BME 290 Final Report

Assistive Robotic Arm

Team 5

Aaron Hernandez, Alon Dagan, and Michael Khalil

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

The assistive robotic device is a device being developed for the assistance of children with cerebral palsy. Cerebral Palsy is a debilitating disease that affects the portions of the brain necessary for fine motor control and stability. As this illness does not affect mental capacity, children can become quite frustrated with the inability to control their own limbs. The assistive robotic device aims to reduce this frustration and provide greater independence for children with cerebral palsy.

Our particular client is a fifth grade boy named Sam. Sam was diagnosed with athetoid cerebral palsy as a toddler and currently attends Hampton Elementary School in Hampton, Connecticut. The robotic assistive device under development will be mounted to his wheelchair to help him accomplish routine tasks in the classroom without the use of an aide.

The assistive robotic device will utilize a dual joystick controller to control the motion of the robotic arm. Two buttons will also be used to control the gripping function of the arm. These controls are ones that Sam is familiar with and they will be modeled after the joysticks he currently uses on his wheelchair. One of the most important novel features of the robotic arm is the use of a microprocessor to coordinate shoulder and elbow motion. In this way Sam will be able to move the grabbing hand in straight lines without continuously correcting the trajectory. This will greatly reduce the frustration for Sam and will allow for maximizing functionality with minimal user input. In order to further simplify the control system, the Z axis has been isolated via an elevator system. This will allow for raising and lowering objects without tipping them. This represents a significant departure from previous designs. The use of two servo motors in the design will enable precise maneuvering of the grabber arm without the use of optical encoders. This will enable a more sophisticated control system without exceeding the budgetary limitations.

A childhood under the shadow of a disease such as cerebral palsy can be extremely difficult. Sam has shown amazing courage and versatility in facing his illness and the assistive robotic device will act as another tool for him to regain his independence. Simple tasks such as holding a glass of water or grabbing a piece of paper can be extremely frustrating for Sam and can require the use of an aide. This can act as a barrier between Sam and his classmates. The assistive robotic device will help Sam integrate into the classroom environment and assert his independence. In this way the assistive robotic device will reduce Sam’s frustrations and fears.
1 Introduction

1.1 Background

To assist a fifth grade child with athetoid cerebral palsy in the classroom, a robotic assistive arm device will be designed and mounted on his wheelchair. This device will be utilized to help him accomplish routine tasks in the classroom without the use of an aide. The client is an extremely bright young man who enjoys academics. He communicates with a voice box and utilizes an electric wheelchair.

Cerebral Palsy is a non progressive disease that causes physical disability in human development. Living with Cerebral Palsy is very difficult because it is a severe handicap and inhibits participation in everyday events that most people take for granted. Our patient is diagnosed with Athetoid Cerebral Palsy. Athetoid Cerebral Palsy occurs due to damage in the basal ganglia and extrapyramidal motor system. This disorder makes fine motor motions very difficult. It is a great challenge for the client to hold objects stationary or maintain posture. Despite these damages to the nervous system, patients with Cerebral Palsy often have no mental handicap; this can make life very frustrating.

1.2 Purpose of Project

The assistive robotic arm will act as a third limb for the client, translating his gross motor movements into fine motions. It is hoped that this will reduce some of the frustration in the client’s life and also give him a greater sense of independence. The discrepancies between the client’s mental and physical capacity can cause a great deal of anxiety and stress. He has difficulty typing, eating, and interacting with other students. While he has an aide who helps him in class he feels a lack of independence which affects his self esteem. The robotic assistive device will help bridge this gap between physical and mental abilities for the client. It is crucial that this device reach the client as soon as possible so that he will no longer be handicapped by his disability.

The assistive robotic arm must be easy for the client to be able to control. It must be safe for the client as well as everyone that he comes in contact with. The device should attach to the clients wheelchair without interfering with the controls or the tray. The assistive robotic arm should provide full range of motion in x, y and z axis. Device should be capable of flexion, extension, pronation, supination, abduction, adduction, opposition, reposition, and rotation which are shown in Figures 1.2.1, and 1.2.2. The device should translate gross motor actions to fine motion in order to compensate for his disability.

The device should be capable of picking up a variety of objects in order for the client to be more independent. The motors and materials used must be both durable and light in order to be integrated efficiently with the wheelchair. The robotic arm must withstand wear and tear as well as the possibility of spillage while eating. The device must be aesthetically pleasing so that the client is not embarrassed to use it and so it does
not cause him to be alienated by his peers. The robotic arm must provide the client with a sense of independence so that he can assimilate with his peers and not be as dependent on his aide.

![Figure 1.2.1: Pronation and Supination](image1)

![Figure 1.2.2: Abduction and Adduction](image2)

Both upper and lower arm will move only on the horizontal plane, and there will be an elevator mechanism at the shoulder to let the hand go up and down. The wrist will have a rotational movement and a gripper movement for the fingers. The project was separated into subunits that handle different functions of the robotic arm.

### 1.3 Previous Work Done by Others

#### 1.3.1 Products

**ARM: Assistive Robotic Manipulator**

The Assistive Robotic Manipulator is a device created to assist disabled people with severe handicaps to the upper limbs. It compensates for lost arm and hand function. Through the use of a keypad or joystick input device. It can be mounted on an electric wheelchair and allows numerous daily living tasks to be carried out in home, at work, and outdoors. This device can be used for an assortment of tasks including eating, drinking, cooking, taking medications, brushing teeth, combing hair, and opening doors and drawers. This Robotic arm consists of a gripper, which has the ability to clamp at a force of twenty Newtons, and a power supply that works along with the power supply of the wheelchair. While this device provides a far greater degree of flexibility than the proposed assistive robotic device, it is significantly larger, more conspicuous, and carries a price tag of over $10,000.
“Clutching and Gripping Device”

The National Science Foundation has sponsored numerous senior design projects to aid people with disabilities. Many of these projects share similarities with our current assistive robotic arm design. An assistive device designed to open doorknobs through leverage rather than pronation was attempted by students at Arizona State University. The “Clutching and Gripping Device” made by Arizona State University was utilized by a client with a motorized scooter, to obtain items that are far out of his reach. The gripping device initially had its prongs closed and then upon depressing a button the prongs would open until the client let go of the trigger and then the prongs would automatically close.

“Assistive Reach Mechanism”

A similar reaching device was also sponsored by the National Science Foundation. This device was implemented by students at the University of Massachusetts. The project was referred to as “The Assistive Reach Mechanism”. It enabled the client to pick up items ranging in size from a small needle to a canned food item. The students at the University also built “The Outreach Reaching Aid”, the device served as an auxiliary to the previous one increasing its strength enabling it to pick up larger objects as well as enhancing the triggering mechanism and enabling it to have a variable length ranging from 12 to 30 inches.

1.3.2 Patent Search Results

US Patent #5413454

A similar device exists under US Patent #5413454 for a mobile robotic arm. The mobile robotic arm relates to another invention but is adapted to grasp objects at low-level, intermediate level and high reach areas of a domestic dwelling. This device is used to obtain household items that are stored or kept in areas which vary in elevation from ground level. The device generally comprises a mobile base having a robotic arm rotatably and pivotally connected thereto. The robotic arm comprises lower arm, mid-
arm, and forearm components which are pivotally interconnected and selectively extensible and retractable through the utilization of a controller which is preferably disposed upon an arm rest portion of a wheelchair.

US Patent #06846331

This patent outlines a gripping device. The device consists of two gripping components that move simultaneously to grab or release an object. An electrical motor is used to power the device.

Figure 1.3.2.1: Gripping Device: Patent #06846331

1.4 Map for the rest of the report

The following report will outline the important aspects of the design process of the assistive robotic device. The report will first discuss three preliminary, alternative designs of the device and provide a comparison between each one. These alternative designs will illustrate the options that have been considered and will reinforce the soundness of our final plan. The final, optimal design will be broken down into numerous subunits which will be discussed in great detail.

