GNG2101

Design Project Progress Update

Accessible Hand Grip -AHG2

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List of Acronyms and Glossary

Provide a list of acronyms and associated literal translations used within the document. List the acronyms in alphabetical order using a tabular format as depicted below.

Table 1. Acronyms

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Provide clear and concise definitions for terms used in this document that may be unfamiliar to readers of the document. Terms are to be listed in alphabetical order.

Table 2. Glossary

|  |  |  |
| --- | --- | --- |
| **Term** | **Acronym** | **Definition** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

# Introduction

Our team is currently focused on designing an accessible hand device for the client’s daughter, who wishes to engage more independently in activities such as eating and painting. The child has difficulty holding objects like spoons or paintbrushes due to wrist positioning, so the device will aim to adjust the angle of the object they are using and improve grip for these tasks.

From our research and recent discussions with the client, we recognize that several key factors must be considered during the design process: the handle should be ergonomic and fit comfortably in the child's hand. The device needs to be lightweight and durable, considering the child is 7 years old and has limited muscle strength. Additionally, it should be safe, with no sharp edges, to ensure its use without causing injury or strain.

The document we’ve prepared is divided into three clear sections: Sustainability Report and DFX, Problem Definition, Concept Development, and Project Plan, and Detailed Design and BOM. The goal of this document is to incorporate sustainability assessments into our design process, explore multiple potential solutions, and provide a comprehensive design for the selected option.

# Sustainability Report and DFX

## Sustainability report

Table 3. Triple Bottom Line Table

|  |  |  |
| --- | --- | --- |
| Triple Bottom Line | Positive Impact | Negative Impact |
| Economic | Mass produced at low cost so more affordable for low-income households | Startup costs will be high, setting up factory, purchasing goods and materials, office spaces, labor |
| Creates more jobs and employment opportunities for manufacturers. |  |
| According to the Bureau of Labor Statistics, 19.3% of persons with a disability were employed in 2019[1]. With independence, affected population can better integrate into working environments and have better job prospects |  |
| Environmental | If manufactured with recyclable or biodegradable materials such as bioplastics, can minimize ecological footprint, fewer replacements. Could reduce emissions up to 73 million tonnes per year [2] | Plastics are generally non-sustainable and have a decomposition time of approximately 400 years[3]. Also, they may contribute to landfill waste, and emissions. |
| Re-using and durability will reduce material waste and extend product life |  |
|  |  |
| Social | Current statistic for when individuals with CP achieve autonomy is in their late 20s [4]. This would significantly improve if more tools were available for making them more independent | Average lifetime cost of catering to individual with CP is $921,000[5]. This limits affordability in low-income households |
|  | There is also risk of over-reliance which may lead to less development of motor skills for client’s daughter. Studies show bilateral motor deficits in reaching for object due to overreliance [6]. |
|  |  |

### Sustainability constraints:

* Low cost-production, optimize material selection and design process to target a broad range of users.
* Focus on using substantiable materials and ensuring device is repairable and recyclable to reduce long term impacts.

Design for comfort, adjustability, to meet needs of users and better affordability will increase inclusivity.

## Life-Cyle Assessment (LCA) Framework

A similar product on which we shall base ourselves for the Life Cycle Assessment (LCA) is (Prosthetics, n.d.).

**Objective and Scope:**

Our group's assessment will start from the extraction of the raw materials used to manufacture the product. These raw materials are mainly plastic materials like polyethylene to form the device's structure. These plastics are petroleum/oil products and need oil extraction. Our scope stops at the end of life of the device as the device ends in landfills.

**Inventory Analysis:**

As forementioned, materials for this device will be predominantly plastic materials. The device could be made from durable materials like AS or recycled polymers. Manufacturing processes like 3D printing and injection molding require significant energy. However, using renewable sources during production would curb the device’s environmental impact. The transport process is an important flow to access. Shipping the product from where it was produced to retail shops or home. Another, important flow is the packaging process to assess the growing or mining of raw materials, processing and creating packaging used for protection and/or advertisement of the product.

**Impact assessment:**

Using metrics such as Global Warming Potential (GWP), lifetime, performance specifications, and usage, we examine the impact of the several materials and flows in our scope. This would also indicate the use of non-renewable resources and waste generated.

**Interpretation:**

Finally, we use our assessment to determine the constraints and presentation of results.

With all this notion, we can build the flow diagram below showing the main processes and material/energy flows for a similar product’s life cycle. By choosing biodegradable plastics, we reduce environmental harm. By using energy efficient production methods, we can bulk produce reducing energy requirements. With a modular design, we also ensure easy disassembly, allowing easy recycling of parts. We shall define our system boundary and scope.

A diagram of a process

Description automatically generated

Figure 1 Life cycle flow diagram

## Design for X

After the first client meeting and our research, we were able to chose the 5 most important factors in our design. As we discuss them in the paragraph below, we shall justify our choice by including common needs for the DFX, examples of metrics, examples of constraints and examples of design criteria.

**1. Design for Usability**

Given that the end user has a disability, our design will be carefully tailored to meet their specific needs while remaining comfortable and intuitive. Since the user has limited motor skills in her fingers, the device will feature large activation points for easier interaction. Additionally, her low grip strength necessitates an ergonomic design that minimizes the need for continuous holding. We will prioritize single-handed operation for the child, focusing on the left hand, her dominant hand, as indicated by the client. To validate usability, we will conduct user tests that measure ease of use and satisfaction. A key metric will be a satisfaction score out of 10, recorded after client trials. Further, we will assess task completion rates and grip efficiency during real-world tasks like eating and painting to ensure optimal performance.

**2. Design for Portability**

Considering the user’s mobility challenges, the device must be lightweight and compact to prevent further hindrance to movement. Our design will be no more than 20 cm in length, to comfortably fit on the user’s forearm, based on anthropometric data for 8-year-old children. To validate portability, we will weigh the device during development, ensuring it remains under 3 lbs. Additionally, we will test it in 20-minute user sessions to monitor for signs of fatigue or discomfort. Further testing will evaluate its compactness and foldability, ensuring the device can be easily stored or transported when not in use.

**3. Design for Safety**

Safety is paramount for our product, given that the user is a young child with impaired muscle coordination. Beyond standard child-safety features such as rounded edges and smooth surfaces, the device will include an automatic release mechanism to allow for quick detachment in emergencies without the need for external assistance. Safety validation will involve simulated emergency scenarios where the automatic release is tested under various conditions to ensure it functions consistently. Additionally, we will track the number of safety-related incidents during user trials, with a target of zero incidents. Non-slip grip surfaces and a securely fitted forearm strap will be incorporated, with testing to confirm that the strap prevents accidental drops without causing discomfort or skin irritation.

**4. Design for Reliability**

The user will depend on our device for activities such as eating and painting, making reliability essential. The device must perform its function flawlessly every time to maintain the user’s independence. To ensure reliability, we will conduct extensive testing across multiple tasks, recording the number of successful operations before any failure. A minimum reliability threshold will be set, with the device expected to handle at least 500 gripping actions without failure. Additionally, we will test its durability under high-temperature conditions, as it must be dishwasher-safe. Materials will be selected for their resistance to wear and thermal fluctuations, with further testing to confirm that locking mechanisms and moving parts maintain their integrity over time.

