Alternative Design 3:  
Assistive Robotic Arm

Group #9:
Danielle McGeary
Megan Madariaga
Asma Ali

Client Contact:
Merriam Kurland
Speech Pathologist
Hampton Elementary School
263 Main Street
Hampton, CT 06247
(860)-455-9490
1 - Introduction

The following design, contained in this report, will aid a client with Quadriplegic Athetoid Cerebral Palsy to function more independently in an integrated classroom setting. Due to the nature of the client’s disability, the client is physically incapable of any fine motor control. The client is confined to a wheelchair and is forced to communicate nonverbally since he is incapable of oral articulation. The design being implemented is an assistive robotic arm that will attach to the client’s wheelchair. Since oral communication is not an option, the client communicates via electronic devices. If the client is engaged in a conversation, he will use the “DynaVox”, a supplementary augmentative communication device that speaks what the client inputs from the keypad. The client is also unable to eat independently and obtain objects for himself. He is not capable of opening his laptop and cannot begin any work until his personal aid is available to assist him. The client is very dependent upon his aid, especially for eating. Everyday for lunch, the client is forced to eat alone with his personal aid. The client’s personal aid hand cuts all of the client’s food and then physically feeds him. This client does not like this and finds it frustrating. Having to be fed by the aid also eliminates a social aspect from the client’s school day that is essential to the learning process.

Academically, the client is at a high school level. He is mentally astute and is capable of expressing himself, on his “DynaVox” unit, in a more mature and descriptive manor than his classmates, who have full verbal capabilities, can. Communication though an augmentative device requires a strong aptitude for spelling and vocabulary. The client proves that he possesses this knowledge and is capable of being independent if given the proper resources.

![Figure 1: Complete Robotic Arm device](image-url)
The assistive robotic arm, as seen in Figure 1, will allow the client to eat independently. The design that is being implemented for this child will allow for all six degrees of freedom that human arm is capable of. The device will also allow the client to obtain objects that he was never capable of obtaining before on his own. This device will provide the client with a sense of independence that he has been a stranger to for so long.

Presented in this design are the following subunits: a base, upper arm, lower arm, wrist, gripping device, microcontroller, motors, batteries, and circuitry. The base will house one motor, a microprocessor, and the circuit board. The base will also have the capability of rotating a full 360 degrees. The base will consist of a rotating plate, similar to that of a microwave that will allow the entire device to rotate. This will allow the client to have the capability to reach anything around his wheelchair. The base will also be securely mounted to the client’s chair. This will allow stability for the device and will also prevent any injury to the client or wheelchair.

The upper arm will then attach to the base. This is the portion of the arm that will rotate 360 degrees with the base. The upper arm’s connection to the base will also function as a hinge joint and extend 90 degrees. Next, the upper arm portion of the device will connect to the elbow joint that will attach to the lower arm. The elbow joint connecting these two components will have the capability of moving -90 to 155 degrees vertically. This is a safety feature for the client. Since the device will be used for eating, the 155 degree limit will prevent the device from over rotating and possibly puncturing the client’s soft pallet with the attachment.

When both of the vertical joints are extended to 120 and 90 degrees simultaneously, a maximum extension of 25 inches can be added to the client’s reach. This extension well surpasses that of a normal human arm. Since the arm will be positioned on the client’s wheelchair, in front of the client, the client will actually have an even larger radius of extension. Finally, the lower arm will be connected to the grippers by a wrist joint. The gripping device itself will be controlled by two gears. One of the gears will be rotated via a motor. The gears will also be padded with rubber so that they will not be slippery. The rubber will also protect any object from becoming scratched. The grippers will also be created to hold a spatula. These utensils will be made out of durable rubber so that they will not injure the client if the arm were to malfunction. Also, the grippers will be constructed in a way that only the specific utensils created in this design will be able to be attached. This will be another safety mechanism to prevent any extraneous objects from becoming attached to the grippers. If time permits, more specialized tools will be created to suit the various needs of the client and to make the device more versatile.

The entire device will be powered by the microprocessor located in the base of the device. The microprocessor will be controlled by an external keypad that will be operated by the client. This keypad will consist of ten keys while being durable and simple to use. Each key will also have a high spring constant to compensate for the aggressive manner in which the client types due to his lack of fine motor control. Finally, the entire device will be constructed out of PVC piping. This piping is extremely durable, light weight, and cheap. The general outline of how the device will function is contained in Figure 1. The client will orient the device to his desired position by operating the keypad. The keypad will then transmit the entered motion via a signal to the microcontroller. The microcontroller will then convert this signal into current that will be passed to any of the
three motors. The motors will function and orient the arm based on the signals transmitted from the microcontroller.