Following the discussion of the subunits, the realistic constrains of the device will be discussed. This section will touch on many factors, including economic, environmental, health and safety, social, and political factors. These all must be considered when creating a device. Next, all of the safety issues that could either affect the client or his peers will also be discussed. This is clearly another important consideration. Following
the safety concerns, the impact of the device will be considered in both economic and social realms. A life-long learning section is also contained within this report to highlight the educational and personal benefits inherent in creating a design such as this one. A time-line and budget analysis will follow which will outline the expected expenditures and schedule for the project. Next, final thoughts and a brief summary of the overall device will contained in conclusion section. Finally, the report will conclude by citing all applicable sources along with providing acknowledgements to all those who assisted in the creation of this device.
2 Project Design

2.1 Design Alternatives

There were 3 previous methods that were proposed for creating the assistive robotic arm. The first design included 2 processing units one that would change data inputted in Cartesian coordinates and changes it to angles and the other processing unit would control the gripper mechanism. This design also included a chain mechanism for the elevator system. Step motors were used in the design and were running and guided by rotary encoders. This design also took advantage of friction between to rubber surfaces to rotate the shoulder mechanism.

In the second alternative the assistive robotic arm was changed to a joint controlled system. Also the elevator system was changed from a noisy chain mechanism to a more subtle screw mechanism which is also sturdier than the previous design. Also the rubber system was exchanged with a belt system. The belt system was more reliable than the rubber system but was more prone to breaking.

The third alternative design the elevator system was replaced with a shoulder mechanism that would only move in a vertical plane and the horizontal movement would be accomplished by rotating the entire base. No microprocessor was utilized because there is no need to control the angles or position of the hand. In addition, our design has been further streamlined through a complete redesign of the gripper system. The new gripper system is based off of a purchased “Big Gripper” servo that will be modified to fit with our system. An attachment unit to safely fix the robotic arm to the client’s electric wheel chair.

2.1.1 Design 1

Both upper and lower arm will move only on the horizontal plane, and there will be an elevator mechanism at the shoulder to let the hand go up and down. The wrist will have a rotational movement and a gripper movement for the fingers. The project was separated in subunits that handle different functions of the robotic arm.

First, the Processing Unit 1 will be one of the unique aspects of the project. It will take care of the position of the hand by monitoring the angles at the elbow and the shoulder. Regular electronic motors working together with encoders will be used to measure the angles and send the data as an additional input to a microprocessor plus the digital input from the joystick. The microprocessor will take the angles and it will calculate the coordinates of the hand by using calculations that will be described later in this paper.

The base of the robotic arm will rotate by a mechanism that takes advantage of the friction between rubber superficies, and it will have the same mechanism of motor-encoder to measure the angle of rotation; this will be to avoid using rubbers which are less appropriate for this kind of system, given the dimensions and weights that are used.

The shoulder mechanism will accomplished the elevation of the upper and forearm will be achieved by using a mechanism that will have two rails, a holder for the arm that
will pass through them, and a metal chain that will do the elevation of the holder along the rails, which are expected to give more stability to the elevation movement.

The wrist will rotate by a common electronic motor that will be operated by one button that will activate the motor to rotate in one direction with a constant speed. The gripper mechanism will have a pressure sensor on the interior part, it will be activated by a button, one press will close the gripper and a second press will released the grabbed object.

**Subunits**

**Controller**

The controller mechanism must be an elegant balance of simple controls and useful functionality. To this end we have designed a controller with four distinct control mechanisms to easily control all of the functions of the arm. These controls are a digital joystick, a pair of up and down buttons, a pair of twist buttons, and one grab and release button. These buttons will be laid out in a plastic control box and will be connected to the base unit via a ribbon cable. The buttons will all be large and easily pressed and the digital joystick will allow for 8 directional motion. The entire control box will be sealed to protect against spillage and wear. In addition, a power button will be located on this control box which will shut off all power directly from the power source.

![Figure 2.1.1.1: Controller](image)

**Processing Unit 1**

Processing Unit 1 is one of the unique aspects of this project. In order to ensure the least amount of frustration and highest usability for the client it is important that the grabbing hand be moved in the x and y directions. This will allow for a much more natural motion than utilizing a joint controlled system. By creating a system in which the shoulder and elbow joints work in concert to coordinate hand motion we can simplify the client’s life greatly. The heart of this system will be a microprocessor.

**Inputs**
The inputs to the microprocessor will be angle position data from two encoders and instructions from the digital joystick. The encoders will be mounted on the shoulder and elbow joints and will convey angular data to the microprocessor. It is important that we use absolute encoders so that angle information is not lost or distorted on powering off and on. In addition, the microprocessor will take inputs from the digital joystick. This information will be sampled based on some fraction of the microprocessor clock speed such that a continuous value of 1 will increment the position of the arm by a given distance every tenth of a second.

Outputs
There will be four outputs for the microprocessor, two for the shoulder joint and two for the elbow joint. Each pair of outputs will simply signal a forward or reverse action on each motor.

Methodology
The purpose of this processing unit is to convert Cartesian instructions from the joystick into coordinated joint control. In order to accomplish this, an algorithm has been developed to convert angle information into Cartesian coordinates. This linear transformation is accomplished by first utilizing the trigonometric functions to project the forearm coordinates onto a vector parallel with the upper arm. These coordinates $x_o$, $y_o$ are then shifted by an angle $\beta$ utilizing a linear transform. The resulting equations are then simplified using trigonometric identities.

Processing Unit 2
Processing Unit 2 is responsible for the grabbing mechanism of the hand. It takes as its inputs pressure sensor information and the grab/release button. By utilizing this microprocessor a specific threshold pressure can be programmed that the grabbing mechanism will never exceed. This will allow for easy and safe use by our client. The processing unit will allow for the first press of the button to begin closing the grab mechanism until the threshold pressure is reached. If at any point the button is pressed again it will begin to release.

A program will be developed in C that will cause the first press of the grab/release button to begin closing the grabbing mechanism. At this point a feedback loop is engaged that continues closing until pressure reaches a preprogrammed threshold value. At this point the motor signal will be stopped and the grabbing mechanism will go into a standby state. If at any point the button is pressed again, the second motor signal will be sent in order to release the gripper. Also programmed into the microprocessor will be boundary restrictions to ensure that the grabber is never worked past its normal range of motion.
Shoulder Mechanism

The shoulder mechanism will be located at the base of the assistive device and will act to rotate the entire arm. It is important that this joint have as little friction as possible and allow for minute control by Processing Unit 1. Three of the most important elements of this joint are the rotating platter, the motor control, and the encoder output.

Elevator System

The elevator system will be utilized to lift the grabbing arm in the z direction. This system is one of the few elements of the assistive robotic device that does not mimic human anatomy. The purpose of this digression is to reduce frustration for the client. While a human arm lifts objects in a radial motion utilizing the shoulder, this action actually requires wrist compensation to ensure that held objects are not tilted. In order to eliminate this added motion for the client we instead isolate the z axis and have designed an elevator like system. This system has three major components: rails, chain drive, and boundary control switches. The entire system will be mounted on the rotating platter element of the shoulder mechanism.
Elbow Mechanism

The elbow mechanism utilized in this design will operate in a single x-y plane specified by the elevator mechanism. The elbow joint will be controlled by Processing Unit 1 by means of an encoder and brushless motor. It is important that the elbow be able to support its own weight and the weight of a load without sagging or breaking. For this reason it will be constructed of a sturdy aluminum joint. This joint will consist of a rubber roller held in place by a metal pin. The roller element will rotate the forearm and gripper while the upper arm is sturdily fixed to the elevator mechanism. In this way the joint will be able to move reliably in one plane.
**Wrist Mechanism**

The wrist mechanism will act to rotate the grabber based on commands from the client. This motion is important for manipulating objects and grasping horizontal objects. The wrist will rotate a full 180 degrees in each direction and will be controlled by two simple twist buttons. In order to accomplish this motion a nested joint mechanism will be used along with a brushless electrical motor.