**5. Design for Maintainability**

Given the user’s need for regular cleaning due to activities like eating and painting, the device will be designed to be easily disassembled for thorough cleaning, either by hand or in a dishwasher. We will minimize areas prone to dirt accumulation by designing smooth surfaces and avoiding small crevices. Maintainability tests will measure the time required for disassembly and cleaning, targeting a time of under five minutes. Additionally, the device will feature easily replaceable components, such as straps and grip pads, which will be validated through user testing to ensure they can be swapped out with minimal effort. The number of modular parts and the ease of replacement will serve as key metrics in evaluating maintainability.

## Conclusion

Our team is developing a product to assist our client’s daughter perform movements that are difficult with her capabilities. The product in development will follow the DFX listed for usability, portability, safety, reliability, and maintainability. Based on the life cycle analysis, the design will be developed around the sustainability of materials used, versatile uses, comfort, and longevity of the product's life.

# Problem Definition, Concept Development, and Project Plan

## Problem definition

After meeting with the client, we gained a clear understanding of the challenges our accessible hand grip is to achieve. Through group discussions, we identified key issues that need to be addressed and outlined specific requirements that will guide the development of our solution.

|  |  |
| --- | --- |
|  | **Client Statements** |
| 1 | Client daughter loves to engage in household activities |
| 2 | Client wants the product to be easy to clean |
| 3 | Client expects activities to last up to 20 minutes |
| 4 | Client’s daughter has weak hand grip |
| 5 | Clients daughter wants to hold objects at the right angle |
| 6 | Client’s daughter wants to hold mixing spoon and help out with baking |
| 7 | Clients daughter wants to hold device comfortably |
| 8 | Client’s daughter wants to paint on her own. |
| 9 | Client wants a large surface button if any button is used in the solution. |
| 10 | Clients daughter wants to be able to grip objects of different sizes |
| 11 | Client wants product to be extremely light |
| 12 | Client wants to be able to strap product to her forearm |
| 14 | Client wants the product to incorporate cartoon dogs into the visual design |
| 15 | Client wants the product to be stable. |
| 16 | Client's daughter is left hand dominant |
| 17 | Client’s daughter wants to feed herself independently. |
| 18 | Client’s daughter is sensitive to noise. |

Based on the client's statements, we compiled a list of client needs in the table below, represented as device characteristics. Furthermore, we assigned an importance rating to each device characteristic.

|  |  |  |
| --- | --- | --- |
|  | **Device characteristics** | **Importance ranking** |
| 1 | Device allows stable grip for manipulating household items | 5 |
| 2 | Device is easy to clean | 4 |
| 3 | Device handle is rigid | 2 |
| 4 | Device supports use for individuals with a weak hand grip | 5 |
| 5 | Device allows objects to be held at an adjustable angle. | 5 |
| 6 | Device ensures safety while accommodating different angles for holding objects. | 3 |
| 7 | Device facilitates cooking utensils such as mixing spoons | 3 |
| 8 | Device can be held for extended periods | 4 |
| 9 | Device enables the clients daughter to paint independently | 4 |
| 10 | Device includes a large surface button for each of use | 3 |
| 11 | Device adapts to gripping objects of different sizes | 4 |
| 12 | Device is lightweight for ease of handling | 5 |
| 13 | Device includes a forearm strap for secure attachment | 5 |
| 14 | Device has a fun, cartoon dog themed design | 3 |
| 15 | Device is stable during use | 3 |
| 16 | Device accommodates left-handed use | 4 |
| 17 | Device allows self-feeding | 5 |
| 18 | Device operates quietly to reduce noise exposure | 4 |

### Problem Statement

Client daughter has limited wrist mobility and struggles to hold objects like spoons or paintbrushes at the right angle, hindering their ability to participate in activities independently. The solution is a lightweight, ergonomic device with an adjustable gripper that accommodates different object sizes and angles, ensuring ease of use, comfort, and durability for a child.

### List of Metrics and Units

The next step in the iterative design process was to do a list of metrics and units including various quantitative and qualitative measures. These metrics provide a standardized way to compare and evaluate different competitors and our concepts later.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Metric # | Need # | Metric | Description | Units | Importance |
| 1 | 8, 12 | Total Weight | Weight of the device. | Grams (g) | 4 |
| 2 | 1, 8 | Time of usage | Time the user will use device | Minutes | 3 |
| 3 | 3, 8 | Grip force applied by user | Friction force holding the object. | Newtons (N) | 3 |
| 4 | 5, 6 | Range of angle | Range of motion of device | Degrees (°) | 4 |
| 5 | 4, | Heat tolerance | The temperature that can be tolerated | °C | 2 |
| 6 | 2, 4, | Easy to clean | Can product be cleaned easily? | Yes/No | 2 |
| 7 | 18, | Noise | Noise the device makes | Decibels (dB) | 2 |
| 8 | 8, 12 | Maximum weight of gripped object | Maximum weight the object can lift. | Grams (g) | 3 |
| 9 | 10 | User interface size (Button size) | How big the button is, if used | Millimeters (mm) | 2 |
| 10 | 16 | Ambidextrous compatibility | Ability to use the device as a left and right handed person | Yes/No | 2 |
| 11 | 7, 9, 11 | Wrist size ranges (Circumference) | Circumference/diameter of device | Millimeters (mm) | 3 |
| 12 | 7, 9 | Cost of Device | Cost of Device | Dollars (CAD$) | 4 |
| 13 | 5, 6 | Degrees of motion | Possible translation and rotations | Planes and directions. | 5 |

### Benchmark on Similar Solutions

Our next step was to start Benchmarking similar solutions which involves analyzing and comparing existing products or services that address the same or similar needs. We focused on ergonomic handle, the grip system and the grip to handle adjustment. This process helps identify standards, and key features across different solutions.

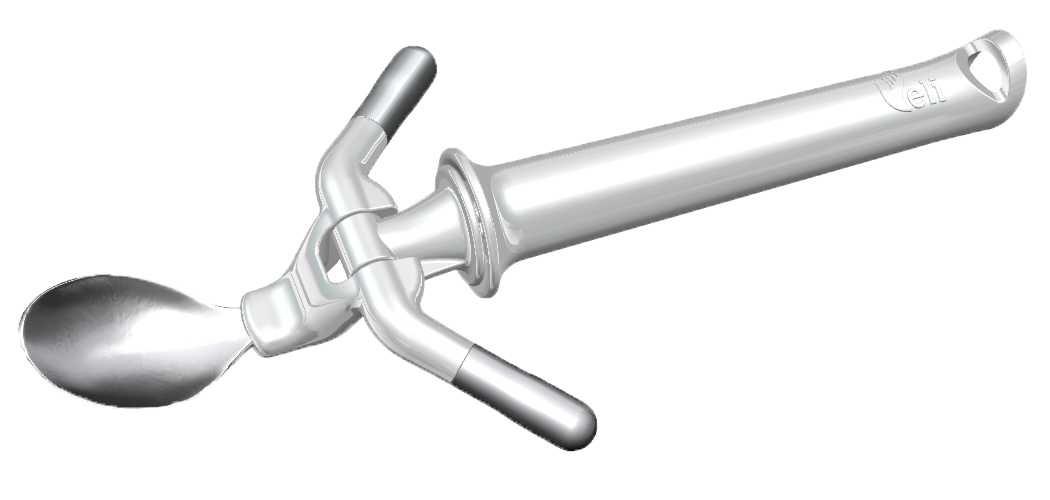


Figure 2 Ellispoon design

Figure 2 shows the Ellispoon which is design to assist with users with limited wrist mobility providing an ergonomic grip, adjustable handle that helps maintain a stable grip and proper angle passively.



Figure 3 Guided hands design

Figure 3 shows the adaptive design that enables users with limited hand dexterity. The XY gantry system allows for ease of writing and use of tools.



