Ergobrush: Rotating Electric Toothbrush

The leading adaptive toothbrush for your accessibility needs

Project Deliverable J: **User Manual**

GNG 2101 – Intro. to Product Dev. and Mgmt. for Engineers

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Abstract

Our group was given the task to develop a device that would provide assistance in the rotation of an electric toothbrush for our client MK. As our client has limited arm mobility, this device would provide her with independence when brushing her teeth. By utilizing the Iterative Engineering Design Process, our group would be well equipped to create a viable solution for our client come design day. We first began our journey by interviewing our client to gain insight on the various needs and wants they wished to be fulfilled. From the data collected, we created a list of target specifications and metrics to which served as a blueprint in our problem refinement loop phase.

Benchmarking was an important factor in further refining our specifications and metrics while also greatly influencing our creativity in generating solutions. Conducting a feasibility study allowed us to identify our constraints by analyzing the Technical, Economical, Legal, Operational and Scheduling constraints at hand. A functional decomposition was done to break down the smaller basic sub-functions identifying the subsystem boundaries using our design criteria. We generated solutions and created a weighted decision matrix to determine the feasibility of each concept.

With the results obtained, a new design was generated and a bill of materials was created. Our initial solution consisted of a traditional rechargeable toothbrush that would be modified to provide two axis of rotation, giving the bristles the ability to rotate and bend forward. Upon presenting the idea to our client, we were met with multiple concerns regarding the complexity, safety and overall lack of feasibility of this device.

Using the client feedback received, we reiterated through the ideation process and created a new solution. Our new prototype would consist of a hand-held device that would attach to our clients toothbrush. It would offer three axis of rotation allowing our client to fully brush her teeth without the need to modify a pre-existing toothbrush.

Upon receiving approval of our new concept, we iterated through many prototypes, testing our assumptions while continuously optimizing our design. Come design day, we presented our fully functional comprehensive prototype branded Ergobrush. The device uses timed positioning sequences that rotate an electric toothbrush, allowing our client to brush all areas of her teeth without necessitating hand movement.

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Introduction

Self-sufficiency is a common goal amongst the general population as no individual is better at assessing one's needs than themselves. This is particularly important for individuals who hold certain disabilities that interfere with their ability in satisfying their basic needs. Creating assistive devices that can be used by individuals with disabilities will enable them to attain a sense of autonomy. Provided with the proper tools, these individuals will feel less ostracized, attaining a sense of freedom and control over their own lives.

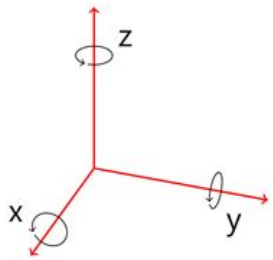
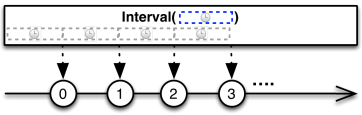
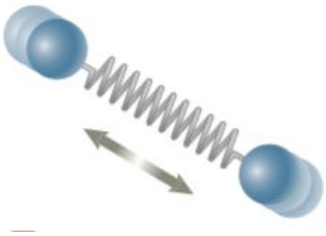
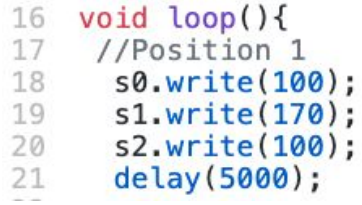
One in five Canadians have a physical disability impacting their daily lives. These disabilities often leave the individual with hindered independence, requiring assistance to complete common tasks such as brushing one's teeth. Our client is a patient at the Saint Vincent Hospital in Ottawa, Ontario, Canada. While she is fairly capable and strives to be as independent as possible, she has a hard time brushing her teeth as she is lacking the ability to fully rotate her wrist.