![Wrist Mechanism Diagram](image)

**Gripper Mechanism**

The gripper mechanism will consist of a vise-like grabbing component connected directly to a motor. Within the vise will be a pressure sensor which will communicate with Processing Unit 2. These components will work together to allow for a sturdy grip that will not endanger the client or his peers.

![Gripper Mechanism Diagram](image)

### 2.1.2 Design 2

In our second alternative design several factors have been rethought. The most substantial of these changes is the change from an x/y controlled system to a joint control system. This change will create a smoother functioning and mechanically stronger robotic assistant with fewer budgetary issues. The elimination of the x/y control system makes expensive and bulky encoders unnecessary and reduces the processing required.

With the alteration of the control system, the controller has also been rethought, with the removal of the digital joystick in favor of two additional sets of buttons. With this button system, the client will be able to isolate each motion individually, to make use of the full range of motion of the assistive device.
In addition, this design features a completely different drive system. While previous designs have relied on rubber interfacing drums, this design will utilize a belt system. This belt system will result in longer lasting equipment and easier repair. This is achieved without losing the important gear ratio that the drum system developed.

This design also has a major change to the elevator system, with the utilization of a screw based drive in place of a chain. This will allow for a much studier and quieter elevator system. This will be an important improvement in assuring that the robotic assistive device is discrete and does not disrupt a classroom.

In addition, a reliable power source has been determined. This is as crucial part of the design as it will completely dictate the functionality of the assistive device.

A pressure sensor that will effectively protect the gripper from damaging the client or his peers has also been determined. This pressure sensor is important for the input to our microprocessor and to ensure client safety.

**Subunits**

![Diagram of subunits](image_url)

**Figure 2.1.2.1: Overall design including subunits.**
Design Alterations

Controller

The controller mechanism must be an elegant balance of simple controls and useful functionality. To this end we have designed a controller with five distinct control mechanisms to easily control all of the functions of the arm. These controls are a pair of shoulder control buttons, a pair of elbow control buttons, a pair of up and down buttons, a pair of twist buttons, and one grab and release button. These buttons will be laid out in a plastic control box and will be connected to the base unit via a ribbon cable. The buttons will all be large and easily pressed. The entire control box will be sealed to protect against spillage and wear. In addition, a power button will be located on this control box which will shut off all power directly from the power source.

![Diagram of Controller](image)

Figure 2.1.2.2: Controller

Elevator System

The elevator system will be utilized to lift the grabbing arm in the z direction. This system is one of the few elements of the assistive robotic device that does not mimic human anatomy. The purpose of this digression is to reduce frustration for the client. While a human arm lifts objects in a radial motion utilizing the shoulder, this action actually requires wrist compensation to ensure that held objects are not tilted. In order to eliminate this added motion for the client we instead isolate the z axis and have designed an elevator like system. This system has three major components: rails, screw drive, and boundary control switches. The entire system will be mounted on the rotating platter element of the shoulder mechanism.
The wrist mechanism will act to rotate the grabber based on commands from the client. This motion is important for manipulating objects and grasping horizontal objects. The wrist will rotate a full 180 degrees in each direction and will be controlled by two simple twist buttons. In order to accomplish this motion a nested joint mechanism will be used along with a brushless electrical motor.

The shoulder mechanism will be located at the base of the assistive device and will act to rotate the entire arm. It is important that this joint have as little friction as possible and allow for minute control by the shoulder control buttons. The most important elements of this joint are the rotating platter, and the motor control system.

Rotating Platter

This mechanism will consist of a large rotating platter upon which the elevator mechanism sits. This platter will be mounted using ball bearings to a central pin. It is
important that the platter be carefully balanced as torques caused by the arm and load will vary with arm motion.

Motor Control
The platter will be rotated by a brushless motor set into the base of the system. This motor will interface with the platter via a rubber belt system. This belt system will be able to achieve a favorable gear ratio without the concerns of wear inherent in a rubberized interface. Because the speed requirements of this joint are not great, this gear system will be extremely useful in increasing the torque of the joint.

Shoulder Joint

Figure 2.1.2.5: Shoulder Mechanism

Microprocessor
The assistive robotic arm will require an augmented microcontroller unit. The unit will be comprised of LEDs, power capacitors, motor drivers, crystal timers and the Programmable Intelligent Computer (PIC) chips. The PIC will be programmed to accommodate for inputs from the control and inputs from an analog to digital converter which receives inputs from a pressure sensor. The microcontroller that will be used is the PIC18F120.

A suitable augmented microcontroller is the PICDEM™ HPC explorer board (DM183022) with the PIC18F120 microcontroller. The explorer board can be used along with the PIC18F120 microcontroller for increased efficiency. It contains full pin break-out which allows for easy wiring. The board also contains a potentiometer (connected to a 10-bit A/D, analog input channel), 8 LEDs and many more useful features.
Power Source

The assistive robotic arm will be powered using deep cycle batteries. A deep cycle battery is designed to deliver a consistent voltage as the battery discharges, in contrast, starter batteries (e.g. most automotive batteries) which are designed to deliver sporadic voltage spikes. Relative to other power sources, deep cycle batteries will be the most beneficial since they allow for an 80% power discharge. This specific type of battery as has a significantly thicker positive lead plate.

This is very significant with regards 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 sediment. The plate thickness of a deep cycle battery even surpasses that of an automotive battery.

The Lead-Anitmony plate 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.
2.1.3 Design 3

The third alternative design features a system designed to compromise budgetary constraints with ease of use for the client. The biggest change made to the previous design is that instead of using the elevation system with the screw, both shoulder and elbow joints will move only at the vertical plane; the movement on the horizontal plane will be accomplished by using the same rotating base of the entire arm. Unlike previous designs, however, no microprocessor will be used for any of the movements, considering that there is no need to control the coordinates, the angles nor position of the hand.

In addition, our design has been further streamlined through a complete redesign of the gripper system. The new gripper system is based off of a purchased “Big Gripper” servo that will be modified to fit with our system. We have also developed a hardware solution for the gripper safety cutoff. This will allow for the client to vary the cutoff value for the gripper. It has a pressure sensor that will allow for the client’s grip strength to be restricted for safety purposes.

A potentiometer and relay is used in place of the microprocessor. This hardware solution reduces the need for processing and gives the client more flexibility.

Instead of using a joystick for the client’s control of the device, a keyboard will be implemented, with ten different buttons for all the functions. In addition, the single grab/release button has been changed to a pair of grab and release buttons to reflect the fact the client now has a finer control over the grabbing arm.

We have also designed an attachment unit to safely fix the robotic arm to the client’s electric wheel chair.
Shoulder Joint
In order to elevate the upper arm, a servo motor will be used at the shoulder joint. The upper arm will be fixed to the rotating axis of the servo, which will be stabilized to a parallel holder to the motor; this will help to make the system steadier.
**Gripper Mechanism**

The gripper mechanism will consist of a vise-like grabbing component connected directly to a motor. Within the vise will be a pressure sensor which will communicate with the pressure sensor cutoff circuitry. These components will work together to allow for a sturdy grip that will not endanger the client or his peers.

Figure 2.1.3.3: Gripper for the Assistive Robotic Arm

The “Big Gripper” shown in the figure can be purchased online with a servo motor for less than $30.00. The gripper’s fingers measure at 3 inches long and open wide enough to grasp a 12 oz tennis ball. The body of the gripper is comprised of a rugged but lightweight PVC plastic.