For this design, some changes have been implemented. The first change is that there will only be three motors powering the arm instead of six. Eliminating these motors will not only decrease the cost of the device but will also eliminate excess weight from the client’s wheelchair. The upper and lower arms will function in tandem to each other instead of operating with separate motors. Another change involves the fork attachment. Originally, a metal fork was going to be altered to fit in the place of the grippers. After consideration, it seemed unsafe to have a sharp fork situated in a device that could undergo sudden brisk movements at a rapid velocity. Instead, a rubber spatula will replace the fork. A specialized tray will also be created to supplement the spatula. This tray will have extremely high sides that will allow the client to scoop food instead of poking it with a sharp object. Finally, the wrist joint will be stationary and will not rotate 90 degrees as previously stated. This motion was eliminated since it is a motion that is not utilized frequently in the human arm. If this rotation were to be eliminated from the human body all together, it would not cause much inhibition to a person’s daily routine. Also, by eliminating this motion from the device, an additional motor was also removed.

1.2 Subunits

The complete robotic arm will provide the form and function that the client will need to use this assistive mobility device. The side view of this device, as shown in Figure 3, depicts a simple design that approximates movements, at each of the three joints, that will cater to the client’s particular needs. The description of the robotic arm will start at the bottom of the apparatus and work upwards.
1.2.1 The Base

The base will be made out of Lexan, PVC panels. The base of the device will be circular and house a stepper motor as seen in Figure 4. This device will be able to attach to the side of the client’s wheelchair. Also connected to the base will be a bearing device that will add support and allow the circular arm base to rotate freely. The arm base will be circular and attach to a stepper motor. This gear will also be attached to the stepper motor. This same gear will also be bolted to the arm base and will allow the base to rotate 360 degrees. To ensure the safety of the client a mechanical constraint will be placed on the base to allow it to only rotate 180 degrees. This way there will be no chance that the robotic arm will contact the client. This can be seen in Figure 5. The base of the robotic arm will be constructed in the University of Connecticut machine shop.
Figure 4: Side view of the base

Figure 5: Top view of the arm base
1.2.2 The Upper Arm

The upper arm will be connected to the base via a shaft that will be constructed out of pillow blocks as seen in Figure 6. The arm will be capable of rotating 180 degrees since it will be attached to the free rotating base. The device will also have the ability to move up and down. The upper arm will be 13 inches (33.02cm) in length.

![Figure 6: Side view of upper arm base connection](image)

The material used for the upper and lower arm will be the PVC piping seen in Figure 7. The piping used will be from schedule 80 and have a 1 inch (2.54 cm) diameter. The inner diameter will be .935 in (2.37 cm) and the outer diameter will be 1.315 in (3.34 cm). These dimensions will give the piping a total thickness of .38 inches (.97cm). The piping will be clear with smooth a finish. The clear finish will allow for visual monitoring of the wires inside the device. The PVC piping will eliminate the potential safety hazard of all wire injuries that could be associated with this device.

![Figure 7: Clear PVC piping](image)
Polyvinyl chloride is produced by the polymerization of the monomer vinyl chloride. Polyvinyl chloride is very similar to polyethylene. Its structure is unique since every other hydrogen along the polyvinyl chloride carbon chain is replaced by chlorine. PVC is widely used in plastics because it is inexpensive and easily obtainable. Also, PVC is useful since it has a high resistivity to fire and water. The material is fire resistant due to the chlorine confirmation that exists within its structure. Chlorine acts an inhibitor to combustion by releasing atoms when burnt. Some important physical properties are included in Table 1.

<table>
<thead>
<tr>
<th>Physical Properties of Polyvinyl Chloride</th>
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<tbody>
<tr>
<td>Density</td>
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<tr>
<td>Young's modulus (E)</td>
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<tr>
<td>Tensile Strength</td>
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<td>Elongation at break</td>
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<td>Notch Test</td>
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<td>Glass Temperature</td>
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<td>Vicat B’</td>
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<tr>
<td>Heat transfer coefficient</td>
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<tr>
<td>Linear expansion</td>
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<td>Specific Heat</td>
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Table 1: Physical properties of Polyvinyl Chloride

1.2.3 The Elbow Joint

The elbow joint will connect the top segment of the upper arm and the proximal section of the lower arm as seen in Figure 8. Since this joint will resemble a hinge, it will have three force components and two couples on the y and z axes. A stepper motor will control both the upper and lower arms. This stepper motor will have a torque of 100 lb·in. This large torque is necessary since the moment about the shoulder was calculated to be 89.04 lb·in. This calculation can be seen in equation 3.
The elbow joint will consist of the four pillow blocks (two on each the lower and upper arm), a shaft that connects all of these components, and a gear that will provide movement as seen in Figure 9. This gear will have teeth. Connected to this gear will be two rubber bands, with indentations, that will intertwine with the teeth on the gears. One of the rubber bands will be located inside of the upper arm. The positioning of this rubber band will function connector between the gear and stepper motor inside the base. The other rubber band will run through the lower arm and attach to the shaft in the wrist. This configuration will cause the lower and upper arms will move together while the wrist is continuously sustained parallel to the ground. This is seen in Figure 10, below. This joint will be controlled by a stepper motor that will receive input from the keys on the keypad.
Figure 9: Elbow joint connection Top View

