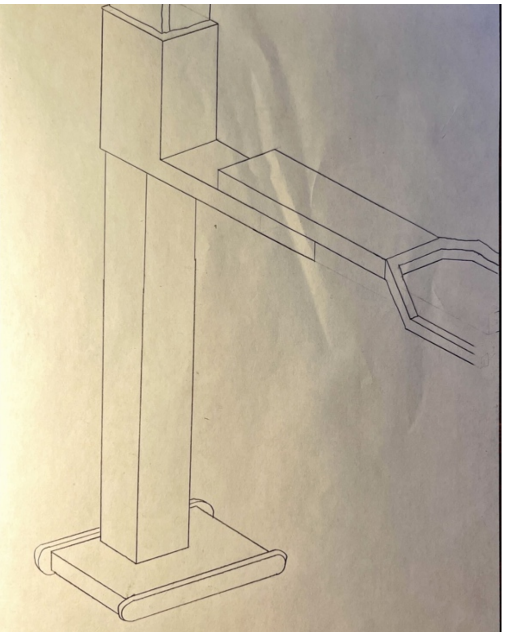
## 2.3 - Global Design Concepts:

The global design concept will use:

- Tracks as the method of locomotion
- A Servo motor as the method of arm motion
- Dual gear claw as the hand mechanism
- MIT inventor will be used to create the app interface
- Arduino will be used as the controller

### 2.3.1 – Visual Representation of Global Concept:





### 2.3.2 – Relation to Target Specifications:

The global design that was created, attempts to satisfy most of the target specification values listed below based upon the evaluation of the concepts for each subsystem. One concern may be the cost of it, as using this global design necessitates greater dimensions for the arm itself which involves more material.

| **Metric #** | **Metric** | **Unit** | **Marginal value** | **Ideal value** |
|---|---|---|---|---|
| 1 | Maximum payload weight | g | 500-1000 | 1000 |
| 2 | Maximum payload width | mm | 100 | 200 |
| 3 | Maximum payload depth | mm | 100 | 200 |
| 4 | Lowest arm range (height) | mm | 500 | 0 |
| 5 | Tallest arm range (height) | mm | 1000 | 2000 |
| 6 | Maximum arm horizontal distance | mm | 300 | 600 |
| 7 | Cost | $$ | <=150 | <=100 |
| 8 | Uses battery | Boolean | False | True |
| 9 | Battery life | Min | 300 | 600 |
| 10 | Power Consumption | W | <25 | <20 |
| 11 | Can move freely around house | Boolean | False | True |
| 12 | How to interface with app | Appendage | Fingers | Nose |
| 13 | Training required to fix/maintain | Capability | Student of GNG2101 | Anyone |
| 14 | Speed of locomotion (wheeled platform) | mm/s | 50 | 150 |