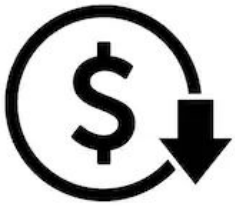
Ergobrush was created to provide a feasible solution for individuals with limited arm and hand movement that wish to brush their teeth independently. By designing an adaptable hand-held toothbrush that emulates a natural brushing experience, Ergobrush offers the assistance necessary while simultaneously providing the satisfaction of brushing one's teeth autonomously. Ergobrush will also reduce the workload on nurses and support staff.

Ergobrush is the only hand-held device that provides three axis of rotation, enabling the user to brush all areas of their teeth effortlessly. It is built using inexpensive, durable yet light-weight, fully recyclable materials, making it far more affordable than any other assistive toothbrush. Using arduino technology, the device can be easily reprogrammed to cater to specific needs and preferences. Also reduce workload on support staff.

User Manual

Features and Functions

Table 1 : Product Features and Functions	
Feature Visualization	Function
Three Degrees of Freedom 	Three degrees of freedom enable the toothbrush to achieve the various positions required to brush all areas of the teeth. This is achieved without requiring the user to move their hand whilst operating the device.
Timed Interval 	Using pre-programmed time dependent sequences increases the accessibility by enabling the user to achieve desired positions without necessitating the use of any buttons.
Vibrating toothbrush 	Scientifically proven to reduce plaque and gingivitis when compared to a manual toothbrush. According to a meta-analysis study conducted by Cochrane Oral Health Group, using a powered toothbrush compared to a manual one was proven to have a 21% reduction in plaque and 11% reduction in gingivitis after three months of use.
Customizable Positioning 	The user is able to update their device to cater to their preferences. Provides a cost-free option to add, remove or adjust various positions and time spent per position. This provides a fully customizable device tailored to each individual's unique needs.
Energy Efficient	Using low energy dependent technologies allow for an extended number of uses before needing to replace or

	recharge the battery.
ON/OFF Switch 	Providing a On/OFF switch simplifies user experience, increasing overall accessibility as the device does not require any pre-existing knowledge to operate.
Low Maintenance 	Device requires minimal maintenance. User is able to replace batteries with ease. Batteries used are AAA and 9V which are relatively inexpensive and widely available.
Low Cost 	Using widely available, inexpensive materials enables the cost of the device to be competitive and low. Directly increasing the accessibility of the device to aid low-income earning individuals. This also creates a ripple effect in the cost of overall accessibility devices as it pressures competing products to lower their product costs.

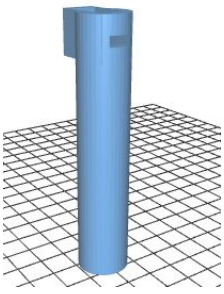
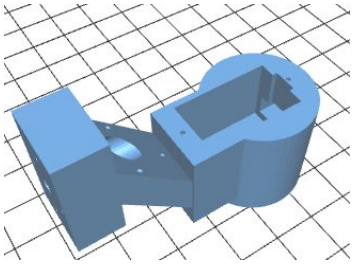
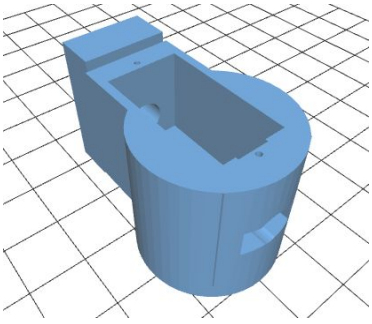
Capabilities