Figure 10: Gear system responsible for the movement of the upper and lower arms
1.2.4. The Lower arm and Wrist

The lower arm will be 12 inches in length (30.48 cm). It will be constructed clear PVC piping with a thickness of .38 inches (.97cm). The lower arm will be constructed in the University of Connecticut machine shop. The lower arm will move in tangent with the upper arm. Both the lower arm and wrist will be powered by a stepper motor stored in the base of the robotic arm.

Connected to the shaft inside the wrist will be the two oil sintered bronze bearings in the lower arm and a gear. This gear will be bolted down to the wrist plate. This attachment will allow the wrist to rotate 90 degrees toward the client in the x plane. The stepper motor will be oriented so that the body of the motor will sit above of the wrist. This configuration will make it possible for the wrist to move toward the client without contacting his tray. A bearing device will be included to give the wrist smooth rotation. Connected to the wrist plate will be the gripping plate. The gripping plate will be the place of attachment for the grippers. This attachment can be seen in Figure 11.

![Figure 11: The Wrist Joint](image-url)
1.2.5 The Gripping Device

Figure 12: Model of gripping device

The gripping device will be constructed on a steel plate with a width of 4 inches (10.16 cm) and length of 3 inches (7.62 cm). Attached to this plate will be two gears. One of the two gears will be attached to a stepper motor. The motion of the gear attached to the motor, will have both gears moving together to open and close the grippers as seen in Figure 13. The grippers will consists of steel plates connected together for support as seen in Figure 14. A plate 3.5 inches long (8.89 cm) will be attached horizontally, in two locations, to each of the gears. This first plate will then be attached to another plate along with a nut, bolt and spacer. This intermediate plate will be 3 inches long (7.62 cm) and attached to the gripping device plate on the top and bottom with spacers to keep the grippers level. Also the intermediate plate is attached to a 1.5 inch (3.81 cm) connector to the actual grippers. These grippers will be made out of steel and then have a rubber covering which will cause less damage on anything that it comes in contact with. The grippers will have indentations in the rubber to fit with the utensils used for eating. An organic solvent base will be used to bond the steel and the rubber together. The grippers will be 2 inches long (5.08 cm) and have width of 1.97 inches (5 cm).
Figure 13: Rotation of the gears to open the grippers

Figure 14: The Grippers
1.2.6 Utensils

The main goal of this device is to give the client more independence, especially when eating. To make sure that this device is safe for the client, the utensil will use a hard rubber spatula. This will have grooves in the handle that will fit together with grooves in the rubber coating of the grippers. This will create a snug fit when the grippers are closed around the utensil, making it impossible for the fork to fall out. This will also act as a safety precaution so no one will be able to put dangerous foreign objects into the grippers when the client is eating. Also an eating platter will be provided for the client. It will contain a plate with high sides, which will give the client the ability to scrape his food onto the utensil. Also the platter will have a spot for his cup. This cup will have a cover and a straw for him to sip out of.

1.2.7 Equations:

The following diagrams and equations were used to calculate the moment at each of the joints. Finding the moments at each of the joint was important to know the torque of the stepper motor that would be needed in the base to move the arm. This calculation was done in the worst case scenario with the arm completely outstretched in the horizontal position. In Fig. 15 the moment was taken about the wrist and was 39.52 lbs-in, calculated from equation 1. In Fig. 16 the moment was calculated about the elbow and was 42.651 lbs-in, calculated from equation 2. Finally the moment about the shoulder was calculated to be 89.041 lbs-in from equation 3. This can be seen in Fig. 17.

**Figure 15:** Moment diagram for the wrist

\[ \sum M_w = 0 = 1''(W_{\text{motor}} \text{ lbs}) + 6.5''(W_{\text{grippers}} \text{ lbs}) + 11''(\text{Load lbs}) - M_w \]  
(eq. 1)
Figure 16: Moment Diagram for the lower arm

\[ \sum M_E = 0.5'(W_{pillow \ blocks \ lbs}) + 7'(W_{lower \ arm \ lbs}) + Mw - M_E \]  
(eq. 2)