**Pressure Sensor**

A pressure sensor will be mounted on the fingers of the gripping mechanism to act as a safeguard against crushing the objects and to prevent injuries to the patient and those that he comes in contact with. The pressure sensor used will be a force sensing resistor (FSR). The FSR come in many sizes and can easily be attached to the grippers. A phidget voltage divider can also be purchased with the FSR for a total of about $25.00. A phidget voltage divider can be used to customize the sensitivity level of the FSR.
adjusting the potentiometer to higher or lower values the sensitivity band can be adjusted up or down. This is perfect for customizing the sensor to the weight of the assistive robotic arm.

![Image](image.png)

Figure 2.1.3.4: A 1.5"Force Sensing Resistor

**Gripper Safety Cutoff**

In order to ensure the safety of the client a safety cutoff must be included that will ensure that there is no danger of the gripper exerting too much force. This safety cutoff can be accomplished with a pure hardware solution. This solution will allow the client or his caretaker to adjust the cutoff pressure using a potentiometer. The following circuit diagram illustrates how a relay, potentiometer, and diode can replace the need for a microprocessor and can give more functionality to the client.

![Diagram](diagram.png)

Figure 2.1.3.5: Safety Cutoff Schematic

**Wheelchair Attachment Unit**

It is extremely important that the assistive robotic device integrate smoothly with the client’s current wheelchair. The client is currently using a Permobil C400 Stander Jr. as shown in figure 2.1.3.6. This wheelchair is capable of carrying loads of up to 155lbs
which is well over the weight of our client and assistive arm. A vise unit has been
developed to firmly attach the assistive robotic device to the wheelchair. This device will
attach on the right side of the wheelchair on the sturdy armrest support using the vise
mechanism described in figure 2.1.3.7.

Figure 2.1.3.6: The Permobil C400 Stander Junior with attachment point.

Figure 2.1.3.7: Vise attachment mechanism.
2.2 Optimal Design

2.2.1 Objective

The assistive robotic arm is designed to aid a young child with athetoid cerebral palsy. The project’s goal is to help this young child become more independent and to help him function more efficiently in his daily routine. This device will enable him to transform his gross motor functions into fine motor functions which are sub par due to his illness.

The assistive robotic arm is comprised of a three major mechanism which mimic the function of the shoulder, elbow and the wrist. The shoulder movement is emulated using a servo motor base. This motor rotates the entire robot arm 180 degrees and will provide the client with a full range of motion to grab objects off his tray or a neighboring desk.

On top of the shoulder mechanism will be an elevator mechanism which will help elevate the arm. The arm will be capable of increasing 6 inches in its height so that he will be able to elevate various objects that he might be using in his class and aid in his final goal of gaining independence. The main component of the elevator mechanism is a motor called a linear actuator which will be capable of lifting the elbow portion of the arm to the motors maximum stroke length of 6 inches.

To mimic the elbow of the assistive robotic arm will have a mechanism controlled by a processing unit which is capable of taking x y coordinates and converting it to angular coordinates for the elbow to move in. This way the movement of the 2 segments of the arm attached to the elbow compensate for each other when they move. The processing unit will send a pulse width modulation signal to a servo motor at the elbow, which determines the duty cycle for the servo motor and allow it to move the segments of the arm to a desired length.

The operation of the wrist will rotate the grabber based on an input from the joystick controller by the client. The wrist will rotate a full 180 degrees in each direction and will be controlled by the joystick. In order to accomplish this motion a nested joint mechanism will be used along with a brushless electrical motor.

The gripper mechanism will consist of a vise-like grabbing component connected directly to a motor. Within the vise will be a pressure sensor which will communicate with the pressure sensor cutoff circuitry. These components will work together to allow for a sturdy grip that will not endanger the client or his peers. An end effector called the “Big Gripper” will be purchased as the gripping mechanism for the assistive robotic arm. The gripper’s fingers measure at 3 inches long and open wide enough to grasp a 12 oz tennis ball. The body of the gripper is comprised of a rugged but lightweight PVC plastic.

In order to increase the functionality of the assistive robotic device, several accessories will be developed for the client. These accessories will be held in the gripper and assist the client in accomplishing various tasks. The accessories currently planned include a marker holder, probe, page turner, and drinking cup. The assistive robotic will surely aid the client in his everyday endeavors and enable him to lead a more independent and fulfilling life.
2.2.2 Subunits

Maximum Shoulder Moment
= (F1*L1) + (F2*L2) + (F3*L3) + (F4*L4) + (F5*L5)

Figure 2.2.2.0: Overall design including subunits.
Torque Calculations

Table 2.2.2.0 Weights and Lengths of Major Subunits

<table>
<thead>
<tr>
<th>Specific Part</th>
<th>Weight, F (N)</th>
<th>Distance, L (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Arm</td>
<td>6.97</td>
<td>15</td>
</tr>
<tr>
<td>Motor at Elbow</td>
<td>1.49</td>
<td>32.5</td>
</tr>
<tr>
<td>Lower Arm</td>
<td>6.97</td>
<td>50</td>
</tr>
<tr>
<td>Motor at Wrist</td>
<td>1.49</td>
<td>65</td>
</tr>
<tr>
<td>Gripper</td>
<td>1.03</td>
<td>65</td>
</tr>
<tr>
<td>Load (12oz can)</td>
<td>3.33</td>
<td>68</td>
</tr>
</tbody>
</table>

\[
M_{\text{max}} = (6.97 \text{N} \times 15 \text{cm}) + (1.49 \text{N} \times 32.5 \text{cm}) + (6.97 \text{N} \times 50 \text{cm}) + (2.52 \text{N} \times 65 \text{cm}) + (3.33 \text{N} \times 68 \text{cm})
\]
\[
= 891.7 \text{ N-cm}
\]
\[
= 8.92 \text{ N-m}
\]

Lower and Upper Arm Measurements = 30\text{cm} \times 7.6\text{cm} \times 7.6\text{cm}

Internal Width = 3\text{mm}
2.2.2.1: Controller

The controller mechanism must be an elegant balance of simple controls and useful functionality. To this end we have designed a controller with only three distinct control mechanisms to easily control all of the functions of the arm. These controls are a pair of grab and release buttons, a joystick controlling the elevator mechanism and wrist motion, and a joystick controlling the x/y location of the arm. These controls will be laid out in a plastic control box and will be connected to the base unit via a ribbon cable. The buttons will all be large and easily pressed. The entire control box will be sealed to protect against spillage and wear. In addition, a power button will be located on this control box which will shut off all power directly from the power source.

X/Y Location

An 8 way directional digital joystick has been chosen for our control as it will represent any gross motion as a digital 1 or 0. Our client has difficulty in producing fine motor control and so a typical analog controller that would allow for variable speed will simply be frustrating for him. Instead, the digital joystick will allow the client’s gross motor actions to be converted to a constant speed in 8 directions. This joystick will control the x/y motion of the grabbing hand in a specific z-plane. The digital outputs will be sent to the microprocessor.

Figure 2.2.2.1.1 Digital Joystick
Figure 2.2.2.1.2 Mounting Dimensions of Digital Joystick

Figure 2.2.2.1.3: Basic Circuit for a Digital Joystick
Figure 2.2.2.1.4: Exploded View of Digital Joystick
Up/Down Control and Twist Controls

The height of the elevator mechanism and the twist mechanism will be controlled by another digital joystick. This joystick will only have 4-way motion. The up and down will control the elevator mechanism and elevate the arm to the desired height. It will allow the client to use gross motions to raise and lower the elevator at a constant speed.

