GNG2101

Design Project User and Product Manual

Accessible Hand Grip – AHG2

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Table 1. Acronyms

Acronym	Definition
CAD	Computer Aided Design
MPU	Motion Processing Unit

Table 2. Glossary

Term	Acronym	Definition
makerepo	NA	Platform used to store all project files.

1 Introduction

This User and Product Manual (UPM) provides the necessary information for a wide range of users, including engineers, designers, and general users, to effectively utilize and maintain the **Handl, an accessible Hand Grip (AHG2)**. It also serves as a comprehensive reference for documenting the final prototype, ensuring the product's continuity and future improvement.

The document is structured to guide users through all essential stages of interaction with the product: understanding its purpose and scope, setting up, operating, troubleshooting, and performing maintenance. Each section has been carefully organized to prioritize clarity, usability, and logical flow, with visual aids included wherever possible.

The primary audience for this manual includes both technical and non-technical users. Special attention has been given to making the content accessible to individuals without an engineering background. Additionally, the manual outlines safety, security, and privacy considerations to ensure responsible and secure use of the AHG2.

This document aims to empower users to maximize the functionality of the AHG2, facilitate ease of use, and serve as a resource for extending the product's capabilities or resolving any issues that may arise.

2 Overview

For the GNG2101 Fall course, our team was tasked with designing a solution for an 8-year-old girl who faces challenges due to limited wrist mobility. She struggles to hold objects like spoons or paintbrushes at the correct angle, which limits her independence in performing everyday tasks such as eating, baking, or painting. This problem is significant as it directly affects her ability to engage in household activities and creative activities. Enhancing her ability to perform these tasks will empower her, boost her confidence, and provide her with a sense of inclusion and accomplishment.

User needs:

1. The user wants to independently hold objects like mixing spoons or paintbrushes
2. The device must be comfortable and easy to use
3. It should allow the gripping of objects of varying sizes at customizable angles.
4. The design should include forearm support to enhance stability.
5. The product must be lightweight and easy to strap onto the forearm.
6. It should be simple to clean and maintain.
7. Noise sensitivity requires the device to operate quietly.
8. The product should include a large surface button for easy activation.
9. Incorporate a visual design element featuring cartoon dogs, as per the client's preference.
10. Activities like painting or baking should be achievable within a 20-minute timeframe.

Our device stands out for its lightweight, user-friendly, and cost-effective design, enhancing independence and functionality. Our device also stands out due to its multi-mode functionality, including static position, dynamic stabilization, and eating assistance. The device is built with a customizable grip with set screws, accommodating various object sizes. Our final prototype is shown in Figure 1 and Figure 2 below:

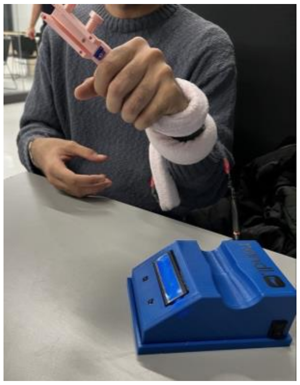

Figure 1: Final Prototype on a User's Hand

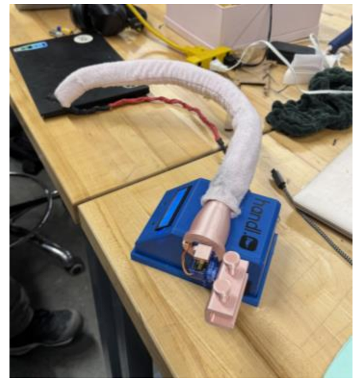

Figure 2: Final Prototype on Docking Station

The device is designed with three main functional components to meet the user's needs. The adjustable forearm support includes a malleable inner material that conforms to the user's arm for comfort and stability during use. The grip and gripper system features an ergonomic hand grip tailored for a child's hand size and a versatile gripper mechanism with set screws to securely hold objects of different shapes and sizes. Finally, the electrical system integrates an IMU sensor to track positional data, while servo motors control the gripper's pitch and roll angles based on signals from an Arduino Uno microcontroller. These features ensure precision, ease of use and adaptability.

The control user interface allows the user to toggle and use three different modes The Static mode locks the gripper at fixed angles for specific tasks. The Dynamic mode stabilizes the gripper, maintaining alignment with a set reference. Finally, the Eating mode provides an initial tilt for scooping food, then transitions to dynamic stabilization.

2.1 Cautions & Warnings

Here is the list of our warnings for our prototype:

1. The device cannot be dropped or submerged in liquids of any type (this doesn't include the tool that is being used with the device, ex: spoon). In the event the device is inadvertently submerged in any liquids, immediately let go of the grip, cease all contact with the device or the liquid, and seek assistance to turn the power of the device OFF as quickly as possible

if the control-unit box isn't wet and/or within the liquid's reach. Failure to do so can result in being subjected to electric shocks.

2. Before opening the control-unit box to change batteries, always make sure the device is turned OFF. Failure to do so can result in being subjected to electric shocks.
3. Before opening the control-unit box or conducting any troubleshooting of any kind (electrical-related or not), always make sure the device is turned OFF. Failure to do so can result in being subjected to electric shocks.

Here is the list of our cautions for our prototype:

1. Use extra caution when using the device near liquids of any type (water, milk, juice, soup, etc.). Adult supervision when using device near liquids is highly recommended for safety.
2. It is recommended to change batteries at the first noticeable sign of motor or screen brightness weakness. Failure to do so can jeopardize device function and user safety.
3. The recommended maximum weight for supported tools is 50g. Beyond this weight, proper device function and safety cannot be guaranteed, and the user could experience discomfort.
4. The recommended maximum length for supported tools is 15 cm. Beyond this length, proper device function and safety cannot be guaranteed, and the user could experience discomfort.