Figure 4 Adaptive spoon for cerebral palsy

Figure 4 has an adjustable handle and soft grip to allow for easy handling, a copper-lined silicone handle provides a ductile design that can wrap around the user’s arm giving stability.



Figure 5 Small item gripping aid

Figure 5 exhibits a gripping aid to assist with limited hand function. This design is reliant on Velcro modular straps allowing for easy angle changes of different tools used. The Table 4 below further details the metric breakdown of benchmarked products.

Table 4 Benchmarking Table

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Metric # | Need #’s | Metric | Unit | Ellispoon | Guided Hands | Adaptive Spoon for Cerebral Palsy | Small Item Gripping Aid |
| 1 | 8, 12 | Total Weight | grams | 78 | 1590 | 65 | 40 |
| 2 | 8 | Time of usage | minutes | Indefinite | Indefinite | 30 | Indefinite |
| 3 | 8 | Grip force | Newton | N/A | N/A | 90 | N/A |
| 4 | 5, 6 | Angle Range | Degrees | 180 | 180 | 180 | 360 |
| 5 | 4 | Heat tolerance | °C | N/A | N/A | 70 | 120 |
| 6 | 2, 4 | Easy to clean? | Binary | Yes | Yes | Yes | No |
| 7 | 18 | Noise | dB | Zero | 20-30 | N/A | N/A |
| 8 | 8, 12 | Maximum weight of gripped object | grams | 15-30 |  | 50 | 20 |
| 9 | 10 | User interface size (Button size) | Millimeters | 1.9 cm handle | N/A | N/A | N/A |
|  |
|  |
| 10 | 16 | Ambidextrous compatibility | Binary | Yes | Yes | Yes | No |  |
| 11 |  | Wrist size range | Millimeters | N/A | N/A | 140-160 | Customizable-  Small (150)/Large(165) |  |
| 12 |  | Cost of device | CAD$ | 90 | 849 | 10 | 100 |  |
| 13 |  | Degrees of motion | Possible translation and rotations | 6 | X-Y plane | 6 | 1 |  |

Table 5 Target Specifications: Marginal and Ideal Values

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Metric # | Metric | Unit | Marginal | Marginal Value Description | Ideal | Ideal Value Description |
| 1 | Total Weight | grams | 80 | Average found between different devices, outliers were omitted | <80 | Online text reviewing hand assist devices show weight of 40g [7]. Add another 40g for tools. |
| 2 | Time of Usage | Minutes | <20 | Should be able to sustain meal/activity period which average 20 mins | <50 | Activities include painting and eating. An average time from online text was found [8] [9] |
| 3 | Grip force | Newtons | NA | Grip force applied by user | >50N | Based on the value found grip strength info for the average 8 year old [10] |
| 4 | Angle Range | Degrees | 180 | Angle achieved by user on planar surface of the hand with respect to handle | 180 | Allow tool to face user and away from user |
| 5 | Heat Tolerance | °C | <70 | Heat tolerance that the product can take | <52 | Acceptable heat tolerance for dishwasher use [11] |
| 6 | Easy to clean? | Binary | Yes | - | Yes | Ideally, must be dishwasher-compatible |
| 7 | Noise | dB | NA | Sound produce by the product | <10 | sound chart shows lower than 10 is unnoticeable [12] |
| 8 | Maximum weight of gripped object | grams | <70 | Based on the mass of the average object being held | <40 | Based on average weight on object and what the object is holding (e.g. spoon with a bite of food) [13] |
| 9 | User interface size (Button size) | millimeters | NA | If buttons were included, what were their size? | 70-80 Diameter | The client gave a qualitative comparison during the meeting |
| 10 | Ambidextrous Compatible | binary | Not all | The device’s compatibility with both hands | No | Priority placed over left-hand |
| 11 | Wrist size range | millimeters | 150-165 | Average wrist size accommodated by benchmarked solutions | Approx 152.8 mm | Wrist size of average 8 year old [14] |
| 12 | Cost of device | Dollars | 70-150 | Guided hand $850 an Eli spoon $70 | >$50 | Less than our budget. |
| 13 | Degrees of freedom | List | >1 | How much translational and rotational movement does it allow? | >1 | Requirement was for angle adjustment which only requires 1 DOF. Additional DOF may improve user comfort |

The final target specifications serve as a detailed guideline that outlines the desired metrics values, functional requirements, and constraints for our accessible grip handler. After analyzing the marginal values and ideal values we were able to set our final specifications.

Table 6 Final Specifications

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Metric # | Metric | Unit | Final Value | Final Value Description |
| 1 | Total Weight | grams | <80 | Same as ideal value from table above. |
| 2 | Time of Usage | Minutes | 20 | According to client need to perform daily activities like baking or eating that usually last about 20 mins |
| 3 | Grip force | Newtons | >50 | Same as ideal value above |
| 4 | Angle Range | Degrees | 180 | Allow tool to face user and away from user |
| 5 | Heat Tolerance | °C | <52 | Value is same as ideal value from table above. |
| 6 | Ease of cleaning | Binary | Yes | Material must be easy to hand-wash |
| 7 | Noise | dB | <10 | sound chart shows lower than 10 is unnoticeable [12] |
| 8 | Maximum weight of gripped object | grams | <40 | Based on average weight on object and what the object is holding (e.g. spoon with a bite of food) [13] |
| 9 | User interface size (Button size) | millimeters | 70-80 Diameter | The client gave a qualitative comparison during meeting |
| 10 | Ambidextrous Compatible | binary | No | Ambidextrous compatibility is not a critical requirement for our device, as it was not prioritized by the client in their specifications. |
| 11 | Wrist size range | millimeters | Approx 152.8 mm | Wrist size of average 8 year old [14] |
| 12 | Cost of device | Dollars | <$50 | Less than our budget. |
| 13 | Degrees of freedom | List | >1 | Requirement was for angle adjustment which only requires 1 DOF. Additional DOF may improve user comfort |

## Concept development

To simplify and better organize concept development, we decided to split the global product concept into three mechanisms/subsystem concepts. These subsystem concepts are the following: the handle, the mobility, and the gripping subsystems. The handle is the mechanism through which the user interacts with the product, meaning it could take other forms than an actual handle (for instance strapping the product on the user’s arm). The gripper subsystem is concerned with how the product holds onto objects. The mobility subsystem encapsulates how our product manipulates the objects it holds, i.e. how the gripper subsystem moves in relation to the handle subsystem.

### Handle Subsystem Concepts

**Self-Rolling Band**

A drawing of a hand holding a strap around arm

Description automatically generated with medium confidence

Figure 6: Self-Rolling Band Concept

The product is strapped to the user’s forearm using a self-rolling bracelet. This bracelet always curls up into its original rolled position, so it can quickly roll around the user’s forearm without the use of velcro. Inside the bracelet are layered stainless steel bistable spring bands that cause the bracelet to always curl up and remain curled up unless acted upon by a large enough force.

**Velcro Straps**

A drawing of a hand and arm

Description automatically generated

Figure 7: Velcro Straps Concept

The device is fixed to the user’s forearm by a velcro strap which is wrapped so that the horizontal strip of velcro parallel to the arm is attached to the perpendicular strips of velcro. The device is attached to the arm strap by means of a dovetail rail that runs along the arm.

**Glove**

**A diagram of a surgical instrument

Description automatically generated**

Figure 8: Glove Concept

The user holds onto the device by wearing a ‘glove’ that covers part of their hand. This ‘glove’ is equipped with an ergonomic handle for additional stability.