The right and left directions of the digital joystick will control the wrist motion and will be clearly labeled and will control the twisting motion of the wrist. This control will not require any signal processing and will be wired directly to the wrist twisting motor circuitry. Combining the two motions into one joystick will enable the client to operate the major functions of the assistive device in a way that he is very familiar with. The client is very efficient at operating his electric wheelchair which also uses a joystick.

Grab/Release Buttons

The controller will contain a pair of buttons for grabbing and releasing the gripper. These controls will output to the gripper after passing through the microprocessor safety cutoff system. In this way the client will have more sensitive control over the grip strength of the gripper. The buttons will be clearly labeled and easily pressed. In addition, they will be spill and wear resistant. Priority will be assigned to one of the buttons to ensure that there will not be any damage caused by pressing both buttons at once.
Figure 2.2.2.1.5 Large Grab/Release Button

Figure 2.2.2.1.6: Large Grab/Release Button (Posterior View)
Optimization Rationale

The client has stated that he is very comfortable using joysticks from the use of his electric wheelchair. For this reason our optimal controller mechanism has been chosen to utilize two joysticks to accomplish most arm control. Both the elevator system and x/y control will utilize digital joysticks. In addition, the single grab/release button has been changed to a pair of grab and release buttons to reflect the fact the client now has a finer control over the grabbing arm. This solution is ideal as it reduces the number of buttons required and takes advantage of the client’s familiarity with joystick control.
2.2.2.2: Power Source

The assistive robotic arm will be powered using deep cycle batteries. A deep cycle battery is designed to deliver a consistent voltage as the battery discharges, in contrast, starter batteries (e.g. most automotive batteries) which are designed to deliver sporadic voltage spikes. Relative to other power sources, deep cycle batteries will be the most beneficial since they allow for an 80% power discharge. This specific type of battery as has a significantly thicker positive lead plate.

![Figure 2.2.2.2.1 Discharge Curve for a Deep Cycle Battery](image)

![Figure 2.2.2.2 Small Scale Deep Cycle Batteries](image)
This is very significant with regards 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 sediment. The plate thickness of a deep cycle battery even surpasses that of an automotive battery.

![Deep Cycle Battery Components](image)

Figure 2.2.2.2.3 Deep Cycle Battery Components

The Lead-Antimony plate 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.
A deep cycle battery is designed to provide a steady amount of current over a long period of time. A deep cycle battery can provide a surge when needed, but nothing like the surge a car battery can. A deep cycle battery is also designed to be deeply discharged over and over again. To accomplish this, a deep cycle battery uses thicker plates.

A car battery typically has two ratings:

CCA (Cold Cranking Amps) - The number of amps that the battery can produce at 32 degrees F (0 degrees C) for 30 seconds

RC (Reserve Capacity) - The number of minutes that the battery can deliver 25 amps while keeping its voltage above 10.5 volts

Typically, a deep cycle battery will have two or three times the RC of a car battery, but will deliver one-half or three-quarters the CCAs. In addition, a deep cycle battery can withstand several hundred total discharge/recharge cycles, while a car battery is not designed to be totally discharged.
Figure 2.2.2.5 Crank Amperes vs. Temperature for Deep Cycle Battery

Optimization Rationale

The deep cycle batteries are the most efficient method to power the assistive robotic device because of their low discharge rate and their long lifespan. The batteries are also corrosion resistant, which is the main cause of battery failures.
2.2.2.3: Shoulder Mechanism

The shoulder mechanism will be located at the base of the assistive device and will act to rotate the entire arm. It is important that this joint have as little friction as possible and allow for minute control by Processing Unit 1. To accomplish this task a Hitec HSR-599TG servo will be utilized in conjunction with ServoPower Gearbox. Affixed to this gearbox will be a ServoPower round servo horn which will act as a rotating platter for the shoulder subunit. The servo will be controlled using a pulse width modulation signal from the microprocessor.

Hitec HSR-599TG

The servo that will be used for the shoulder mechanism is the HSR-599TG. This servo has a torque 417 oz-in which will be more than sufficient to rotate the assistive robotic arm. The servo motor has a full set of titanium gears which has almost 50 times the strengths of nylon gears. This servo is not cheap, it is priced at approximately $120 but will provide the backbone of the assistive robotic device and needs to be extremely powerful. Because many servos are designed for low load applications, it is important that we purchase a high torque servo such as this one.

The HSR-599TG will operate at 6V with a current drain of only 300mA while idle and 4.2 amps at a full stall. Due to the usage of a gearbox and the normal loads expected by the assistive robotic device, a full stall is not expected and a normal current drain of less than 3 amps is expected. The motor itself is a coreless metal brush motor capable of operation between 4.8 and 7.4 volts.

Figure 2.2.2.3.1: Servo Motor and Base that will be attached to it.
Servo Control

The Hitec HSR-599TG servo motor will be set into the base of the system. The motor will receive pulses from the microprocessor which will indicate the degrees it must be rotated. The standard relationship between the pulse width and the angle of rotation is shown below. The Hitec HSR-599TG responds to a square wave ranging from 3.3 to 7.4 volts peak to peak.
Figure 2.2.2.3.4 The standard time vs. angle chart for a servo motor

**ServoPower Gearbox**

The HSR-599TG servo will be purchased mounted onto the ServoPower Gearbox. In this configuration it will be able to produce over 2000 oz-in of torque. It is capable of rotating 180 degrees which is what the assistive robotic device requires. The ServoPower Gearbox can be purchased fully assembled with the HSR-599TG servo with a gear ratio of 5:1 for optimal power. In addition, the gearbox will be ordered with metal gears. This will ensure that our shoulder joint will not fail. Will this will add extra expense to our already limited budget it represents a significant improvement over plastic gears. This shoulder joint will be subject to high torsion forces when the arm is extended. The risk of the plastic gears failing and the entire system being ruined is mitigated by spending slightly more money for a more robust product.
Figure 2.2.2.3.5 Servo in side the ServoPower Gearbox

Figure 2.2.2.3.6: Servo inside of the ServoPower Gearbox
Servo Horn
Mounted to the
The round arm that will be placed on the servo motor is under $15.

Figure 2.2.2.3.7 Round Arm for servo motor.

Optimization Rationale

This design has been optimized through the use of a sturdy servo and gear mechanism. This purchased combination will allow for precise angle control without the use of separate encoders. The servo chosen contains sturdy titanium gears and a 5:1 gear ratio which will allow for a reliable motion of the platter. This design is superior to previous designs as it does not require the difficult manufacturing of a smoothly operating platter and does not rely on rubber parts which may wear out.
2.2.2.4: Elevator System

The elevator system will be utilized to lift the grabbing arm in the z direction. This system is one of the few elements of the assistive robotic device that does not mimic human anatomy. The purpose of this digression is to reduce frustration for the client. While a human arm lifts objects in a radial motion utilizing the shoulder, this action actually requires wrist compensation to ensure that held objects are not tilted. In order to eliminate this added motion for the client we instead isolate the z axis and have designed an elevator like system. This system will consist of a linear actuator with internal limit switches which will be mounted on top of the shoulder mechanism. An aluminum plate will be mounted on the moving portion of the linear actuator and the elbow segment of the assistive robotic arm will be attached to the bottom of the aluminum plate.

The linear actuator that is used will have a 6 inch stroke and will elevate the arm. A bracket will be inserted through the ¼ inch diameter hole present at the top of the linear actuator and the aluminum plate will be attached to the bracket. By mounting the elbow on the aluminum plate the arm is no longer restricted to the minimum distance defined by the collapsed length of the linear actuator and can therefore be more useful to the client. The client will be able to pick up items that are below the collapsed length of the linear actuator. Therefore the elbow can be used to help the client obtain things level with the tray on his wheel chair such as a book from a neighboring desk.