3 Getting started

The Handl system is comprised of a grip mechanism, handle, forearm support, and an electrical control system. Before the Handl is operational, there is some setup required. First open the control box housing the electrical system and locate the black battery box. The battery box has a cutoff switch, make sure the battery box is set to on. Before closing the control box housing, ensure all wire connections are secure. Now that the system has power, turn on the switch on the right side of the control unit. The lcd screen should now power on with the mode selection interface open. To interact with the user interface there are two buttons on the front. A select button marked with an X and next button marked with an arrow. To cycle through the three modes, static, dynamic, and eating, the next button is used. To select the mode use the selection button. Dynamic mode and eating mode require a calibration step when selected. To calibrate the Handl, place the grip in the detent in the control box, or hold the grip in a reference position that you want the Handl to stabilize at. When the grip is in the reference position, push the select button and hold the grip still in the reference position until the lcd screen displays the calibration is completed. Finally before the Handl is ready to use, wrap the forearm support around the user's forearm so that the grip is in their grasp with the forearm support wrapping steep around the wrist and gradually wrapping at a more shallow angle. If the forearm support is loose, pinch the forearm support so the aluminum wire inside conforms better to the forearm. Now to unlock the Handl and engage the stabilization, hold the grip in the reference position and push the select button. If the grip is moved in an unsafe motion or position, the stabilization will lock until it is unlocked. To switch modes turn the unit off then on again using the power switch on the right side.

3.1 Configuration Considerations

The Handl was thoughtfully designed to ensure ease of use and comfort for non-technical users. Each component is assembled to provide functionality and adaptability.

The forearm support features a malleable inner core made of aluminum with an outer layer of polyurethane foam. This core provides a stable yet flexible base that conforms to the user's forearm. To enhance comfort, the foam is encased in a soft fleece cover, offering a gentle and nonirritating surface. Electrical wires are routed along the foam, concealed under the fleece cover to protect them from wear and tear while maintaining a neat appearance.

The grip assembly is constructed from lightweight PLA, which is both durable and ergonomic. The grip attaches securely to the forearm support via a lip with two holes, fastened using aluminum coiling for stability. Inside the grip, a servo motor and an MPU (motion processing unit) are housed to control the pitch angle of the device. Externally, another servo motor is mounted for roll adjustments. The grip's design ensures that all components remain stable during operation.

The gripper mechanism is attached to the external servo motor using a 6 mm screw, enabling precise and secure movements. A protective housing connection encases the gripper and servo, safeguarding the system while maintaining smooth functionality. This design allows the device to hold and adjust objects of various sizes and shapes securely.

To assemble or adjust the system, users will need a small screwdriver (6 mm compatible) to fasten or detach the gripper as needed. Quick-connect wires link the forearm support to the control unit box, providing power and communication between components. These wires are color-coded for user convenience, making setup intuitive and straightforward.

The device is designed for household environments, emphasizing portability and compatibility. The adjustable grip and support accommodate a variety of forearm sizes, ensuring it meets the needs of different users effectively. This configuration balances technical sophistication with user accessibility, making the Handl device practical and easy to operate for non-technical individuals.

3.2 User Access Considerations

The different group of users that could be using our prototype are:

Individuals with reduced grip strength, whether due to aging, arthritis, or temporary weakness who often face challenges in performing daily tasks. The prototype is designed to enhance their grip strength, helping restore functionality and independence. To ensure safety, the device's force output is carefully calibrated, preventing overcompensation and reducing the risk of strain or discomfort.

Furthermore, individuals with permanent disabilities that impact hand strength or coordination could use the prototype as an essential assistive tool. It promotes greater autonomy in everyday activities by adapting to their unique needs.

Finally, those recovering from injuries, such as fractures or muscle damage, could also benefit from the prototype during their rehabilitation process. By providing controlled and adjustable support, the device could aid with recovery.

3.3 Accessing/setting up the System

To set up the device, begin by inspecting it for any signs of damage or loose wiring that could present a safety risk. Ensure all components are securely connected and in good condition before use. Once the inspection is complete, detach the forearm support from the control unit box using the quick detachment points.

The user should start by wrapping the support around their forearm. First, hold the grip comfortably in the palm, then wrap the support around the wrist and forearm in multiple turns. This ensures even weight distribution and enhances stability. More wraps provide better distribution of load and improve comfort during use.

Once the forearm support is securely and comfortably positioned, reconnect the quick-detach wires to the control unit. These wires are color-coded to simplify the process for the user. After ensuring all connections are secure, switch on the control unit. The device will display a message, "Device On," confirming that it is ready for operation.

The user can then use the selection button and toggle button to navigate between different modes. For static mode, no calibration is necessary. Upon selecting this mode, the user will be prompted to input the desired pitch and roll angles. These angles can be adjusted in discrete steps within the range of -90° to 90°, allowing for precise customization.

For dynamic mode or eating mode, initial calibration is required. Place the device in the docking station to align it in the horizontal reference position as shown in Figure 3.

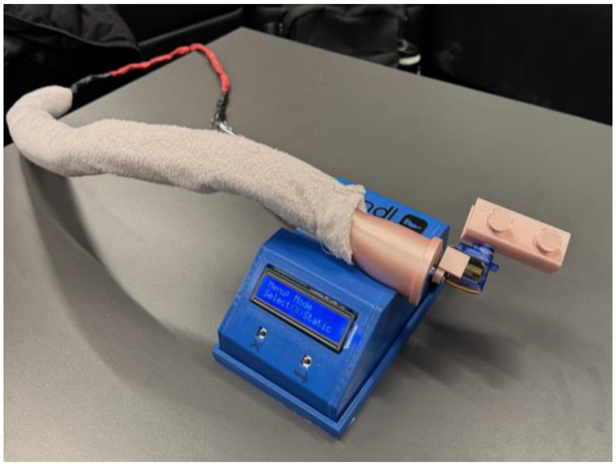

Figure 3: Handl Held in Reference Position for Calibration

.The docking station features a cavity in the control unit box to hold the device securely, and adjustments can be made to accommodate minor differences in placement. Once the device is docked, press the selection button to initiate the calibration phase. After calibration, the device locks for safety and can be activated for use by pressing the button again.