### Mobility Subsystem Concepts

**Robotic Stabilizer**

A drawing of a mechanical arm

Description automatically generated

Figure 9: Robotic Stabilizer Concept

The function of this subsystem would be to maintain the gripper horizontal regardless of the forearm movement and angle. An inertia measurement unit (IMU) is housed inside the body of the device and feeds movement data to a microcontroller (also housed inside the body of the device). The microcontroller controls a set of 3 servo motors all moving in a way that neutralizes forearm movement, guaranteeing the gripper will always be horizontal or at a specified angle relative to ground.

**Ball joint**

A diagram of a ball joint

Description automatically generated

Figure 10: Ball Joint Concept

The device adjusts between the gripper and means of attachment by use of a ball joint which is tightened by a threaded knob which puts force against the ball joint and tightens the movement.

**Revolute Joint**

**A drawing of a faucet

Description automatically generated**

Figure 11: Revolute Joint Concept

The revolute joint allows planar movement to bring about changes in angle.

**Rotating Disk**

**A diagram of a surgical instrument

Description automatically generated**

Figure 12: Rotating Disk Concept

The rotating disc mechanism is composed of a spring that pushes against the rotor ensuring discrete angular adjustments, thereby providing a 360 degree range of motion for the user.

### Gripper Subsystem Concepts

**Adjustable Jaws**

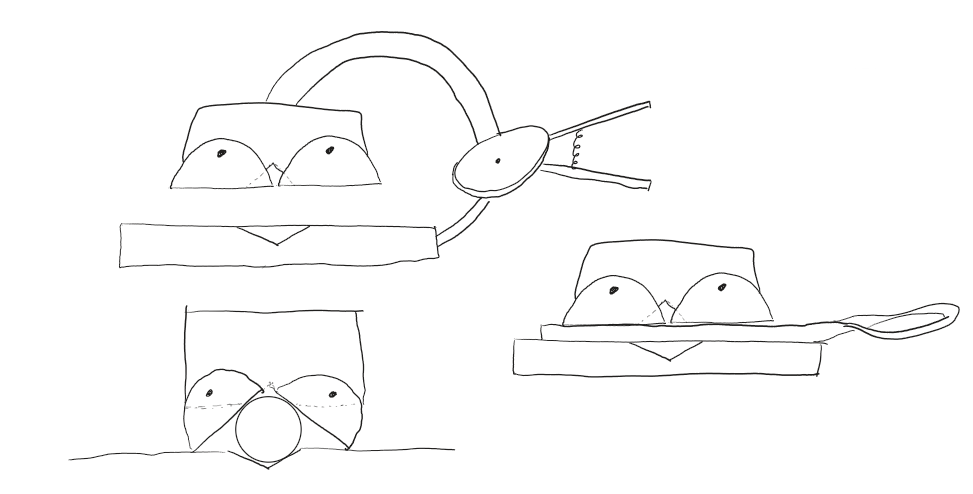


Figure 13: Adjustable Jaws Concept

The product will grip objects using jaws similar to a fractal vise, which conforms to the shape of the objects being held. The top jaws conform to flat shapes, and round shapes, while the bottom jaws are flat with a small divet for round objects to rest inside and center.

**Three-Jaw Chuck**

**A drawing of a faucet

Description automatically generated**

Figure 14: Three-Jaw Chuck

Rotation of the outside of the structure moves three jaws inward or outward to grasp objects of varying diameters.

**Adjustable rubber strap**

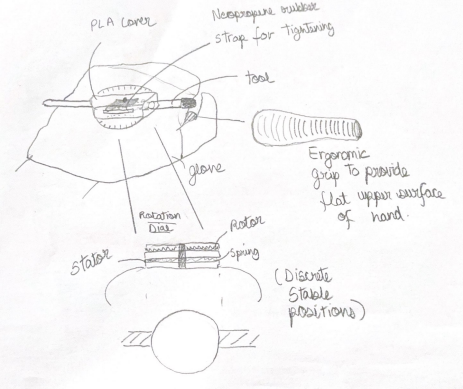
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Figure 15: Adjustable Rubber Strap

Adjustable rubber strap grips onto the exterior surface of the object using friction.

### Weighted Decision Matrices

For each subsystem, we list below each of our design concepts and compare them based on our target specifications and their respective weights. Each concept is given a relative rating for each criteria, and a weighted total of those ratings is computed to determine the best concept for each subsystem.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weighted Decision Matrix for the Handle Subsystem** | | | | |
| **Criteria/Metric** | **Weight** | **Self-Rolling Band** | **Glove** | **Velcro Strap** |
| Total Weight | 0.103 | 3  Stainless steel layers make it heavier than alternatives | 4  Smaller total surface but handle adds weight | 4  Lightest solution but greatest surface area. |
| Time of Usage | 0.077 | 4  None of the concepts are time sensitive. | 4 | 4 |
| Grip force | 0.077 | 5  No grip needed | 4  Light grip | 5  No grip needed |
| Angle Range | 0.103 | NA  This subsystem doesn’t handle the mobility function. | NA | NA |
| Heat Tolerance | 0.051 | 4  Steel doesn’t lose  mechanical properties below 350°C. | 4  Can tolerate up to 70°C depending on material. | 2  Velcro is the most heat sensitive |
| Ease of cleaning | 0.051 | 4 Stainless steel is dishwasher safe. | 3 Glove could be depending on material | 0 Velcro is heat sensitive |
| Noise | 0.051 | NA  Subsystem doesn’t have moving parts | NA | NA |
| Maximum weight of gripped object | 0.077 | 2 A large enough weight will unfold and/or move the band. | 5 Glove can’t fail unless it is manually removed. | 3 A large enough weight will detach the Velcro. |
| User interface size (Button size) | 0.051 | NA  No buttons are involved in this subsystem. | NA | NA |
| Ambidextrous Compatible | 0.051 | 4 Design is identical for both arms. | 2 Different design for each hand. | 3 Design is similar but not identical. |
| Wrist/Hand size range | 0.077 | 4  Adapts to a wide range of wrist sizes. | 2  Fits a specific hand size. | 3  Adapts to a defined ranged of wrist sizes. |
| Cost of device | 0.103 | 2 Most expensive | 3 Second cheapest | 4 Cheapest |
| Degrees of freedom | 0.128 | NA No moving parts when placed on forearm/hand. | NA | NA |
| **Total:** | | **2.282** | **2.335** | **2.234** |

The best concept design for the handle subsystem is the **Glove**.