The linear actuator operates at 12V DC while the rest of the major components operate at 6V DC. The specifications state that the linear actuator will still operate at 6V DC but will operate at a much slower speed than at 12V DC. Since speed is not an important design constraint in the assistive robotic device the linear actuator will be run at 6V DC. In testing the linear actuator it was deduced that while it does operate slower at 6V DC than at 12V DC it will operate at a lower noise level. This is very beneficial to the client because he will utilize the arm in a school setting and will cause fewer disturbances to the class if the linear actuator produces less noise.

Figure 2.2.2.4.1 Linear Actuator
## Hole To Hole Dimensions

<table>
<thead>
<tr>
<th>Stroke Size (Inches)</th>
<th>Collapsed Length (Inches)</th>
<th>Extended Length (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6.3</td>
<td>8.3</td>
</tr>
<tr>
<td>3</td>
<td>7.3</td>
<td>10.3</td>
</tr>
<tr>
<td>4</td>
<td>8.3</td>
<td>12.3</td>
</tr>
<tr>
<td>6</td>
<td>10.3</td>
<td>16.3</td>
</tr>
<tr>
<td>8</td>
<td>12.3</td>
<td>20.3</td>
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<td>9</td>
<td>13.3</td>
<td>22.3</td>
</tr>
<tr>
<td>10</td>
<td>14.3</td>
<td>24.3</td>
</tr>
<tr>
<td>12</td>
<td>16.3</td>
<td>28.3</td>
</tr>
<tr>
<td>18</td>
<td>22.3</td>
<td>40.3</td>
</tr>
<tr>
<td>24</td>
<td>28.3</td>
<td>52.3</td>
</tr>
</tbody>
</table>

Figure 2.2.2.4.2 Linear Actuator Dimensions
Figure 2.2.2.4.3 Elevator System (collapsed length)
Figure 2.2.2.4.4: Elevator Mechanism (maximum length)
Figure 2.2.2.4.5: Elevator Mechanism (Top View)
Testing Protocol

A linear actuator was obtained and tested to see if it was capable of being used in the assistive robotic arm. The linear actuator was originally at its collapsed length and was tested to see if it would extend to its full 6 inch stroke and if the limit switches would work and prevent the linear actuator from trying to extend at its peak.

To test the linear actuator a power source was utilized and set to 12V DC and the linear actuator was placed in the power source to determine if it would in fact extend as well as test the built in limit of the device. After placing the linear actuator in the power source it was evident that it was functioning as expected. It increased to its maximum stroke length and stopped trying to increase upon arrival of its maximum length despite leaving it in the 12 V DC power source. This verified that it could be utilized in the assistive robotic device and was capable of being the elevator mechanism.

Figure 2.2.2.4.6 Collapsed Length Linear Actuator
The hole into which the bracket is to be inserted was also present in the available linear actuator and will provide a steady means of attachment for the aluminum plate and the elbow mechanism of the assistive robotic device.
The other motors in the assistive robotic arm all function under 6V DC while the linear actuator requires 12 V DC. To verify what costs would be lost if the linear actuator was run at 6V DC as opposed to 12 V DC, the motor was placed in a DC Power Supply and tested. As previously discussed it functioned perfectly at 12 V DC. At 6 V DC it also worked as expected, it was capable of reaching its full 6 inch and stopped functioning when it reached its maximum length proving that the limits worked perfectly. The only drawback to running the linear actuator at 6 V DC is that it ran at approximately half the speed as it did with 12 V DC. This is not a significant problem because speed is not a factor for the assistive robotic device.

![Image of linear actuator testing](image)

**Figure 2.2.2.4.9 Testing of the Linear Actuator at 6 V DC**

**Optimization Rationale**

The linear actuator was chosen because it requires less manufacturing than the other proposed designs. The linear actuator is able to provide the correct range of motion as well as a reduced noise level relative to a screw or chain mechanism. This is important for the client because it will allow for the precise and steady motion of the arm without being a distraction to his classmates. An elevator system was chosen over a joint system as it will isolate the x/y plane of motion. This will not only reduce frustration for the client but will also prevent tilting of the hand during raising and lifting. This will allow for beverages to be maneuvered without spilling.
2.2.2.5: Elbow Mechanism

The elbow mechanism utilized in this design will operate in a single x-y plane specified by the elevator mechanism. The elbow joint will be controlled by Processing Unit 1 by means of pulse width modulation in conjunction with the servo motors. It is important that the elbow be able to support its own weight and the weight of a load without sagging or breaking. This joint will consist of a servo motor attached to a servo horn. The servo motor will rotate the forearm and gripper while the upper arm is sturdily fixed to the elevator mechanism. In this way the joint will be able to move reliably in one plane.

Figure 2.2.2.5.1 Servo and Servo Horn

The HS-815BB is a perfect candidate to control the assistive robotic arm. It has a range of motion of 140 degrees which means it can rotate 50 degrees more than the average servo which can rotate about 90 degrees. The servo has 343 oz-in torque which will be able to handle the weight on the elbow. The servo also has heavy duty nylon gears which are used to increase its strength.
Figure 2.2.2.5.2 Degree of Rotation of the Servo Motor.

Figure 2.2.2.5.3: Elbow Mechanism

Optimization Rationale

This optimal design was selected because it allows for specific angle control without the use of encoders. In addition, by mounting the forearm directly to the servo horn we eliminate the need for a belt or gear system. This limits the complexity of the joint and the possibility for mechanical failure. This will allow the elbow joint to reliably coordinate the motion of the assistive device.
2.2.2.6: Wrist Mechanism

The wrist mechanism will act to rotate the grabber based on commands from the client. This motion is important for manipulating objects and grasping horizontal objects. The wrist will rotate a full 180 degrees in each direction and will be controlled by the joystick. In order to accomplish this motion a nested joint mechanism will be used along with a brushless electrical motor.

Joint Mechanism

The joint will consist of nested pipes with a lubricated interface. This will allow for a sturdy construction while maintaining a full range of motion. In addition the hollow design will minimize wire tangling during twisting. See Fig 1.2.6.3.

Motor Control

The motor control will consist of a brushless electric motor with a rubberized cylinder fixed to the tip. This high friction surface will interface with a rubberized ring on the outside of the wrist mechanism. In this way the motor spinning will be translated into a twisting motion on the wrist. The motor will be controlled directly from the controller with no signal processing required.

Figure 2.2.2.6.1: Model of a brushless motor
Figure 2.2.2.6.2 Built in brushless motor

Figure 2.2.2.6.3: Wrist Mechanism

Optimization Rationale

The wrist mechanism was chosen because it allows for twisting motion which mimics the human body and has a sturdy design. The belt system is much less likely to break and in the event that it is damaged can be replaced. The rubber system is much less efficient and is not as reliable as the belt system and will be more difficult to implement.
2.2.2.7: Gripper Mechanism

Gripper

The gripper mechanism will consist of a vise-like grabbing component connected directly to a motor. Within the vise will be a pressure sensor which will communicate with the pressure sensor cutoff circuitry. These components will work together to allow for a sturdy grip that will not endanger the client or his peers.

Figure 2.2.2.7.1 Various Different Gripper Designs

The “Big Gripper” shown in the figure above can be purchased online with a servo motor for less than $30.00. The gripper’s fingers measure at 3 inches long and open wide enough to grasp a 12 oz tennis ball as shown in the figure below. The body of the gripper is comprised of a rugged but lightweight PVC plastic.

Figure 2.2.2.7.2 The Big Gripper with a 12oz tennis ball in its fingers
The gripper also contains mounting holes so that it can be easily attached to the body of the assistive robotic arm. Rubber cushions can be added over the length of the fingers so that the gripper can function more safely and can be grip smooth objects more effectively.

Big Gripper measures 6" long, 2 3/4" wide and 1 1/4" thick (with servo the total thickness is 2"). Weight with servo is 3.7 ounces. Lifting capacity is 8-12 ounces, but is conservatively limited by the wrist mechanism you use, if any. Full-open to full-close of the fingers requires approximately 90 degrees of servo rotation.