3.4 System Organization & Navigation

3.4.1 Forearm support installation

To install the device on the user, coil the forearm support around the user’s arm. First allow the user to grab the grip, then start coiling the snake-like forearm support around her/his arm. Complete as many loops and tighten as much as necessary to guarantee stability. Be mindful not to overtighten, as it could cause discomfort to the user.

3.4.2 Mode Selection Process

The handl. device has three operational modes it can be used in: static, dynamic and eating. Each mode is distinct and tailored to different types of activities that require a particular set of movements, or lack thereof. Only a single mode can be used at once, and the user can only change modes by restarting the device and going through the mode selection process described below.

When the device is first turned on, a selection menu is projected on the LCD screen with the current mode about to be selected. By default, the static mode appears first. By pressing repeatedly on the button marked with an '→' for next, the user can cycle through all three modes indefinitely in this order: Static → Dynamic → Eating → Static → Dynamic → … By pressing the select button ('X'), the user selects the mode currently being displayed on the LCD screen as the mode they'd like to use and exits the mode selection menu.

Figure 4 Different modes in which the device can be used

3.4.3 Static Mode Navigation

If the user selected the mode as Static in the previous step, they will now be prompted to configure the pitch and roll angles they would like to fix, in that order. By default, the user is prompted to configure the pitch first, and the default value displayed on the LCD screen is -90, in degrees. To cycle through values ranging from -90 to 90 degrees in steps of 15 degrees (by default), the user presses the next button ('→'). By pressing the select button (X'), the user chooses the angle last displayed on the LCD screen as the fixed pitch angle.

Figure 5 Pitch angle selection during static mode

Immediately following that selection, a similar menu is displayed for the roll angle, and the process is identical. When the roll angle is selected, the fixed angle selection menu is exited and a prompt to engage the device appears. By pressing select (X'), Static Mode is engaged, and the servo motors move to the selected orientation once and only once.

3.4.4 Dynamic Mode Navigation

If the user selects Dynamic Mode, the device will begin initializing the sensor. If the connection is successful, a 'Connection Successful' message will appear, shortly followed by another message prompting the user to set the reference for the device. The reference is the orientation that the user wishes to use the tool in. For instance, for maintaining a object level with the ground, the user places the grip flat against a counter or table, or any horizontal, level surface. Once the device is in the appropriate reference position, the user must press select ('X') while holding the device in position while the screen displays 'Calibrating…'. Once calibration is completed, the user will be prompted to press select (X') to engage the device. At this point, the user can move the device away from the from the control-unit box, and press select (X') to begin use when ready.

3.4.5 Eating Mode Navigation

If the user selects Eating Mode, the process is identical to Dynamic Mode, with one exception. For optimal function, the reference position must be set by placing the grip inside the docking area on the control-unit box, and making sure the grip is flush against this surface.

The rest of the steps are identical to Dynamic Mode.

3.5 Exiting the System

To exit the system, begin by switching off the control unit box using the designated power switch. Ensure the device is fully powered down before proceeding to avoid any unintentional movement or electrical hazards. Once the system is off, disconnect the quick-connect wires carefully. These are designed for ease of use and can be safely detached without requiring excessive force.

Next, unwrap the forearm support from the user’s arm. Start at the wrist and work your way down, ensuring the support is fully unwrapped and removed comfortably. To prepare the device for storage, neatly coil the forearm support. This helps maintain its shape and allows it to fit into compact spaces for easy storage or transport.

Before storing the device, inspect it for any wear or damage that may have occurred during use. Clean the components as necessary to maintain hygiene, especially if the device has been used for activities like eating or painting. Properly coiling the support and organizing the quick-connect wires can help ensure the device is ready for future use with minimal preparation.

4 Using the System

The following sub-sections provide detailed step-by-step instructions on how to use the various functions or features of our system.

4.1 Static Mode

In Static Mode, no further input is needed from the user while the device is engaged. The user can simply maneuver the device as they see fit. Static Mode is recommended for activities requiring a tool be held steadily in a fixed orientation relative to the user's arm (ex: writing, painting, mixing, brushing teeth).

4.2 Dynamic Mode

In Dynamic Mode, once the device has been engaged by pressing the select button (X'), the user can move their wrist to the position they find most comfortable, and the device will make sure the tool is held at the desired angle. If the user experiences spasms or does an abrupt movement that exceeds supported range (180 degrees), the device will automatically lock.

While in this frozen state, the device will not move despite still being ON. To unlock the device, the user will need someone to press the select button ('X') when it is deemed the user is ready to use the device safely again. In short, if the device is locked, pressing the select button ('X') will unlock it, and if the device is unlocked and operational, pressing the select button ('X') will lock it.

4.3 Eating Mode

Eating Mode is used in the same way as Dynamic Mode. The select button is used to lock/unlock the device.

Figure 6: Eating Mode Engage Prompt

Since Eating Mode allows tools to be held at a slightly negative pitch angle, while still providing the angle redirection the user requires, we recommend this mode be used for eating, or any activity requiring scooping while still needing active stabilization. To scoop up food, the user simply rotates their arm slightly and the device will tilt the tool down while stabilizing, allowing the user to scoop or pinch.

4.4 Changing gripped object

Our device is designed to grip objects of various geometries, enabling users to perform a wide range of daily activities. This versatility ensures that the device can accommodate different tools or items based on the user's needs, enhancing its practicality and usability.

Objects are secured to the device using 3D-printed set screws, which firmly attach them to a 3D-printed C-shaped bracket. As shown in the image below, a fork can be attached securely to the device using this mechanism. This setup ensures that the gripped object remains stable and reliable during use.