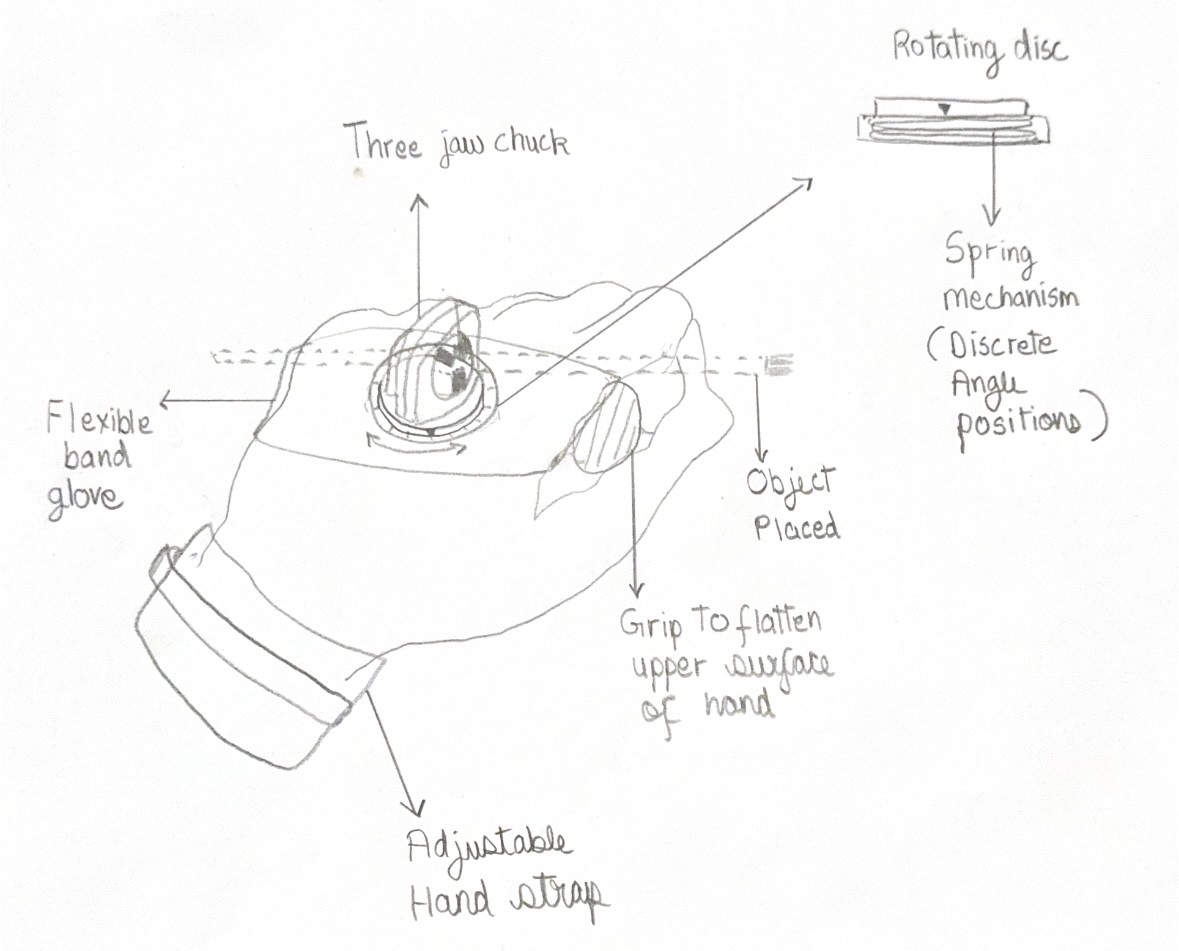
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weighted Decision Matrix for the Mobility Subsystem** | | | | |
| **Criteria/Metric** | **Weight** | **Revolute joint** | **Rotating Disc** | **Robotic Stabilizer** |
| Total Weight | 0.103 | 4 Lightest (15g) based on fewer moving parts. | 3 Middle ground. | 2 Heaviest based on more moving parts. |
| Time of Usage | 0.077 | 5 Indefinite. | 4 If electronics are used, limited by battery life. | 3 Limited by battery life. |
| Grip force | 0.077 | 3 Some dexterity is needed | 5 No grip needed to control | 4 No grip needed to persay |
| Angle Range | 0.103 | 2 Limited to 180 degrees. | 4 360 degrees. | 4 360 degrees. |
| Heat Tolerance | 0.051 | 4  PLA-150**°**C | 4  PLA-150**°**C, Spring-800**°**C | 3 |
| Ease of cleaning | 0.051 | 3 Dishwasher safe | 2 Not waterproof if electronics are used. | 0 Not waterproof. |
| Noise | 0.051 | 4 Silent | 3 Slightly noisy (if electronics used) | 2 Most noisy |
| Maximum weight of gripped object | 0.077 | 4  PLA withstands 30g-200 g | 5 No torque since tool rests directly on axis of rotation. | 3 Torque makes design sensitive to weight. |
| User interface size (Button size) | 0.051 | 3  Buckle lift large enough for hand (40mm) | 5 No button involved. | 4 Doesn’t necessarily involve a button. |
| Ambidextrous Compatible | 0.051 | 3 All solutions are equally ambidextrous compatible | 3 | 3 |
| Wrist size range | 0.077 | NA | NA | NA |
| Cost of device | 0.103 | 4 Cheapest given fully 3D printable. | 3 Not fully 3D-printable. | 2.5 Most expensive given heavy use of electronics |
| Degrees of freedom | 0.128 | 4 1 DOF | 4 1 DOF | 5 3 DOF |
| **Total:** | | **3.333** | **3.487** | **2.898** |

The best concept design for the mobility subsystem is the **Rotating Disk**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weighted Decision Matrix for the Gripper Subsystem** | | | | |
| **Criteria/Metric** | **Weight** | **Adaptable Jaws** | **Three-Jaw Chuck** | **Adjustable Rubber Strap** |
| Total Weight | 0.103 | 4 Fewer moving parts than jaw chuck | 3 Heaviest. | 5 Lightest solution. |
| Time of Usage | 0.077 | 4 Not time sensitive system. | 4 | 4 |
| Grip force | 0.077 | 2 Significant grip is needed to activate/deactivate. | 3 Some grip/friction needed to activate/deactivate. | 4 No grip needed (use mouth). |
| Angle Range | 0.103 | NA | NA | NA |
| Heat Tolerance | 0.051 | 4 Depending on material, lower if PLA. | 4 Depending on material, lower if PLA. | 2 Rubber deteriorates under high heat. |
| Dishwasher compatibility | 0.051 | 4 Yes. | 4 Yes. | 2 Rubber deteriorates under high heat. |
| Noise | 0.051 | 3 Some noise when activated/deactivated | 3 Some noise when activated/deactivated | 4 Silent |
| Maximum weight of gripped object | 0.077 | 5 PLA jaws have strength to grasp objects, max. 400 g | 5 PLA jaws with high infill can carry max 200 g before buckling | 1 With rubber against metal, coefficient of friction=.64[15], not the best. May slip if not tight |
| User interface size (Button size) | 0.051 | 2 Smallest interaction area: spring loaded grip. Requires gripping. | 5 Big activation area: outer part of the chuck. | 3 Activated with mouth by pulling. |
| Ambidextrous Compatible | 0.051 | 3 All solutions are equally ambidextrous compatible. | 3 | 3 |
| Wrist size range | 0.077 | N/A | N/A | N/A |
| Cost of device | 0.103 | 3 Second cheapest | 2 Most expensive since most parts and more complex parts | 4 Cheapest since fewer parts. |
| Degrees of freedom | 0.128 | NA The gripper isn’t supposed to move the tool, only secure it. | NA | NA |
| **Total:** | | **2.384** | **2.408** | **2.385** |

The best concept design for the gripper subsystem is the **Three-Jaw Chuck**.

**Global concept**



**Comparison with target specifications**

The global concept optimizes the data provided in the target specifications table. With its lightweight design with the use of low-density plastic and flexible materials, the product is predicted to weigh approximately under 80 grams ensuring the user does not feel fatigued during use. Activities like eating and painting tend to be time-consuming and hence, with an ergonomic grip design as well as adjustable hand support, comfort is optimized.

The three-jaw chuck employs a reliable mechanism to grip onto objects with variable diameters as well as cross sections. This design meets the 50 N grip force requirement set.

With the use of the rotating disc mechanism, the angle can be adjusted with a gentle push on the top portion, allowing for 180 degrees of rotation. However, a drawback is that the user must use another part of the body such as mouth or neck to push down for angle adjustments. The device can also handle temperatures of 52 °C and can easily be cleaned due to the usage of plastic and rubber. Unfortunately, the chuck mechanism has ridges where food particles and paint can get trapped.