![Figure 2.2.7.3 Gripper for the Assistive Robotic Arm](image)

The gripper will be modified by adding pressure sensors on to the fingers so that it will be able calculate how much force it is applying onto the object it is grabbing. It will be controlled by two buttons one will open the fingers and the other will close them that way if the pressure sensor for some reason malfunctions it will not cause the fingers to crush the object or damage itself.
Pressure Sensor

A pressure sensor will be mounted on the fingers of the gripping mechanism to act as a safeguard against crushing the objects and to prevent injuries to the patient and those that he comes in contact with. The *FlexiForce* A201 force sensor is an ultra-thin, flexible printed circuit. The force sensors are constructed of two layers of substrate (polyester/polyimide) film. On each layer, a conductive material (silver) is applied, followed by a layer of pressure-sensitive ink. Adhesive is then used to laminate the two layers of substrate together to form the force sensor.

![Figure 2.2.2.7.4 A 1.5" Force Sensing Resistor](image1)

The active sensing area is defined by the silver circle on top of the pressure-sensitive ink. Silver extends from the sensing area to the connectors at the other end of the sensor, forming the conductive leads. A201 sensors are terminated with male square pins, allowing them to be easily incorporated into a circuit. The two outer pins of the connector are active and the center pin is inactive. This is perfect for customizing the sensor to the weight of the assistive robotic arm.

![Figure 2.2.2.7.5 A 1.5” Force Sensing Resistor (alternative view)](image2)
The touch sensor will calculate the gripping force of the assistive robotic device. As shown in the figure its compact size and light weight will enable it to be placed within the gripper to record the force of the gripper. By recording the pressure it will provide the cutoff circuitry with information and serve as a safeguard to protect everyone that comes in contact with the client and insures their safety by signaling the cutoff circuitry to stop the vise mechanism if a certain cutoff pressure is reached. This information is essential because of the school environment that the assistive robotic arm will be used in, is full of young children and faculty that could be injured if the pressure sensor was not present.

Figure 2.2.2.7.6 Circuit for Pressure Sensor

The *FlexiForce* single element force sensor acts as a force sensing resistor in an electrical circuit. When the force sensor is unloaded, its resistance is very high. When a force is applied to the sensor, this resistance decreases. The resistance can be read by connecting a multimeter to the outer two pins, then applying a force to the sensing area. In the image below, the plot shows both the Force vs. resistance and Force vs. conductance (1/R). Note that the conductance curve is linear, and therefore useful in calibration.
One way to integrate the A201 force sensor into an application is to incorporate it into a force-to-voltage circuit. A means of calibration must then be established to convert the output into the appropriate engineering units. Depending on the setup, an adjustment could then be done to increase or decrease the sensitivity of the force sensor. The chart to the right shows a typical sensor response.

Figure 2.2.2.7.8 Force vs. Volts

Optimization Rationale

The “Big Gripper” was chosen as the optimal design for the gripper of the assistive robotic device because of its light weight, ease of integration with the rest of the device and its relatively low price. The original designs proposed will be much more difficult to implement while utilizing tried and true technology will be much more feasible. The Big Gripper has enough strength and size to function and satiate the client’s needs.
2.2.2.8 Gripper Safety Cutoff

In order to ensure the safety of the client a safety cutoff must be included that will ensure that there is no danger of the gripper exerting too much force. This safety cutoff can be accomplished with a microprocessor and pressure sensor. The microprocessor will take in the pressure sensor voltage and the close gripper signal and output a modified closed gripper signal. When the pressure sensor registers a value over the preprogrammed cutoff the microprocessor will output a zero to the gripper regardless of whether or not the close gripper button is still being pushed. This will ensure that the gripper does not continue to close after the pressure cutoff is reached.

The microprocessor that will be utilized in this design need not be very complex as it only requires one analog input (for the pressure sensor), one digital input (for the close gripper button) and one digital output (for the modified gripper signal). All of this can be accomplished using the existing dsPIC30F3011 processor being used for servo control. By simply using the touch sensor as an analog input and the close gripper button as a digital input we can output a pulse width modulation signal to control the closing of the gripper. This will ensure that when the pressure cutoff is reached, that the gripper will not close any further.

Optimization Rationale

The optimal design for the gripper safety cutoff includes utilizing the microprocessor and an input from the touch sensor to act as a safeguard and give a cutoff pressure that the gripper cannot exceed. This design is much more efficient the previous designs that were proposed. The design that used a relay and a diode to act as a cut-off is not necessary due to the microprocessor that is added to this design which has many analog and digital I/O pins. Also the relay and diode combination would draw a lot of power and add more electrical safety hazards to the assistive robotic device. The relay and diode combination would require purchasing more parts, while the microprocessor has many I/O pins that are not utilized.
2.2.2.9: Processing Unit 1

Processing Unit 1 is one of the unique aspects of this project. In order to ensure the least amount of frustration and highest usability for the client it is important that the grabbing hand be moved in the x and y directions. This will allow for a much more natural motion than utilizing a joint controlled system. By creating a system in which the shoulder and elbow joints work in concert to coordinate hand motion we can simplify the client’s life greatly. The heart of this system will be a microprocessor.

Inputs

The inputs to the microprocessor will be four digital inputs from the x/y joystick. These four inputs will represent the four cardinal directions and combinations of two will allow for diagonal movements. These inputs will be sampled to ensure that holding the joystick forward will continuously move the arm.

Outputs

The outputs of Processing Unit 1 will be two pulse trains used to control the elbow and shoulder servos. These pulse width modulation signals will accurately dictate the appropriate angle for the servos. In this way the shoulder and elbow joints can be coordinated.

Methodology

The purpose of this processing unit is to convert Cartesian instructions from the joystick into coordinated joint control. In order to accomplish this, an algorithm has been developed to convert angle information into Cartesian coordinates. This linear transformation is accomplished by first utilizing the trigonometric functions to project the forearm coordinates onto a vector parallel with the upper arm. These coordinates \( x_o, y_o \) are then shifted by an angle \( \beta \) utilizing a linear transform. The resulting equations are then simplified using trigonometric identities.
Figure 2.2.9.1: Cartesian to Angle Conversion. (A=upper length, B=forearm length)

\[ x_0 = A + B \cos (180 - \alpha) \]

\[ y_0 = B \sin (180 - \alpha) \]

Linear Rotation Transformation:

\[
\begin{bmatrix}
    x' \\
    y'
\end{bmatrix} =
\begin{bmatrix}
    \cos \theta & -\sin \theta \\
    \sin \theta & \cos \theta
\end{bmatrix}
\begin{bmatrix}
    x \\
    y
\end{bmatrix}
\]

Carrying out the matrix multiplication and changing terms we get the two equations:

\[ X = x_0 \cos(\beta) - y_0 \sin(\beta) \]

\[ Y = x_0 \sin(\beta) + y_0 \cos(\beta) \]

Using the previously derived definitions of \( x_0 \) and \( y_0 \) we then get the equations:

\[ X = [A + B \cos (180 - \alpha)] \cos(\beta) - B \sin (180 - \alpha) \sin(\beta) \]

\[ Y = [A + B \cos (180 - \alpha)] \sin(\beta) + B \sin (180 - \alpha) \cos(\beta) \]
These equations can be further simplified utilizing trigonometric identities as follows:

For the X coordinates:

\[ X = A \cos(\beta) - B \cos(\alpha) \cos(\beta) - B \sin(180-\alpha) \sin(\beta) \]

\[ X = A \cos(\beta) - B \cos(\alpha) \cos(\beta) - B \sin(\alpha) \sin(\beta) \]

\[ X = A \cos(\beta) - B \left[ \cos(\alpha - \beta) \right] \]

For the Y coordinates:

\[ Y = A \sin(\beta) - B \cos(\alpha) \sin(\beta) + B \sin(180-\alpha) \cos(\beta) \]

\[ Y = A \sin(\beta) - B \cos(\alpha) \sin(\beta) + B \sin(\alpha) \cos(\beta) \]

\[ Y = A \sin(\beta) - B \sin(\beta - \alpha) \]

Thus we have the following linear transformation from angle measurement to Cartesian coordinates:

\[ X = A \cos(\beta) - B \cos(\alpha - \beta) \]

\[ Y = A \sin(\beta) - B \sin(\beta - \alpha) \]
Testing Protocol

To test the processing unit a LabVIEW code was written to verify that the angle calculations were feasible and that it would accurately calculate the angles if given the coordinates and the lengths of the segments. It worked as expected and will therefore be used in the design of the assistive robotic device.