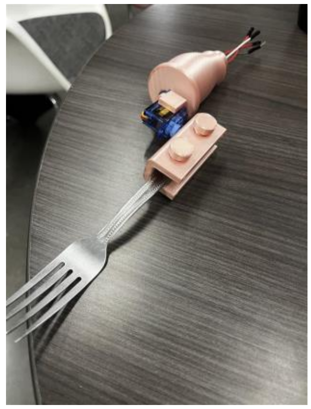

Figure 7: Gripped Fork

To replace the object being gripped, the user or client simply unscrews the two set screws to loosen the current object. The object can then be removed and replaced with another item of choice. The new object is then secured in place by tightening the set screws. For instance, in the image below, a pencil is attached to the device using the same set screws.

Figure 8 Gripped pencil

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

Device skipped calibration: this is caused by loose connections in the wires running between the control unit and the electronics in the grip. Check that all connections are secure and restart the Handl by turning it off and on again.

Connection to the MPU Failed: This error is displayed on the lcd screen when the connection between the control unit and the MPU in the grip is disconnected. Check that the wires are securely connected and restart the Handl by turning it off and on again.

Forearm Support Wire is too stiff: As the aluminum wires in the forearm support are bent repeatedly, they harden in those areas, so to solve this problem, remove the wire core and anneal them. To do this heat the wire with a lighter or heating source that will not melt the wire, let the wire cool to room temperature and put back into the Handl.

5.2 Special Considerations

However, there are certain circumstances and considerations to keep in mind to ensure the device operates effectively and safely over time.

While the device features electronic components that are concealed for protection, it is important to note that the system is water-resistant but not waterproof. Care must be taken to avoid submerging the device in water or exposing it to heavy moisture, such as during washing or use in wet environments. If cleaning is necessary, gently wipe the exterior with a damp cloth, ensuring no liquid seeps into the housing or through connection points.

Additionally, the quick-connect wires that link the forearm support to the control unit box should always be checked for secure attachment. Loose or disconnected wires may lead to functionality issues, including the device failing to turn on or operate as intended. When disconnecting these wires, avoid pulling them by the cords; always grip the connector itself to prevent damage.

5.3 Maintenance

The regular maintenance of the Handl prototype should be done to maintain the product's usability and functionality.

Forearm Support: To maintain the forearm support, the fleece cover is removable and can be hand-washed or machine washed. The foam layer can be hand washed if it gets dirty.

Gripper: To maintain functionality of the gripper, clean any debris from the threads on the housing and screws. To extend life of the threads on the housing, do not over tighten the screws as the threads will lose their effectiveness to provide force. Tighten the screws to hold the gripped object firmly so it does not move and no more.

Grip: The grip houses the servo motors and MPU, so to maintain functionality of these electrical components, any liquids that are spilled on the device should be cleaned immediately. To maintain wire connections in the grip, do not pull on the wires leading into the grip from beneath the forearm support with excessive force.

Power: To ensure the device functions reliably, it is important to change the batteries as soon as any weakness in the device's movement is noticed. Make sure the switch is OFF, then open the control-unit box, and locate the black box. Open the black box by sliding the cover and replace the 4 AA batteries by fully charged batteries with a capacity of at least 2000mAh (ex Duracell, Energizer). Make sure the polarity on the batteries is correct, or the device will not work. Close the black box, then close the control-unit box.

5.4 Support

If users encounter issues with the device for issues related to the functionality or physical components of the device, users can reach out to us the support team. Our team is responsible for addressing defects, replacements, or system upgrades.

Primary contact:

Franck Pradel Tchombe, ftcho088@uottawa.ca

Secondary contact:

Eduardo Cabada Delgado, ecaba024@uottawa.ca

Sebastian Schwabe, sschw066@uottawa.ca

Hatim Shakir, hshak070@uottawa.ca

To report issues, users should follow these steps:

1. Document the problem, including the error message (if applicable) or a description of the malfunction.
2. Take clear photos or videos of the issue to aid in diagnostics.
3. Email the primary contact with a detailed account of the problem, attaching any relevant images or videos.

The client should receive a respond in the following 48hours. In case no response is received in this timeframe, the client should email any of the secondary contact.

6 Product Documentation

6.1 Forearm support system

6.1.1 BOM (Bill of Materials)

Description	**Material**	**Size**	**Quantity**	**Price ($CAD)**
Upholstery foam	Polyurethane	2-1/4” by 2’strip 10mm thick	1	2.5
Fabric covering	Fleece	3” by 4’	1	1.5
Wire core	Aluminum	10’ length 13-gauge	1	2.0

6.1.2 Equipment list

To build this subsystem the only tools needed is a sewing machine and related materials, such as thread, fabric scissors, and clips to hold the fabric in place while sewing.

6.1.3 Instructions

To build the wire core, take the 10-foot length of aluminum wire and bend it at 2-feet until the wire core has 5 wires running along one another all while still connected. To allow the wire to attach to the grip divide the 2-3 inches from the ends of the wire into two by gently bending them away from each other. Do not cut the wire, just bend the two sections outwards slightly and twist together slightly as shown below.

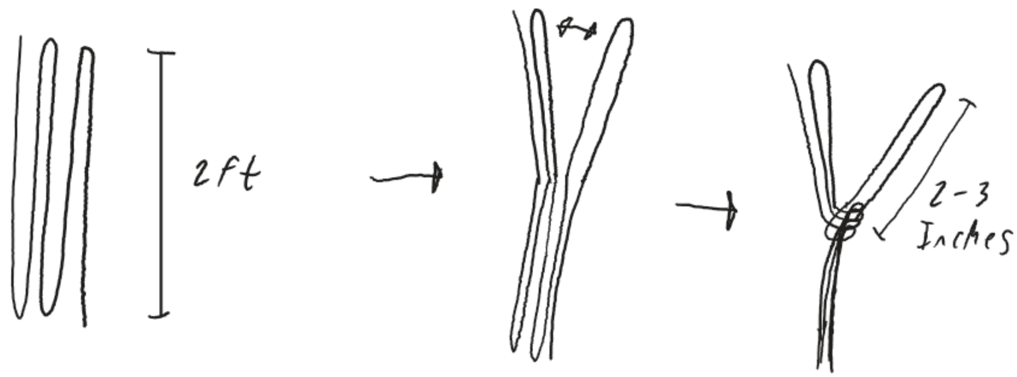

Figure 9. Wire construction

To fix the wire to the grip, feed the two sections through the two holes opposite to one another, then twist around the cylinder. As shown below, the red arrows display the path of the wires.