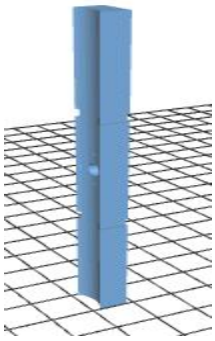
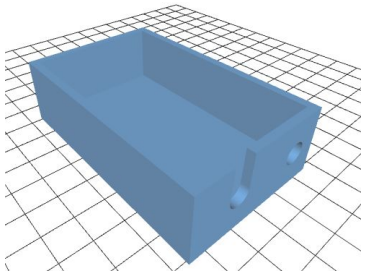
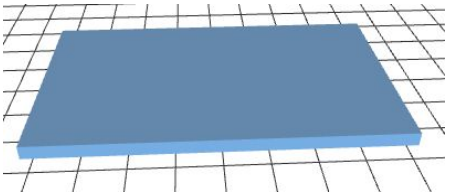
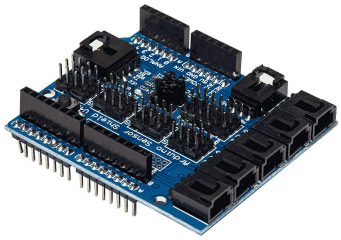
Table 2 : Product Specifications	
Cost of manufacturing	CAD$96.58
Mass of Product	175g
Uses per charge	>15
Degrees of freedom	3
Cycle Runtime	Variable

Prototype Development

Product Composition

Ergobrush is composed of various sub-systems that work synergistically to effectively rotate and position an electric toothbrush. Notably, the device in its entirety can be broken down into two categories: 3D printed components and the purchased components. The 3D printed pieces are composed of ABS filament and serves as the device's casing and structure. The purchased components power the device and contain the various technologies used in changing the toothbrushe's position.

Table 3: Product Components		
3D Printed Components		
Handle 	Joint 1 	Joint 2 

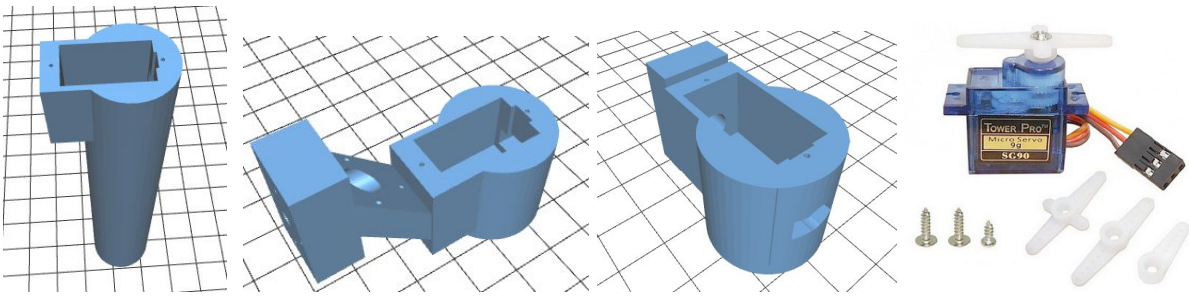
Toothbrush Stabilizer 	Arduino Case 	Arduino Case Lid 
Purchased Components		
Micro Servo + Horn x3 	Servo Extension Cord 	Arduino Uno r3 
9v Battery Holder with ON/OFF Switch for Arduino 	Sensor Shield V4 Digital Analog Module for Arduino 	GUM Daily Clean Sonic Battery Powered Electric Toothbrush 
9 Volt Battery	AAA Battery	Zip Ties x2

Product Assembly

The assembly of our prototype is relatively easy and straightforward due to its minimal and ergonomic design. The product assembly can be broken down into a few simple steps.

Table 4: Product Assembly Steps
Step 1
Begin by adding a servo extension cord to each servo. This will ensure that the wire can be passed through the handle and reach the arduino.  + 
Step 2
Insert a micro servo in the handle piece, joint 1 piece and joint 2 piece. Passing the servo wire through each joint exit hole and into the main exit hole found in the handle.

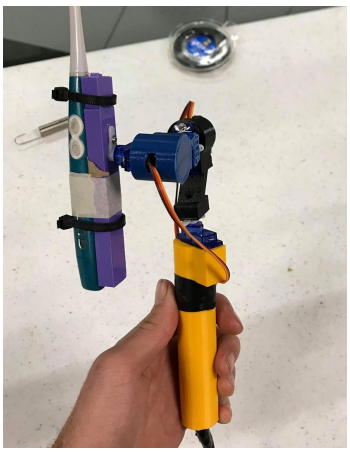


Step 3

Attach the toothbrush to toothbrush stabilizing piece. This is done using zip ties and tape if necessary.