Figure 17: Moment diagram for the upper arm

\[ \sum M_s = 0.5'(W_{pillow \ blocks \ lbs}) + 7.5'(W_{upper \ arm \ lbs}) + 14.5'(W_{pillow \ blocks \ lbs}) + M_E - M_s \]  
(eq. 3)
The user will be able to control the arm using a keypad. This keypad is designed to function like a joystick with all the controls built into keys. Each set of four keys is designed to mimic the controls of a joystick. As mentioned in the beginning of the report, the arm will consist of three joints; shoulder, elbow and the wrist where all the attachments and grippers can be installed based on various functional needs. Since the shoulder and wrist joints consist of a 360° rotation, there are four keys governing the movements; up and down, left and right. There are two keys for grippers; open and close. Similarly the keys for elbow joint will be functioning in terms of up and down as well.
This is a basic mechanical robotic arm with three different joints running by the stepper motors. It is a small motor that is wired to the receiver. If given instructions to do so by the transistor, each motor will move a certain amount. Also, there is a user interface that is controlled by the ten separate input keys. User will be able to control the movements of each joint by pressing the forward or backward keys. Since the client has gross motor controls, he is still able to use a keyboard without any problems. Even though, the motors will be driven by the analog signals, a microcontroller is used to convert the digital signal input from the keypad and then it transmits the signal to the stepper motors located in each joint. Figure 19 above explains a general overview. The power source is connected to both circuit and the motors. Circuit is then responsible for generating the current and then transmitting to the input keypad and microcontroller. User input keypad generates a digital signal and then sends out to the microcontroller. Microcontroller produces output signals to control motor controllers. These signals are then interpreted by the stepper motors for movements and desired positioning of each joint.

### 1.2.9 Sensors
Sensors are resistors that can be altered with the amount of light being reflected upon them. The type of sensor being used in the design for the robotic arm is called a photoresistor. This type of sensor is being used in order to detect/perform a sudden stop if the arm is reaching close to an object. With having a sensor in the design, the arm will not be able to harm the client or anyone around.

Photoresistor function by varying the resistance of the resistors upon contact with light. With a change in the intensity of light, it will alter the resistance of the resistor in the analog port of the microcontroller and then movement of the joint can be stopped with programmed signals sent out by the microcontroller.
Photoresistor Voltage Divider Circuits

Voltage Increases with Light

To choose resistor values:

\[
\frac{(R \times V_{\text{in}})}{(R + R_p)} = V_{\text{out}}
\]

Voltage Decreases with Light

To choose resistor values:

\[
\frac{(R_p \times V_{\text{in}})}{(R_p + R)} = V_{\text{out}}
\]

Figure 20: Implementation of the Photoresistors/Sensors:

These sensors will be one of the components of augmented microcontroller board bought from MICROCHIP. The final values of the resistors will be determined with respect to the other components of the board.

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1 www.societyofrobots.com
1.2.10 Motor Breaking
Another way of stopping the motors is to implement a motor breaking circuitry.

Figure 21: Block diagram of motor breaking

The basic concept of using a transistor is applied to the motor breaking. It will be controlled by microcontroller, and then attached to each of the motors in order to regulate the functional rotation about each joint.

Figure 22: Use of MC3479
MC3479 are the motor controller integrated chips. With the use of MC3479, it will be easier to control the movement of each motor using simple instructions processed from the microcontroller. It has built in clamp diodes and provides back EMF suppression. The MC3479 is designed to drive a two–phase stepper motor in the bipolar mode. The circuit consists of four input sections, a logic decoding/sequencing section, two driver–stages for the motor coils, and an output to indicate the Phase A(bar) drive state.

Figure 23: Specifications of MC3479 Integrated Chip
1.2.11 Circuitry

Figure 24: Schematic

1.2.12 Microcontroller

Figure 24: An overview of Microcontroller.
Figure 24 above explains the process about microcontroller. User input from the keypad is transmitted to microcontroller for the processing. It is responsible for converting digital signal from keypad to analog signal for the stepper motors. Also, at this point, all other error checks are conducted to see if all joints are functional and not moving. It is important to have this check because problems can arise if any other parts of arm are in motion before analog signals are received. Once all the checks are approved, microcontroller will send out the series of signal which will allow the stepper motor to position the rotational joints in desired orientation.

In general a microcontroller is implemented as depicted in the figure 25 below:

![Figure 25: Implementation of a general PIC chip without an augmented board](http://oak.cats.ohiou.edu/~db283101/pichowto.html)

Clock speed will determine the frequency of the signals going into the microcontroller. Faster clock speed will result in faster movements of joints since it will allow the microprocessor to control the movements at a better pace.