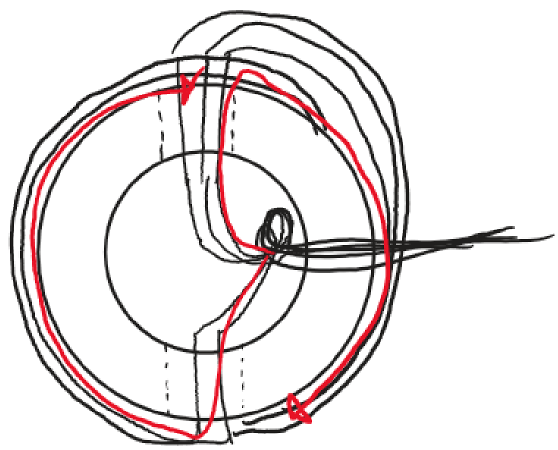

Figure 10. Fixing the wire core to the grip

To build the foam cover, fold the foam strip in half as shown below.

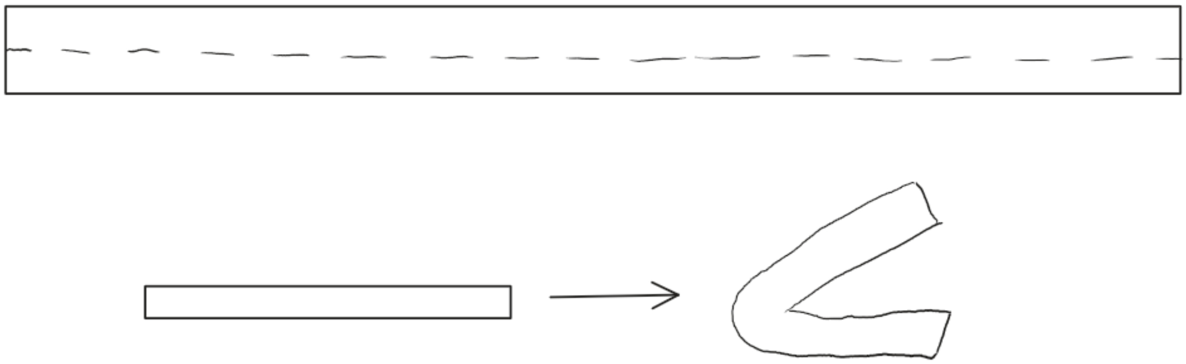

Figure 11. Folding of the foam for sewing

The foam is then clipped in place so the strip can be sewn without unfolding. It helps to compress the foam as it is fed under the sewing machine foot and use a foot that will not catch on the foam or tear it.

To construct the fabric sleeve, fold the 4-foot strip in half so the fabric is two layers of 2-foot length. Start to sew one of the two sides at ¼-inch from the edge. Then do the same for the other side. To place the fabric sleeve on the foam it will need to be turned inside out over the foam as shown below. The seams should be on the outside, then fold one end into the inside of the sleeve and insert the foam tube and turn the rest of the fabric inside out overtop the foam. This process is shown in the image below.

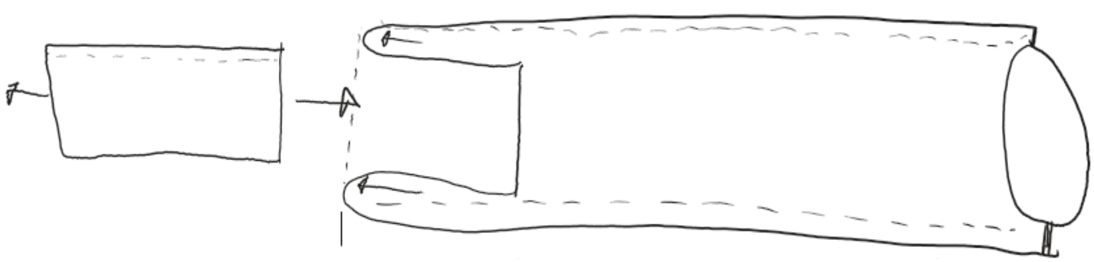

Figure 12. Inserting the foam into the sewn fabric to unroll onto foam

6.2 Gripper and Grip

6.2.1 BOM (Bill of Materials)

Description	Material	Size (mm)	Quantity	Price ($CAD)
Gripper	PLA	60 x 25 x 22	1	0
Grip	PLA	Ø40 x 4	1	0
Grip Cover	PLA	Ø23 x 1	1	0
Pitch servo bracket	PLA	23 x 21 x 15	1	0
Set screws	PLA	M10 x 0.1	2	0

6.2.2 Equipment list

To build this subsystem, a SolidWorks software license was used to design and produce ready to print stl files. An ultimaker 3D-printer was used to produce the parts from PLA.

6.2.3 Instructions

As mentioned above, all the parts in this subsystem were first designed in SolidWorks before being fabricated through 3D printing. This approach ensured precise modeling of each component, allowing for accurate and efficient production of the prototype.

For the CAD work in SolidWorks, the components were designed with special attention to critical factors such as sharp edges, ergonomics for the grip, and overall aesthetics. These considerations aimed to create a functional, user-friendly, and visually appealing design. Images of the CAD models, as shown below, illustrate these design priorities. The CAD for each of these components will be attached to the makerepo depository.