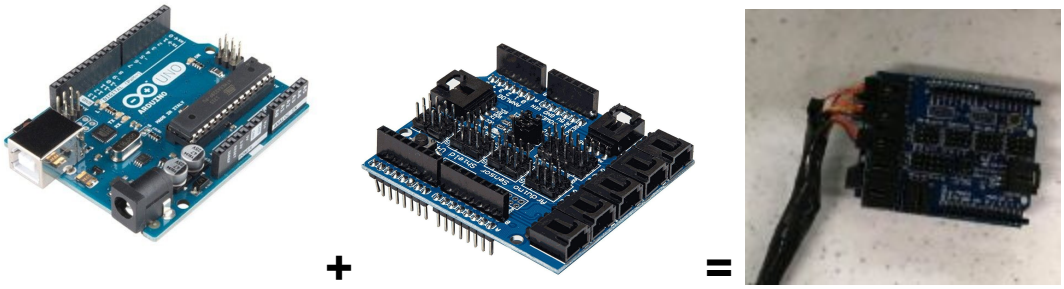
Step 4

Attach each micro servo horn to its designated piece as stated below:
4.1 - Screw the handle piece's micro servo to the base of joint 1.
4.2 - Screw joint 1's micro servo to the base of joint 2.
4.3 - Screw joint 2's micro servo to the center of the stabilizing piece opposite of the toothbrush.
Together, the device should look like this:



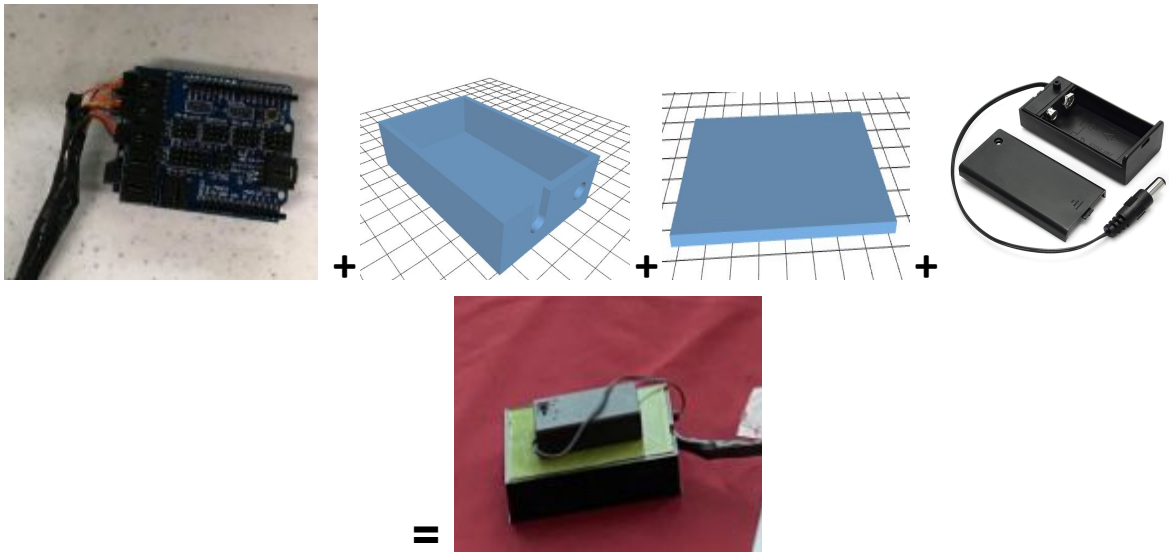
Step 5

Connect the micro servo cables to the Arduino shield and attach the Arduino Shield V4 to the preprogrammed Arduino Uno r3 as stated below:
5.1 - Micro Servo 1 to shield slot A0
5.2 - Micro Servo 1 to shield slot A1
5.3 - Micro Servo 1 to shield slot A2
5.4 - Attach the Arduino Shield V4 to the Arduino Uno