An augmented microcontroller unit will be implemented in the design. This unit will consist of motor drivers, crystal timers, LEDs, power capacitors and a PIC chip. This PIC chip will be programmed in C++.
The PICDEM™ HPC explorer board (DM183022) would be an ideal augmented microcontroller unit for this application. It would be an excellent addition to a PIC18F1230 that is used as a microcontroller. (1)

**Figure 26:** PICDEM HPC™ Explorer Board by MICROCHIP®

It can be customized with PIC18F120 microcontroller according to user’s need. It has full pin break-out for easy wire wrap/prototyping, RS-232 port (9 pin D type connector, UART1, potentiometer (connected to 10-bit A/D, analog input channel), 8 LEDs (connected to PORTD with jumper disable), reset button and much more. (1)

**Figure 27:** Pin connections for Microcontroller PIC18F1230

It consists of four crystal modes that are up to 40Hz, two RC modes, two clock modes, internal oscillator block and a fall safe clock monitor. Other features include flash memory retention, self programmable under software control, priority levels for interrupt, extended timer, code protection, in circuit debug at two pins, wide operating voltage range. (2)

**1.2.13 Stepper Motors**

Stepper motors consist of a stepper drive and controller. The control of the stepper motor comes from providing the drive with step and direction signals. The drive then takes the signal and powers the motor. The stepper motor is comprised of a permanent magnet rotating shaft and electromagnets. The permanent magnet rotating
shaft is called the rotor. The electromagnets on the stationary position surrounding the motor are called the stator.

Stepper motors are not like typical DC motors because they do not run freely, they move in a step pattern. It is important to understand the movement of a stepper motor, so this is a simple example to make it clear. The goal is to get a complete rotation from a motor of 90 degree resolution. The rotor starts at the upper electromagnet which is active meaning that it has voltage applied to it. Next to move the rotor clockwise, the upper electromagnet is deactivated and the right electromagnet is activated. That causes the rotor to move 90 degrees in the clockwise direction. This is followed by the deactivation of the right electromagnet and the activation of the lower electromagnet to move the rotor another 90 degrees. The same process is followed to inactivate the lower and activate the left electromagnet to move the rotor 90 degrees further. Finally the cycle is completed as the left electromagnet is deactivated and the upper electromagnet is activated. It is important to note that this example of 90 degrees resolution is not practical. An average resolution is 5 degrees per step so to rotate a complete 360 degrees, it would take 72 pulses (steps). Another term associated with the rotation of device is “half-stepping”. This is when instead of switching to the next electromagnet in the rotation, with a half step it turns on both electromagnets. This causes an equal attraction in between doubling the resolution. That would mean that if you had the 5 degree stepper motor half stepping it would take 144 steps to complete 360 degrees, instead of the already specified 72 steps.

Stepper motors have some unique characteristics that make them effective. First the stepper motors produce high torque at low speeds. The motor also possesses the ability to hold its torque. This means each motor has the ability to firmly hold its position when not turning. It is good for things that stop and start a lot. Other advantages are the low cost, no feedback required in the open loop, rugged for any environment and there is no tuning involved.

1.2.14 Batteries

In this design, deep cycle batteries will be used to power the arm. Compared to other sources of power, deep cycle batteries will be the most beneficial since they allow for an 80% power discharge. This specific type of battery has a significantly thicker positive lead plate. This factor is crucial to the elongation of battery life since a thicker plate is a key factor in the prevention Positive Grid Corrosion. This factor is one of the most common reasons that lead to a battery’s failure. In any battery the positive plate slowly degrades over time. When the positive plate is completely consumed it falls to the bottom of the battery creating a sediment. Due to the durability of deep cycle batteries, they are often used in forklifts and golf carts. The plate thickness of a deep cycle battery even supersedes that of an automotive battery. Unlike the automobile battery, these batteries are quite powerful and do not need to depend upon a medium, such as an alternator, to keep a machine functioning. Another reason that an automobile battery would not be suitable for this application is because it provides a large amount of current over a short period of time.

Most deep cycle batteries contain Lead-Anitmony plates rather than the traditional Lead-Calcium plate. The unique alloy also increases plate life and strength.
The Lead-Antimony plate additionally allows for a plate to discharge at a rate of about 1-2% per month where other batteries discharge at a rate of 2% per week. Since the robotic arm will be utilized quite frequently within his academic setting, the type of battery that can produce the longest life span would be the most economical and beneficial to the client.

![Deep Cycle Batteries](image)

**Figure 28: Deep Cycle Batteries**

1.2.15 Testing of Subunits

Many parts of this design will have to be tested for stability and functionality. A major durability concern would be for that of the keypad. It is essential that the keypad be able to withstand vigorous and aggressive movement since it is essential for proper functioning of the arm. In order to test this, each individual key on the keypad will be aggressively 150 times and then tested for proper functioning. Ultimately, the keypad should be able to withstand approximately 1 million punches. If the client were to use one particular button fifty times a school day everyday, the keypad would have a life span of 55 years.