This solution does not produce any noise and can grip small objects very easily including spoons and paintbrushes. There is no usage of buttons in the design making the user experience more manageable. The design can be customized to the user’s wrist size and the total cost of the product is less than $50 making this a very affordable solution.

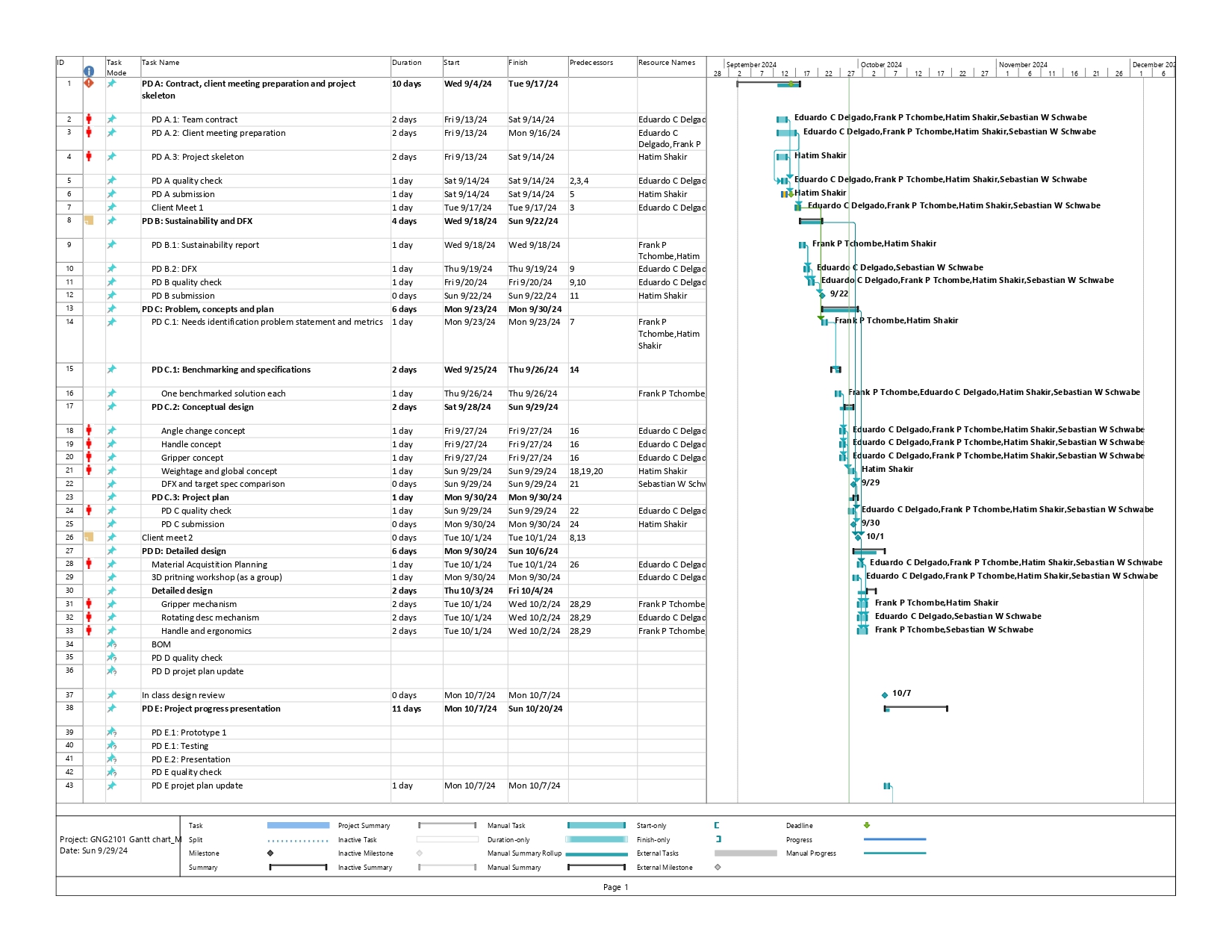
With the use of a rotating disc allowing angle adjustments, the device has only 1 DOF, which contributes to stability. Having considered these factors, it’s also important to know how this device affects the DFX principles set in previous sections.

**DFX comparison**

To begin, the product design for **usability** is important as the global concept will accommodate a variety of uses, so the three-jaw chuck is used, as it can securely hold onto round or flat objects depending on the placement.

The rotating disk is used when considering the **usability** of the product because it is simple to adjust and lock into place. The glove contributes to the usability of the product by providing a secure attachment to the user’s hand. The global design concept accounts for the **safety** of the user. The components of the product do not provide any pinch points where the user could injure themselves as well as the glove providing an additional layer of protection. The global concept provides **maintainability** in the use of closed mechanisms that will be less likely to get larger amounts of dirt inside. The concept relates to a design for **reliability** as three jaw chuck used to grip objects will hold them securely, while the glove will provide a secure base while on the user’s hand. The rotating disk used for adjustments will secure the gripper at various angle adjustments **reliably**. The **portability** of the global concept was considered in the components, as the glove would be more portable than arm straps, additionally the three-jaw chuck used for gripping is compact and uses a self-contained mechanism.

## Project plan



# Detailed Design and BOM

## Detailed design

1. ***Summarize the client feedback that you received during your second client meeting and clearly state what needs to be changed or improved in your design.***

We presented our preliminary concepts to the client, and his initial impression was that our designs looked promising; however, he expressed concern about the possible weight of the devices. He also suggested separating any electrical components, such as the motor or battery, so they could be placed on a table, ensuring that the parts attached to his daughter’s hand would remain as light as possible.

Through further discussions, we learned that the client’s daughter cannot extend her thumb, move her fingers up and down, or pinch with just two fingers; instead, she uses her whole hand to grasp objects. We then asked if she could use her chin to activate some mechanisms in our preliminary designs, but we discovered that she does not have sufficient neck control to reach her hand. Additionally, the client mentioned that while the device could be designed for him to set up initially before use, his daughter prefers to operate it with minimal assistance for everyday activities.

From this feedback, we adjusted our design. We gained a better understanding of the range of mobility his daughter has; initially, we believed her wrist bent inward towards her, but it actually bends inward towards her forearm, which helped us determine the correct axis of rotation for the motors in our device. We also noticed the client’s enthusiasm for a gimbal-like system to adjust the angle and provide stability, so we decided to pursue this concept further.

Below is an updated final design to reflect user needs.

A diagram of a hand holding a device

Description automatically generated

Figure 16 Drawing of our new design

In Figure 16, the current design introduces several modifications compared to the earlier versions. This design features a wraparound forearm support for stability. This subsystem is shown as having a braided copper core with an exterior layer of polyethylene foam, providing a low-cost and reusable solution. At the end of this forearm support, an ergonomic handle is attached with the use of silicone heat shrink tubing. The hollow interior of the grip accommodates small electronic components such as an IMU, as well as a servo motor, to provide pitch stabilization. Another servo is mounted to handle roll adjustment allowing smooth operation of the device. On this last servo motor, a compact gripper mechanism is placed which holds varying shaft sizes and cross-sectional geometries with a pair of elastic bands.

A drawing of a table

Description automatically generated with medium confidence

Figure 17 Drawings of the gripper subsystem

Figure 17 shows the gripper subsystem in more detail. The pin ensures the lower platform is secured in place and can accommodate varying object insertions.