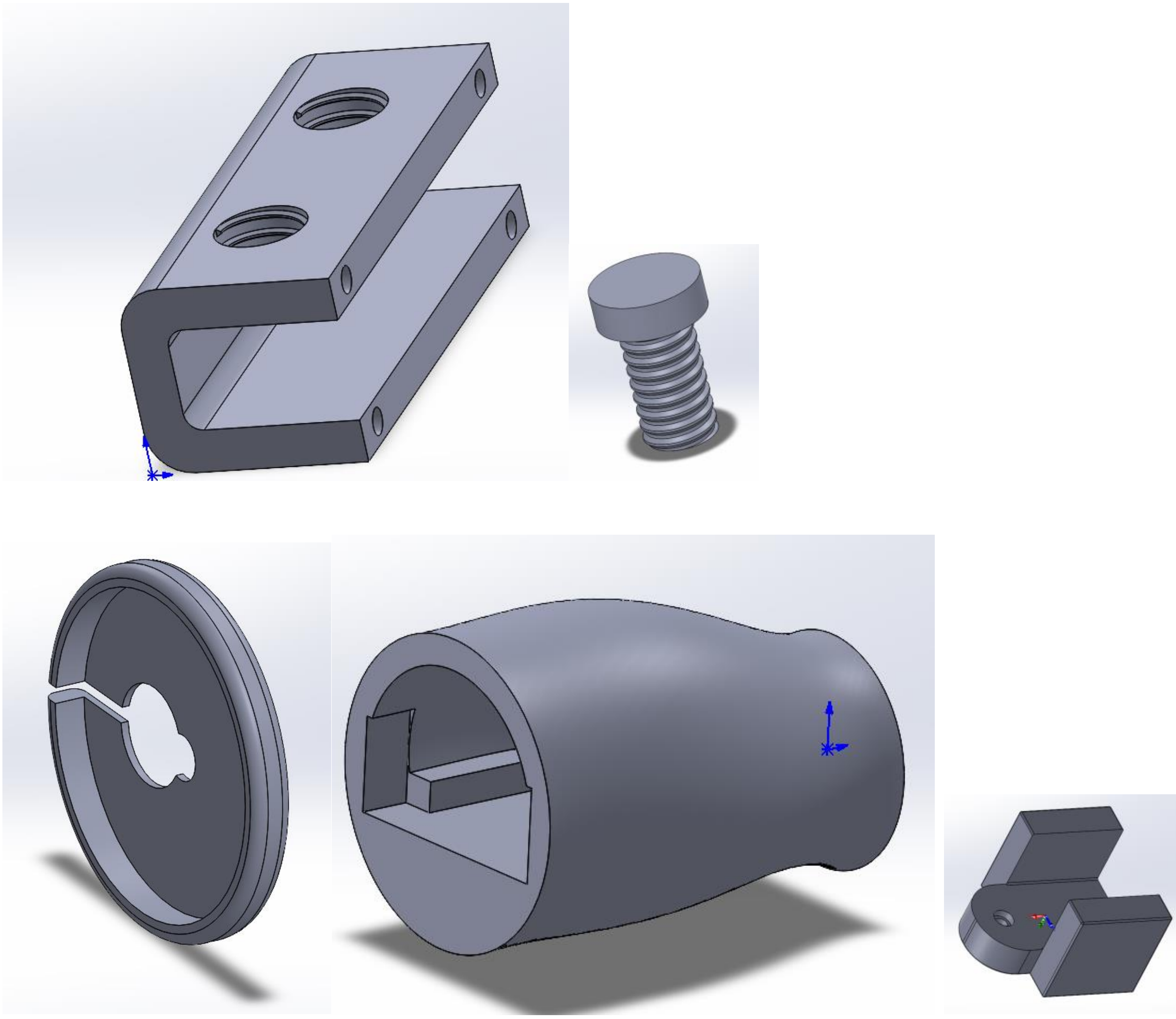

Figure 13 3D printed components: gripper, set screw, grip cap, and grip

During 3D printing, an in-fill percentage of 30% was selected to balance the product's lightweight nature with sufficient durability to prevent breakage under typical usage conditions. Notably, the CAD design for the set screws was tailored to account for the accuracy of the 3D printer, particularly considering the 0.4mm nozzle size used. This ensured a high level of precision in producing components critical to the subsystem's functionality.

6.3 Electronic system

6.3.1 BOM (Bill of Materials)

Description	Material	Size	Quantity	Price ($CAD)
Arduino UNO	Electric Components	18 x 45 mm	1	5
Hookup Wires	Copper	60 cm	7	5
Micro Servo 9g	Plastic, Metal	23 x 11.5 x 24mm	2	4
MPU 6050 (IMU)	Electronic Sensor	20 x 16 mm	1	6
Switch	Metal, Plastic	20 x 6 x 7 mm	1	1.5
LCD screen	Electric Components	85.0 x 29.5 x 13.5 mm	1	4
AA battery	Alkaline Battery	N/A	4	3

6.3.2 Equipment list

To build this subsystem, having access to a soldering station is necessary. For this project, we used the Makerspace's soldering station. This includes, a soldering iron, lead-free solder, a sponge to clean the iron, and a set of helping hands.Some of the tools used to build the handl. electrical circuit include a wire-stripper, a wire-cutter, desoldering tools such as a solder-sucker or solder wick and tip tinner to clean the soldering iron.

For this subsystem, having access to measuring tools like a multimeter and an oscilloscope is paramount for troubleshooting.

6.3.3 Instructions

To build the circuitry of the Handl., simply follow the schematic showed in Figure 7 below. Elements needed include an Arduino UNO, an LCD display (16x02), 2 push buttons, a rocker switch, 2 SG 90 servo motors, an MPU6050 module, a perfboard, approximately 4 m of hookup wire, and a 6V voltage source. The final prototype uses a 4 AA battery pack as the 6V voltage source. Other options such as a rechargeable 6V battery were considered but ultimately decided against due to cost constraints.