Step 6

Connect the 9 Volt battery case to the the Arduino using the DC power cord and add the protective casing to the Arduino Uno r3 and Arduino Shield V4.
If your Arduino Uno r3 is not preprogrammed, you may consult the code provided in the Design Files table. To learn how to install and program your Arduino Uno watch this video: https://www.youtube.com/watch?v=5OtMqr5hGjE



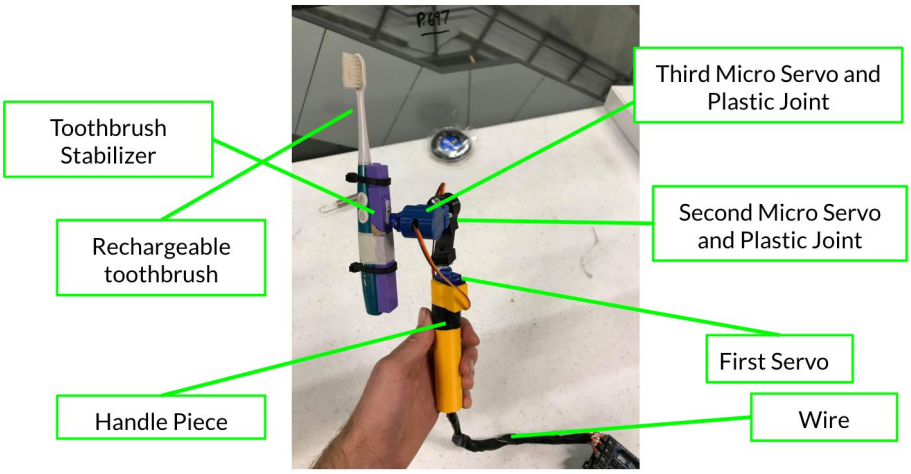
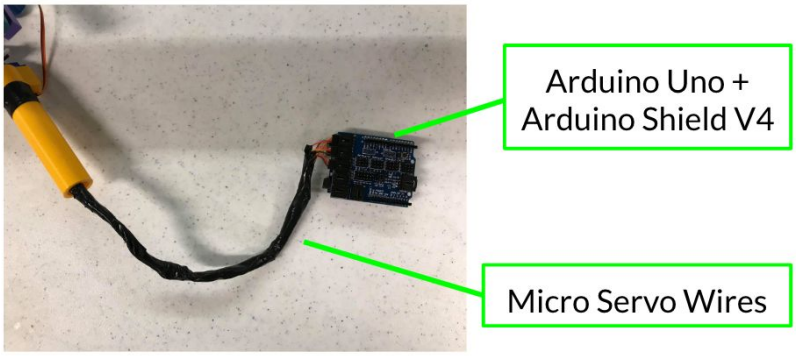
Step 7

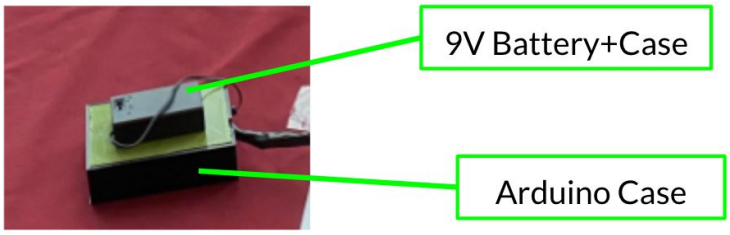
Insert 9 Volt battery in 9 Volt Case and AAA Battery in the electric toothbrush.

Device Operation

The device operates by rotating each servo receiving directions from the Arduino Uno r3. Each servo movement is programmed to have a certain degree and delay. When coded in a certain sequence, this enables the toothbrush to hold desirable positions, allowing the user to brush all areas of their teeth while keeping their arm still. Simply begin by wetting and applying toothpaste to the brush, powering the toothbrush on and finally turning on the arduino via the 9 Volt power switch. Once you have completely brushed your teeth, power off the arduino and toothbrush and rinse the bristles.