A grey plastic pipe with parts

Description automatically generated with medium confidence

A computer cable with a plug in

Description automatically generated with medium confidence

Figure 18 CAD model of global design

**A circuit board with wires

Description automatically generated**

Figure 19 Circuit Schematic for the Angle Adjustment subsystem

Using the diagram in Figure 19, the pitch and roll can be adjusted to change the angle of the object being help.

***3. Explain what considerations you must take to design or manufacture your concept, based on your updated detailed design, to meet your DFX factors. Are some factors more important than others? Why?***

**Usability**

The device must be comfortable and easy to use for the user and the person assisting them from start to finish. First, to ensure fast and swift installation, the handle should be flexible enough that it can be rolled around the user’s forearm very easily. Installation should not take more than **15 seconds** from beginning to end. Second, to guarantee **comfortability** for the user, the part of the handle that curls around her forearm must be made of a soft and/or squishy material (silicone, foam, etc.). We want this part of the handle to provide support while still allowing the user some **flexibility**. The handle cannot be rigid as that would be uncomfortable for the user. Third, for better usability, we require the design not be overly restrictive of the user’s arm movements, as that would lead to poor user experience. Any electrical should have enough **slack** in them to accommodate the user’s usual range of arm movements.

**Safety**

The product must be safe for the user and the people around them while in use. All electrical components (IMU, microcontroller, servo motors, battery) must be **encased** to prevent them getting damaged during use, which could cause short circuits. All exposed electrical wires must be completely **insulated** by a nonconductive material (thermoplastic) to prevent the user or anyone else from receiving electric shocks. Furthermore, the **routing** of the electrical wires must be itself safe, meaning its not possible for the user’s arm or other body parts to get entangled by the wires, no matter how the user moves. The design cannot include any rough or pointy edges that could potentially harm the user and the entirety of the surface the user interacts with must be **smooth/soft** for the same reason. All parts must be mated tightly enough to withstand sudden and/or erratic user arm movements without the device falling apart.

**Maintainability**

For our design to have a long useful life, it must be maintainable in a way that doesn’t require our team’s (or a technical person’s) intervention. One particular concern is cleanliness given our product will be near food. The gripper subsystem (the most likely to get dirty from contact with food or paint) of our design will be fully detachable so it can be handwashed separately. The gripper must be **waterproof**. The gripper will be connected to the rest of the device with an accessible flathead screw that allows for easy disassembly when cleaning is required. Since our design is portable, it will use a battery as the voltage source for the electrical circuitry, located in the control unit box (containing the Arduino and the battery). To allow the client to change device’s battery when depleted, the control unit box will be openable with a screwdriver and the **battery** will be **visible and easily retrievable** (the battery will sit in a battery holder instead of being directly connected to the rest of the circuit).

**Reliability**

It is important for us that our product functions in a predictable way so that our client (and user) can fully trust it when using it. Since the voltage source (battery) powering our device is **independent** from the electrical grid, it ensures our user can rely on our product under any circumstances, whether they are close to an electrical outlet or not. However, it is crucial our device has a way of **alerting** the user and the client when battery is running low, so it can be changed before the device stops working reliably mid-use (a simple LED on the control unit box turning bright red when batteries need to be replaced). As far as the gripping subsystem goes, our device should accommodate a known and clear range of shapes of which the client is made aware of, as to limit surprises. We would rather limit the scope of applicability of our product as to guarantee **full reliability** than extend the scope of applicability of our product but underdeliver.

**Portability**

To improve the portability of our device, it will be fundamental to limit **weight** and **size**. For these reasons, we plan to use micro servo motors (SG90) given our application does not require significant torque. If possible, we will use even smaller servos to limit size and weight further. As far as the handle goes, we plan to use **foam** to provide the necessary firmness without increasing the weight. Furthermore, any components that do not need to be on the user’s arm itself will be in the **control unit box**, which will be resting close to the user but not on them (on their wheelchair, table, nightstand, etc.). Heavy components such as the battery, can be thus isolated away such that they don’t weigh down the user. The usage of batteries itself is also a way to make the device fully portable.

***4. Provide a detailed list of skills and resources you have at your disposal that will enable you to create your design. If there are skills or resources missing to complete your design, describe how you will obtain them.***

Our first prototype, as described above, is a flexible forearm band with a gimbal mounted at the end. The gimbal is attached to a gripper designed to hold various objects like a spoon, toothbrush, or paintbrush. We have several skills and resources at our disposal to create our design.

* Eduardo, who is in electrical engineering, will be leading the tasks of building the circuit that connects our two servo motors, IMU, and Arduino.
* Both Hatim and Eduardo have experience coding for IMUs and Arduino, which will be valuable for the programming aspect.
* Most of the team has extensive experience with CAD design and 3D printing, which will be used to create the handle component of our device.
* Sebastien has experience with and access to a private laser cutter that we can use to build the casing for our gripper.
* Hatim also has servomotors, an Arduino, and mini protoboards from previous courses that could aid in building our first prototype.

However, we are aware of some skill gaps we may face.

* None of us is in computer or software engineering, so debugging or enhancing our code might be challenging. To address this, we have reached out to various project managers (PMs) who have expressed willingness to assist.
* Furthermore, we will need to 3D print components, and the university's makerspace is likely to be crowded after reading week due to the number of people working on their prototypes at that time. To address this issue, we plan to prioritize 3D printing during reading week to ensure we make significant progress on our project.
* Finally, we acknowledge that our budget for the project is quite limited, ranging from $50 to $100. Therefore, we intend to budget carefully and purchase materials from affordable suppliers such as Amazon and Temu.

***5. Provide a realistic assessment of the time required to implement your design and the actual time your group and its individual members have at their disposal.***

The Gantt chart at the end of this document provides a clear and detailed plan that our team is following to achieve our final design. To implement the proposed design, we divided the tasks among team members and estimated the time required for each. This breakdown ensures that everyone has a specific role and timeline to follow, keeping the project on track for completion.

Table 7 Task and Average estimate time required

|  |  |  |  |
| --- | --- | --- | --- |
| Task # | Task descriptions | Responsible | Average estimate time required |
|  | Fabricate malleable handle. | Sebastian and Franck | 6 hours |
|  | Acquire electronic components. | Eduardo and Hatim | 4 hours |
|  | Design and laser cut gripper. | Sebastian | 5 hours |
|  | Built electronic circuit. | Eduardo and Hatim | 6 hours |
|  | Code and debug Arduino script. | Eduardo and Hatim | 4 hours |
|  | Design and 3D print connection between handler and gripper. | Sebastian and Franck | 6 hours |
|  | Assemble the device | Everyone | 6 hours |

A screen shot of a computer

Description automatically generatedUsing the task duration estimation we modified our average estimates to be 90% reliable.

Figure 20 Task Duration Estimation Formula

The table below shows the actual time our group and individual members have available.

Table 8 Tasks and Actual time available.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Task # | Task descriptions | Responsible | Best estimate time required | Actual time available. |
|  | Fabricate malleable handle. | Sebastian and Franck | 7.5 hours | 5 hours |
|  | Acquire electronic components. | Eduardo and Hatim | 5 hours | 5 hours |
|  | Design and laser cut gripper. | Sebastian | 6.25 hours | 3 hours |
|  | Built electronic circuit. | Eduardo and Hatim | 7.5 hours | 5 hours |
|  | Code and debug Arduino script. | Eduardo and Hatim | 5 hours | 5 hours |
|  | Design and 3D print connection between handler and gripper. | Sebastian and Franck | 7.5 hours | 7 hours |
|  | Assemble the device | Everyone | 7.5 hours | 8 hours |

Our actual available time is based on our current course schedule. During the reading week, we plan to put more time working on our design.