It is also important to observe how the device functions in space after vigorous consistent motion. In order to test this each motion, along with its opposition motion, will be conducted 100 times. This will show if any particular motion is space will degrade or malfunction over time. Tipping is also another major concern for the device. Since the arm will be attached to the side of the client’s wheel chair, the device will be positioned in the where its center of gravity is furthest from the chair. This position will be located when the arm is fully extended perpendicular to the side of wheelchair’s arm. This test will be conducted when the client is not in the wheel chair. If the chair does not tip when the client is absent from his seat, the chair will never tip with the client is sitting in it.

2 - Realistic Constraints

This design incorporated many engineering standards, along with health and safety concerns, to produce a device that best benefits the client. The PVC piping and
plastic materials that were chosen for this device will provide the client with the same reliability that would be expected of any product currently on the market. The materials chosen are very adaptable to various deviations in weather and temperature. This abides by engineering standard 60605-3-4. Engineering standard 60812 was also followed since a safety mechanism was implemented incase of a device failure. By calculating all of the mathematical expressions that correspond to the various orientations and motions of the device, another standard, 61703, was followed. Ultimately, the completed device will be durable and provide much functionality for the client. This would be desirable of any product currently on the market today.

**Economic**

A major economic constraint for the project is the budget. The budget allotted for all design projects sponsored by the National Science Foundation is 750 dollars. This is a concern since many assistive mobility products on the market can cost an upwards of one thousand dollars. The budget places a limit on the versatility and sophistication of the completed device.

**Environmental**

Environmental constraints include variations in weather and temperature. The device must be able to withstand moisture in the form of precipitation or humidity. Also, the device should be able to function flawlessly in extreme temperatures. The device should not breakdown when relocating to an area of opposite climate. Since the client is in an elementary school environment, there is a strong possibility of accidents with food and beverages. The device should not malfunction and should show no signs of corrosion if this were to happen. Finally, the client will also be using this device for his sixth grade gardening project. The corrosive nature of soil should not deteriorate the device by becoming interlocked within any joints.

**Sustainability**

The device should be composed out of a durable and corrosive resistant material such as PVC piping and plastic. PVC piping is a good material of choice since its unique molecular structure allows it to be durable. This material is both extremely robust and is ideal for mechanical applications involving stress and strain. PVC piping is relatively cheap and easy to obtain. The device should also be weather proofed at any joints as a precautionary act.

**Manufacturability**

If this device were to be manufactured for a company, the device would have to be made custom to fit the needs of each individual client. This particular device will be manufactured for a child who only has control of his right hand. This specificity poses a manufacturing discrepancy since some clients may only have control limited to their left hand. Eventually, the device would be much more effective if it had the capability to be reoriented for usage with either hand. This way two separate devices would not have to be created depending upon which side is dominant to a patient. Also, other clients many have severe impairments that limit them to the usage of only a solitary finger. The device
would have to be adaptable for any of these circumstances in order to be truly effective and sold on the market.

Health and Safety Concerns

The device must not only be safe for the client to use, but should not pose a potential injury to any of the client’s surrounding peers. The device should not be capable of producing any form of an electrical shock or impulse under any circumstance. The device should also have a safety release mechanism in case it were to become attached to any part of the client’s body. The current running through the motor should be kept within a narrow limit so that the device will not over heat or become extremely hot. Also, since the client will be feeding himself independently with the device, it is important to consider the potential injury fork moving a high velocity could cause to the patient’s throat or soft pallet. It is essential that the elbow joint of the device can move no further than 155 degrees towards the clients face. Since the entire arm will be placed infront of the client, the client will be forced to lean forward to obtain his food from the fork. The client does have enough head control to perform this motion.

Since the client only had gross motor control, he is required to meet with an occupational and physical therapist frequently. Once this design is partially created, it is important that the keypad be integrated into the client’s occupational therapy routine. Also, since the client has a very limited range of motion it is essential to constantly communicate with the therapists so that the device that is being created for the client is as convenient and simple for him to use as possible.

Social

Socially, the client never wants to deviate from the norm. With an assistive device it is hard to make a disability inconspicuous. Also, even with this assistive device, the client will never be capable of accomplishing complete independence. In some cases, individuals may be derogatory to those with impairments. This could cause frustration to any client and may cause the device to not appear as appealing.

Political

It is also important that all FDA and OSHA regulations be followed in the creation of this device. It is not uncommon for the government to step in if they feel that a device is doing more harm then it is good. Also, patent infringement is always a lingering concern. It is crucial that the device being created does not mimic any other device too closely.