Furthermore, we soldered our circuit on a perfboard. Soldering allowed us to get rid of all the loose connections that were present in the previous prototypes with the breadboard. This improved the durability of our design quite a bit. However, if costs and time had permitted, we would rather have built the circuit using a PCB, thus eliminating the risks inherent to using a perfboard, like short-circuits. It is also worth mentioning that the choice of hookup wire is important. We went with 28-gauge hookup wire because it happened to be what we had access to at the time. It is preferable however to use thicker wire when possible to improve durability since there are so many moving parts that cause stress and bends o the wires.

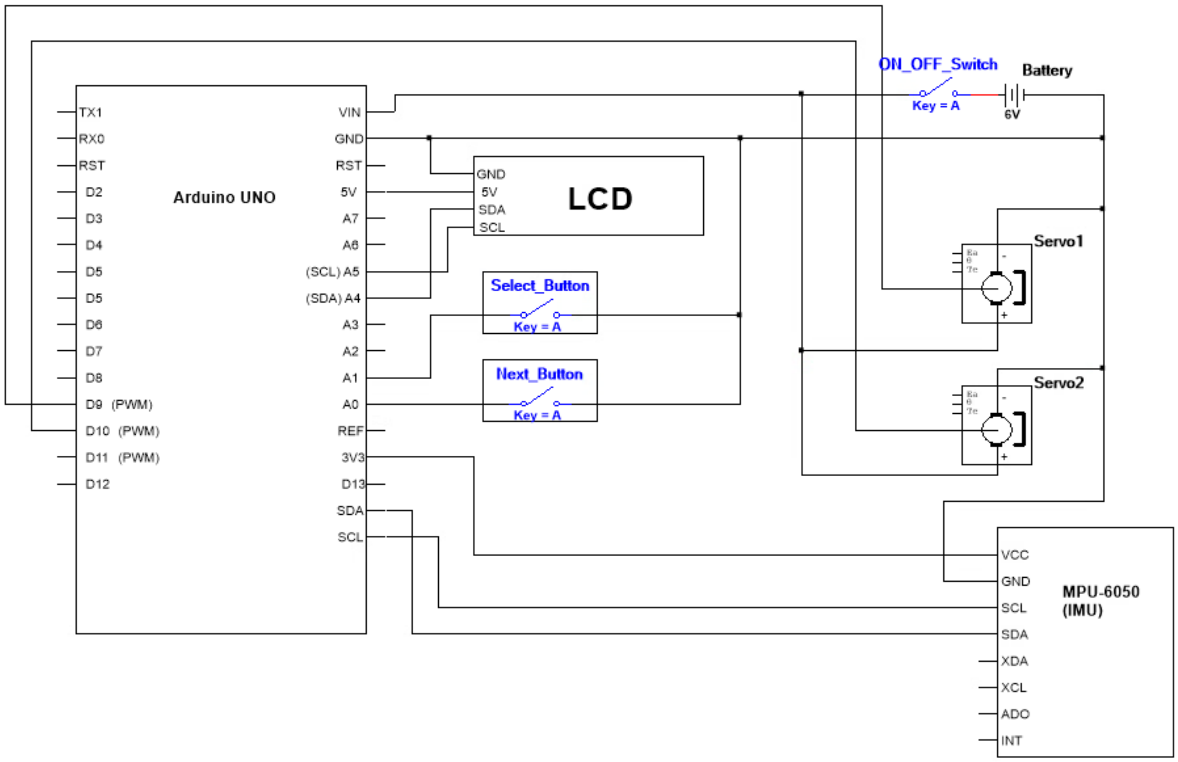

Figure 14 Circuit Schematic for Handl.

6.3.4 Software

In terms of software, we used the Arduino IDE with all of its default libraries, as well as the following libraries:

-Wire

-MPU6050_6Axis_MotionApps612

-MPU6050

-Servo

-Button

-LiquidCrystal_I2C

-quat_to_ypr

quat_to_ypr is a proprietary library of our own making, while all of the rest are public libraries installed from the Arduino IDE itself. You can find all of our software under MULTIMODAL_HANDLE.ino and quat_to_ypr.cpp files in our MakerRepo. For the device to work reliably, it is paramount to test the MPU6050 module to ensure it is providing accurate readings. This type of sensor is very cheap and a surprisingly high percentage of them are defective right out of the factory.

6.4 Control User Interface system

The control user interface box is designed to provide a safe and intuitive way for the client to operate the device. The outer shell is fabricated using durable PLA plastic, chosen for its lightweight properties and ease of molding is shown below.

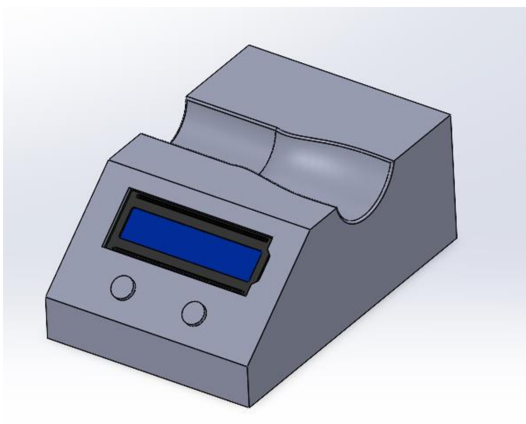

Figure 15: User Interface CAD Model

This shell includes an in-built cavity to serve as a reference position for the grip during calibration, as well as filleted edges for safety.

Some important components of the interface include an LCD panel securely glued to the PLA surface for clear, real-time feedback, such as mode selection and calibration progress. Push buttons, which are press-fitted into pre-designed square cutouts, allow for seamless and ergonomic operation. A side cutout is incorporated into the design to neatly route wires, minimizing clutter and ensuring durability during repeated use.