***6. Define any other critical product assumptions that could affect your ability to implement your design. For example: the acceptable values for a specification, availability of material/component, or a critical functionality***

The device is assumed to be washable to clean any food or paints that may got on the device during use. This assumption is that the electrical components will not be washed, as it would damage the functionality of the electronics.

The user is assumed to have average arm mobility but requires assistance regarding wrist motion and stabilization.

It is assumed that during the use of the device, it will not be submerged in liquid. For example, if the user is eating soup with the assistance of the device, the electronics will not be purposely submerged in the soup.

## BOM

Table 9 Bill of Material

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Item # | Description | Material | Size | Quantity | Price ($CAD) | | Justification | |
| 1 | Arduino Nano | Electric Components | 18 x 45 mm | 1 | 5 | | Arduino Nano is one of the cheapest and smallest MCUs. Purchasable online if needed. | |
| 2 | Jumper Wires | Copper, PVC coated | 10 cm long | 2 0 | 5 | | Ideally, we shall be able to get them from the university | |
| 3 | Micro Servo 9g | Plastic, Metal | 23 x 11.5 x 24mm | 2 | 4 | | Cheap, lightweight and efficient. Purchasable online if needed. | |
| 4 | Protoboard | Fiberglass plate | 8 cm x 12 cm | 1 | 4 | | Ideally, we will use one from a previous project or class. | |
| 5 | MPU 6050 (IMU) | Electronic Sensor | 20 x 16 mm | 1 | 6 | | MPU-6050 is cheap and easy to use. Purchasable online if needed. | |
| 6 | Switch | Metal, Plastic | 20 x 6 x 7 mm | 1 | 1.5 | | Amazon, or CBY lab | |
| 7 | 9V Battery | Alkaline Battery | 20 x 40 x 30 mm | 1 | 3 | | Bought from Dollar store. | |
| 8 | Polyethylene Foam | Polyethylene | OD-30 mm, 30 cm length | 1 roll | 2.5 | | Walmart | |
| 9 | Rubber Casing (Neopropene) | Rubber | OD-30 mm, 40 cm length | 1 roll | 2 | | Canadian tire. | |
| 10 | Copper Wire-Bendability | Copper | OD-2 mm | 1 meter | 7 | | Ideally, obtained from CBY lab | |
| 11 | 1.6 mm Screw | Metal | 1.6 diameter | 5 pk. | 1.5 | | Amazon | |
| 12 | Elastic Bands | Rubber | 4 cm diameter (unstretched) | 5 pk | 0.5 | | Bought from Dollar store | |
| 13 | PLA | PLA Plastic | TBD | 1 kg spool | - | Maker Space | |
| 14 | Silicone Rubber Sheet for Lining Surfaces | Silicone | 10 cm x 10 cm | 1 sheet | 3 | Amazon | |
| 15 | Silicon Heat Shrink Tubing | Silicone | 3 cm Diameter | 10 cm length | 2 | Amazon, but also available at Makerspace | |
| **Total Estimated Cost** | | | | | 50 |  | |

## Project plan update

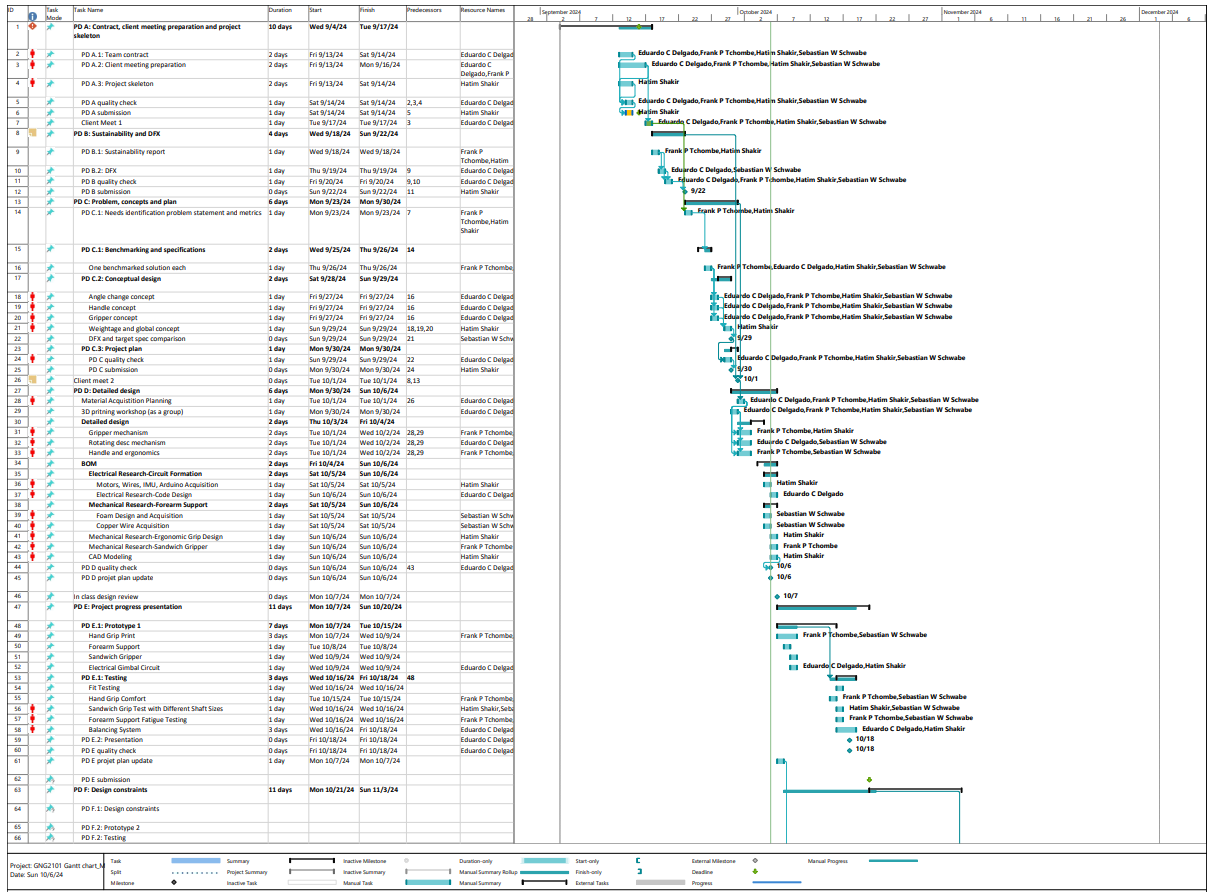


Figure 21 Project plan update

# Conclusions

Throughout the development of the accessible hand grip device, our team learned the importance of aligning design features closely with the user's specific needs and capabilities. Through the different clients meetings, we were able to gather information about mobility limitations and adjust our prototype accordingly, ensuring it remains lightweight, easy to operate, and effective for various daily activities.

We also recognized the value of interdisciplinary collaboration, combining electrical engineering, CAD design, and 3D printing skills to create a functional prototype. However, we forecast potential challenges, particularly in code writing and debugging. To mitigate this, we reached out to external project managers for coding support.

Despite our progress, some issues remain, such as ensuring the device’s durability and reliability during extended use. Additionally, refining the user interface for optimal comfort and safety will be critical as we move forward. As we continue testing and refining our design, maintaining close communication with the client and conducting thorough evaluations will be essential for delivering a successful final product.

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