3 - Safety Issues

Electrical

Safety issues regarding electricity were a primary concern when implementing this design. Given the nature of the device, many electric components are necessary in order for it to function properly. The circuit board, which consists of electrical wiring that will generate a current, is housed within the base unit. This was designed for the protection of the client. Water is an excellent conductor of electricity and should not come in contact with any of the internal circuitry in the electrical board. This could pose
a potential danger and shock to the client. All wires running externally from the base to any of the outside motors should be completely covered. It is pivotal that no bare wire be exposed. Bare wire has to the potential to create a short within the circuit. The short could either cause the arm to either shut down or malfunction in a dangerous way. Bare wire also poses the risk a potential electrical shock to the client or any of his peers. It was also determined that the maximum velocity that any of the motors should operate at is 6 cm/sec. For any joint to exceed this speed, the current being generated throughout the device would have to surpass the limit that is considered safe.

**Mechanical**

A safety release mechanism will be implemented into this design in the case of a mechanical malfunction. While the microprocessor should be telling the arm exactly how to position itself, there is always a risk of the arm becoming clamped around an unwanted object. There is also the risk of the arm gripping an object too tightly. Mechanically, the gripper should never attach to an object at a force any tighter than 10N. This determined ultimate force is essential so that objects, such as those composed of glass, do not shatter and cause harm to the client or any of his surrounding peers. This force is also important so that objects will not be gripped too loosely and later be dropped while in transportation. The breaking of any object is always a potential risk of harm. It is also important to have a safety release mechanism since the client has only gross motor skills. Since the client has limited mobility, it is a strong possibility the client could accidentally press a button that he did not intend to. This possibility could lead to a major safety hazard. If the client were to trigger a button unintentionally, the client could mount onto another person or even the client, himself. While the grippers are not strong enough to crush major bones within the body, they could still present quite an injury. It is important that a safety mechanism be implemented into the design.

Another safety concern is that of the client when he is eating with a fork. Instead of a fork, a rubber spatula will be used. This is to prevent injury to the client or his peers. If the device were to malfunction and enter the client’s mouth at a fast rate, the client could risk puncturing his soft pallet or trachea. Sustaining an injury such as this could be very critical. Also, another concern is the client’s teeth. The constant banging of metal on the clients front teeth could potential cause them to chip or discolor.

**Chemical Hazards – Corrosion**

Another potential safety hazard that corresponds to the nature of this device is corrosion. Since there are many nooks, crannies, and connections within this device, there is a risk of crevice corrosion. Crevice corrosion occurs when moisture and debris collects within a crevice and become stagnant. When moisture and debris remains trapped in a fissure, the surrounding surface beings to dry out and oxidize. When this happens an anodic attack of the metal takes place near the mouth of the crevice and a cathodic reduction of oxygen takes place on the surface surrounding the metal. The reaction is as follows:

Anode: \( \text{Me} \rightarrow \text{Me}^{n+} + n\text{e}^- \)
Cathode: \( \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- \)
This is very important to this device since the risk of crevice corrosion is especially heightened in passive metals such as stainless steel, which the grippers will be constructed out of. Crevice corrosion can also be catalyzed when a metal is contacting a nonmetal. This was taken into account in the planning of this design. In the PVC piping, there will be many joint connections, it is important to make sure that no debris becomes lodged within the connections. In order to prevent this from happening, all joints and crevices must be sealed and protected by an anodic inhibitor such as a protective paint or rubber. This is also important if the client will be using this device around soil. Soil is a very corrosive material that can cause deposit corrosion. Deposit corrosion is very similar to crevice corrosion. Deposit corrosion happens when moisture forms and becomes trapped under a deposit. In this situation, the area directly under the deposit acts as the anode and the area surround the deposit functions as the cathode. Corrosion protection is very important to the proper functioning of this device. If significant corrosion were to occur, the device could severely malfunction.

Another chemical hazard is from the deep cycle batteries. Since batteries all contain acid, it is important to make sure that they do not leak. It is also important to be sure that these batteries are discharging to their full 80% capability so that the battery life will be maximized.

4 – Impact of Engineering Solutions

This device has the potential to bring independence to those who are confined to a wheelchair and lack the basic mobility that many take for granted. Many who are confined to this state, lack the basic ability to eat, open doors, cabinets, or refrigerators, and obtain objects independently. This device, specifically for this client, will aid him within his classroom setting so that his academic prowess will not diminish over time.

This product will socially benefit the client greatly. Since the client has only gross motor skills, it is very hard for him to communicate. Since he is a determined individual, he succeeds fairly well although he finds his means of communication difficult. The assistive robotic arm will provide this child with a simple way of operating his two main communication devices; the Dyna Vox unit and his laptop. For the client, providing him with a new communication device would be expensive. Also communication devices and computer keypads on the market that are geared for persons with disabilities still require fine motor control. Unfortunately the level of control that many of these communicative devices require far exceeds what the client is capable of. The device being implemented in this will allow the client to operate these two communicative devices with more ease. This will place the client on a new level socially.