The system is designed to operate in multiple modes to address different user needs. When the device is switched on, it displays a "Device On" message on the LCD panel, signaling readiness for operation. As shown in Figure 16, various modes can be toggled through by the client; markedly: Static mode, Dynamic mode, and Eating mode.

Figure 16: Different Modes of Control User Interface

6.5 Testing & Validation

The prototype was tested for user comfort and stability. For comfort, the arm wrap was worn for 20 minutes, both directly on the arm and over a long-sleeved garment. The foam padding provided adequate cushioning, preventing discomfort from the aluminum wire while maintaining flexibility and a secure fit.

For stability, the arm wrap was tested with objects of varying masses. It held a 100-gram object without deformation and maintained stability with a 200-gram object, though slight elastic deformation was observed.

Grip and Gripper

To test the grip's ergonomics and to evaluate how well it conforms to the user's palm, it was important to determine whether it minimizes fatigue or strain during prolonged use without slipping.

The prototype was 3D printed and tested by assessing comfort and grip force. Images of the grip being help in the palm to demonstrate how it fits into the hand.

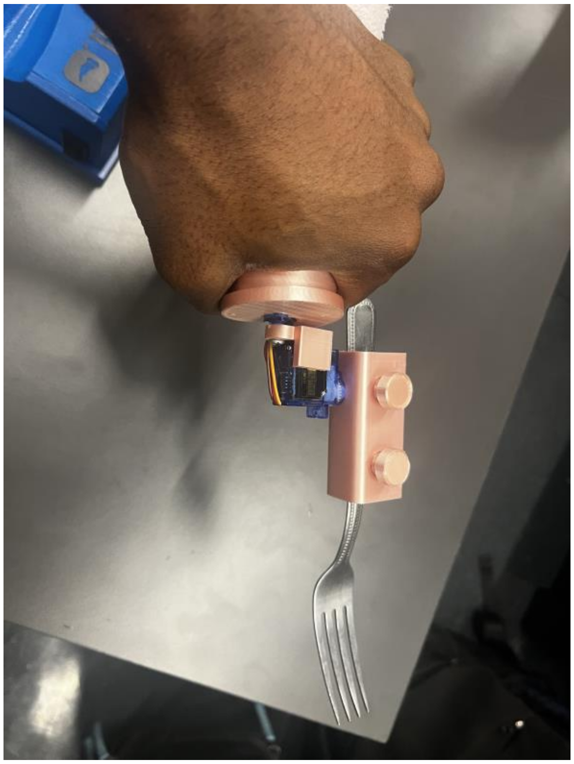

Figure 17 Grip and how well it fits to human hand

The gripper's design is based on the assumption that it can securely hold objects of varying cross-sectional geometries without causing slippage or damage. The prototype was developed to validate the gripper's ability to adapt to different shapes and sizes, such as a spoon or pen, and hold them firmly using two plates held by elastic bands. The purpose of this test was to assess the grip strength and adaptability, ensuring the gripper could maintain a secure hold on objects with minimal effort. Testing involves placing various items in the gripper and analyzing how effectively they help against the force of gravity, this prototype aligns with the durability and functionality factors outlined in earlier in this document.

Gimbal/Electrical system

Soldering Testing

To ensure that our soldering had been successful and there were no short-circuits, or loose connections, we simply turned on and tested our device fully, just like an user would. We tested all three modes: static, dynamic and eating mode, going through the selection and calibration process, so not only did we test the gimbal system, but also the use interface and the entire circuitry. It is also worth mentioning that we used a multimeter to test connectivity as we soldered the device, before conducting a general electrical test.

Mobility Testing

We also tested for mobility, that is the effectiveness of the gimbal itself when powered from our 6V voltage source (battery pack), which is simultaneously powering an LCD screen at full brightness. With this test, we wanted to make sure that the power supply was sufficient to power both components, the LCD screen and the servos.

Table 3 Testing servo motors' current draw effects on source voltage

Servo Motor State	Voltage Potential at Source
Idle	6.345
Maximum movement	6.140

The voltage drop wasn't significant even at max current draw, confirming the power source was sufficient to power the whole system.

7 Conclusions and Recommendations for Future Work

Through the development of the Handl Accessibility Device, we learned the importance of user-centered design and iterative prototyping. Engaging with the client's feedback allowed use to create a solution tailored to the specific needs of an 8-year old girl with limited wrist mobility. Balancing comfort and functionality, we learned the value of simplifying complex systems for the end user. Additionally, integrating mechanical, electronic, and ergonomic features into a product highlighted the challenges of interdisciplinary collaboration.

Despite our progress, several areas could be explored further. If given a few more months, we would refine the stability and responsiveness of the gimbal system by implementing more advanced control algorithms to minimize latency. Additionally, we would use better-quality electronic components and transfer our circuitry to a PCB for a more organized solution. Exploring alternative materials like magnetic attachments for forearm supports is also an avenue that would boost ease of use for the user. Moreover, enhancing the aesthetic design would make the product more visually appealing for the child.

Time constraints significantly prevented us from incorporating certain features that would significantly improve usability and function. A more robust quick-detach mechanism could improve the convenience of setup and removal. Additionally, introducing a rechargeable battery with a longer lifespan would enhance the device's practicality for extended activities.

For future iterations, other groups could build upon our work by integrating wireless solutions, which would reduce the risk of user entanglement. Developing a modular system, with various griop or attachments that can be swapped out would also benefit the overall design.
By addressing these areas, future teams can take our prototype to the next level, enhancing the user's quality of life and allowing her to **handl** everyday tasks.

APPENDICES

8 APPENDIX I: Design Files

Table 4. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
MakerRepo	https://makerepo.com/HatimShakir/2250.handl	12/3/2024