Table 5: Device Overview

Main Device	
Microcontroller	

Microcontroller With Cover and Battery	
Arduino Code	``` #include <Servo.h> Servo s0; Servo s1; Servo s2; void setup() { // put your setup code here, to run once: pinMode(LED_BUILTIN, OUTPUT); digitalWrite(LED_BUILTIN, LOW); s0.attach(A0); s1.attach(A1); s2.attach(A2); } void loop(){ //Position 1 s0.write(100); s1.write(170); s2.write(100); delay(5000); //Position 2 s0.write(75); s1.write(180); s2.write(10); delay(5000); //Position 3 s0.write(125); s1.write(180); s2.write(10); delay(5000); //Position 4 s0.write(125); s1.write(0); s2.write(0); delay(5000); //postion 5 s0.write(75); s1.write(0); s2.write(0); delay(5000); } ```

Safety Guidelines and Troubleshooting

As the device will be used near water, it was essential to design a water resistant device to ensure user safety. The device operates on a very low voltage and has it's main electrical components secured in a water resistant casing, distant from the toothbrush. This provides safety to the user and ensures the products longevity. If the user desires to power off the device at any time, ensure that the 9 volt switch is off and unplugged from the arduino. As the device is programmed to begin at the same position at every initial use, if any issues were to occur during product operation simply troubleshoot by reset the device by turning the power off and on.

Design Files

All Files can be found on our MakerRepo and GitHub page.

MakerRepo: https://makerepo.com/GeorgeA/gng2101a10-adaptable-toothbrush-fall-2019
GitHub: https://github.com/ergobrush/ergobrush.github.io

Table 6: Design Files and Explanation

Design File Name	Explanation	File Link
1-Handle.STL	The 3D model of the handle stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/1-Handle.STL
2-JointOne.STL	The 3D model of the first joint stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/2-JointOne.STL
3-JointTwo.STL	The 3D model of the second joint stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/3-JointTwo.STL
4-BrushHandle.STL	The 3D model of the toothbrush stabilizer stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/4-BrushHandle.STL
5-BoxCase.STL	The 3D model of the Arduino box case stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/5-BoxCase.STL
6-BoxLid.STL	The 3D model of the Arduino box lid stored in .stl file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/3D%20Models/6-BoxLid.STL
Brush.ino	The Arduino code that is used to set the operating patterns of the toothbrush stored in .ino file format	https://github.com/ergobrush/ergobrush.github.io/blob/master/brush/brush.ino

Conclusion

In conclusion, Ergobrush was designed and created to provide individuals with limited arm and hand mobility a feasible solution to brush their teeth independently. We came up with the idea of designing Ergobrush after meeting many times with our client MK and listening to her needs. We then moved on to generating ideas and prototyping to get to our final design we are presenting. Its movement capacity, composed of three axis of rotation is the only hand-held device enabling the user to brush all areas of their teeth effortlessly. Using arduino technology, the device can be programmed to fit the needs of our current client MK and implement the teeth brushing sequence that she prefers.

Future Work

In the future, having more resources and time to work on this design would allow us to implement several changes to make Ergobrush more accessible and adaptable to a variety of clients. With more financial resources, we would be able to use better servos to have more stable joints to improve the durability of the toothbrush. Also, with more time, we could implement more functions and programs for the microcontroller to be able to offer a wider range of toothbrush sequencing and programming options to various clients. That way, Ergobrush could be programmed for a variety of clients and we could design personalized brushing sequences based on their specific needs.

Bibliography and Appendices

Number of Individuals with Disabilities in Canada
https://www150.statcan.gc.ca/n1/pub/89-654-x/89-654-x2018002-eng.htm
Psychological implications of lack of independence and mental health:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4046637/
Vibrating toothbrush health benefits meta analysis
https://www.cochrane.org/CD002281/ORAL_poweredelectric-toothbrushes-compared-to-manual-toothbrushes-for-maintaining-oral-health
Project Deliverables : https://github.com/ergobrush/ergobrush.github.io/tree/master/Deliverables