Being able to eat independently will also embellish the client’s life style socially. He will be able to join his peers during lunch hour instead of eating alone with his personal aid. If the client’s personal assistant cuts his food before lunch, this device will allow him to eat independently with a rubber spatula resembling a fork. Also, since the grippers are made to be interchangeable, they can be customized for any task that the client would desire as long as the diameter of the inserted tool is the same as the insert socket on the grippers.

Many devices on the market that could be purchased for the client are extremely expensive and do not provide enough features to suit the client’s needs. This can become
quite frustrating to the client since he only wants to fit in amongst his peers. This device will be effective since it is being created to cater specifically to his individual needs. Many products on the market today are not durable enough to withstand the force at which the client types. This device will compensate for this by providing an extremely large keypad with a high spring constant. This feature would be beneficial to any patient with limited motor control.

Globally, a custom made device similar to the one described in this design could revolutionize the field of medicine. While many devices on the market today are very beneficial to aid a patient’s needs, they are often created in a very generic style in hopes to a broad array of individuals. Since there are so many debilitating diseases and medical conditions, it is almost impossible for a patient to reap the full benefits of any device. The device may either contain too many features or may not contain enough. This is very important since an individual may be paying for features that could potentially never be utilized.

Since an ongoing dispute in the medical realm is insurance and high costs, this device was created to be relatively inexpensive. Many patients cannot afford the outrageous prices of the devices that exist on the market. Ironically, patients are often not concerned with having the most high-tech or savvy device on the market. They are often just concerned with being able to complete a daily routine and feasible manor. This device is capable of making that happen for many.

For this client, and for any other student, this device will make an academic setting more welcoming. Students and young children will not feel as secluded for their peers and surroundings. In the client’s specific case, being able to eat lunch with his peers will give him the opportunity to make new friends and expand upon preexisting relationships. For a child to always be segregated from his setting eventually becomes a mental burden with age. No child waits to deviate from the norm. While it is unrealistic that any supplementary device could completely compensate for such an impairment, this device has the potential to embellish the client’s quality of life.

This device will also allow for the client to not fall as far behind academically. To some students, this constant struggle may cause a child to give up and work to their full potential. In the case of the client, he is often required to come in early and stay late after school to compensate for all the extra time he requires. The client puts in an additional three hours a day compared to the other children. If a device such as this one could be implemented into school system globally, many students who are mentally sharp and exceptionally bright would not require special education classes to take away time from the normal school day. The client is not attending special education classes because he struggles in school; he is the most intelligent child in the classroom.

Economically, these devices could also lower costs and school budgets. If children with solely physical disabilities were capable of functioning independently in regards to completing class and homework, additional help sessions before and after school could be cut back. These children would be relieved and excited to leave school with their peers. From an additional economic standpoint, mentally astute individuals, with the aid of an assistive device, may be able to obtain entry-level jobs. This would create a new found sense of independence in each of these individuals.
5 - Life long Learning

This project consists of life long learning in that we are always trying to increase knowledge with each of our alternative designs. In a sense we are learning the technical things such as what batteries to use, how to create a circuit and how much torque it will require to move the robotic arm. Also, we are learning how to work under pressure and finish by a certain deadline. Finally, the most important aspect of these alternative designs is to realize that when designing something, nothing is ever foolproof. All of the projects have many unforeseen obstacles to overcome before becoming functional. Another lesson learned from the creation of these designs is how beneficial the collaborations of one’s thoughts can be with another. When creating a device such as this, there are often an infinite number of directions to proceed with a design. Since everyone is unique, these directions are often all interpreted in a numerous amount of ways. It is this differentiation in interpretation that often leads to success. We have been able to witness first hand just how ideas and improvements can spawn from an idea of a peer. We have also learned just how important it is to be challenged by our mentors. These challenges often come in the form of constructive criticism that enlighten our minds and embellishes our ideas.

Paralleling with these thoughts, it is often important to seek out and utilize the resources that we are surrounded by. With this idea, it is important to seek out help of others who are more knowledgeable than ourselves. In order to survive in the field of engineering it is essential to be open-minded and value the ideas given by others. This will allow for a much more eclectic design and ultimately lead to a greater success. Since our world is filled with such a plethora of information, it is impossible for one person to possess all the knowledge needed to create a design independently. In the field of engineering teamwork and communication is essential.

Some of the most valuable resources are the challenges that we face on a daily basis. The testing and failure of a device should not be viewed as a disappointment but as a learning experience. Failure does not define unintelligence, defeat does. It is important to possess a drive and ambition that continuously leads one towards the improvement of one’s work and knowledge. These essential qualities also lead to respect, which is essential to survive in such a demanding field.
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