The front panel enabled a user to input the length of the elbow segments which would be hard-coded into the microprocessor. The X and Y inputs will come from the 8 directional digital joystick and will then be converted to the angles.
The block diagram contains the linear rotation conversions which will enable the microprocessor to change the Cartesian coordinates into the angles of the segments and will have a much smoother control than a joint controlled system.
Using this transformation a block diagram can be outlined illustrating how the joystick can be utilized to move the arm in the x-y directions by controlling the joint angles. (Figure 2.2.2.9.4)

Figure 2.2.2.9.4: Program Block Diagram.
On power up, the robotic arm will initialize by sending a 0 degree command to the servos. This will prime the robot arm in a completely retracted position and will allow for a known initial state. This program will be developed in C and loaded onto a microprocessor. In this way calculations can be accomplished quickly and efficiently. The output signals to the motors will directly control the joints and coordinate them to allow for smooth motions. Another consideration that will be included in the programming is the creation of boundaries to account for cases where the joystick is signaling a position that the arm cannot reach.

Optimization Rationale

The optimal design for processing unit 1 has been modified to utilize a pulse width modulation scheme and a servo control. This modification includes the need for a power-on initialization of the servos to 0 degrees. This will be done automatically and will allow for a precise knowledge of arm location at all times. This design is superior to previous designs as it does not require the use of expensive absolute encoders nor does it require the client to position the arm specifically during power off.
2.2.2.10 Microprocessor

The assistive robotic arm will require a microcontroller unit. The PIC dsPIC30F3011 will be utilized as it provides ample digital and analog input and output pins, pulse width modulation output and can accomplish trigonometric mathematics with the use of the MPLAB C30 C compiler.

![Microcontroller connected to a servo motor.](image1)

There are pins in the microprocessor which are allotted for creating the square waves which will be used to control the servos in the assistive robotic arm. It will send square wave to turn the servo motor on and off at a fast pace so it will be almost like sending out any required analog voltage. Another term for these square waves is pulse width modulation (PWM).

![Pulse Width Modulation Generated by Microcontroller](image2)

Figure 2.2.2.10.1 Microcontroller connected to a servo motor.

Figure 2.2.2.10.2 Pulse Width Modulation Generated by Microcontroller
The microcontroller that will be used is the dsPIC30F3011.

**Input Pins:**

Pins 2, 3, 4 and 5 will all be allotted to the digital joystick. The first 2 pins will input to the microcontroller from the digital joystick moving up or down. The pins 6 and 7 will input to the microcontroller telling it whether to move left or right. Combinations of the 4 pins will call the robot arm to move in a diagonal in the NE, NW, SE, and SW directions. Also inputted to the microprocessor will be the Gripper Close button, this will be allotted to pin 7 on the microprocessor.

**Output Pins:**

Pins 34, 36, 38, and 18 and will output a square wave using Pulse Width Modulation to power the servo motors in the shoulder, elbow and the gripper.
Optimization Rationale

For the Optimal Design we introduced a more powerful microprocessor than the previous alternative designs. The microprocessor contains 6 different pins capable of producing pulse width modulation; therefore it is capable of powering 6 different motors with 3 different duty cycles. This microprocessor has more I/O pins and is capable of taking analog and digital inputs.

At a price of $5.00 this microprocessor will not be a significant factor of the budget and a spare can be purchased incase the original is short circuited. With its ability to generate pulse width modulation to power the servos and its increased number of I/O the dsPIC30F3011 microprocessor is a much more reliable and apt candidate than the previous chips in the older alternative designs.
2.2.2.11 Wheelchair Attachment Unit

It is extremely important that the assistive robotic device integrate smoothly with the client’s current wheelchair. The client is currently using a Permobil C400 Stander Jr. as shown in figure 2.2.2.11.1. This wheelchair is capable of carrying loads of up to 155lbs which is well over the weight of our client and assistive arm. A vise unit has been developed to firmly attach the assistive robotic device to the wheelchair. This device will attach on the right side of the wheelchair on the sturdy armrest support using the vise mechanism described in figure 2.2.2.11.2.

Figure 2.2.2.11.1: The Permobil C400 Stander Junior with attachment point.
Figure 2.2.2.11.2: Vise attachment mechanism.

Optimization Rationale
The vise attach mechanism will provide a sturdy and stable way to mount the assistive robotic device to the clients electrical wheelchair. It will not consume too much space while allowing the arm to be efficiently placed on the wheelchair for easy use by the client.
2.2.2.12 Accessories

In order to increase the functionality of the assistive robotic device, several accessories will be developed for the client. These accessories will be held in the gripper and assist the client in accomplishing various tasks. The accessories currently planned include a marker holder, probe, page turner, and drinking cup.

Marker Holder

This accessory is necessary to allow the assistive robotic device to securely hold a marker. The accessory will simply consist of a rubber cylinder with a diameter large enough to make grasping with the robotic gripper easy. At the center of the cylinder will be drilled a hole slightly smaller than the diameter of the marker. The rubber cylinder will be heated and will expand. This will allow the marker to be easily inserted into the cylinder. Upon cooling, the rubber will shrink and hold the marker snugly. If the marker needs to be replaced the accessory simply must be placed in hot water and it will easily release.

This accessory will be very useful and fun for the client. Due to the innovative microprocessor controlled system and isolated z axis, the client will be able to lower and raise the marker from a page and accurately control its motion. This will be a huge benefit for the client who currently has difficulty holding his arm steadily and moving with precision.

Figure 2.2.2.12.1: Cross Section of Marker Holder with Marker.
Probe

The probe accessory will be useful for the client in pressing buttons and manipulating objects on his desk. This simple device will consist of a large cylinder which will be easily grasped by the gripper and a slender cylinder which will act as a probe. This probe will come down to a dull point. The probe will be especially useful for pressing small keys such as those found on a keyboard or telephone. It is important that the probe not be sharp so the client does not hurt himself, his peers, or damage anything.

Figure 2.2.12.2: Side View of Probe Accessory

Drinking Cup

A drinking cup will be selected which will easily fit in the gripper hand. The cup will include a top and straw to assist the client and prevent spillage. The cup will be modified to ensure that it will not slip out of the gripper hand even when filled with liquid. The client has commented that Sam requires an aide for assisting with drinking. With this accessory, he will no longer require this assistance.
Page Turner

In order to assist the client in the classroom a page turner attachment will also be fabricated. This accessory will consist of an easy to grip handle and a flexible rubberized tip. The tip will have a sufficiently high coefficient of friction to allow for pages to be turned when it is brushed across a page. The client will be able to use this repeatedly during classes and at his leisure to help read without the assistance of others.

Figure 2.2.2.12.3: Page Turner Accessory with Tip
3 Realistic Constraints

This design utilizes various engineering standards, along with many health and safety concerns, to produce an assistive robotic arm that most effectively benefits the client. The design abides by engineering standard 60605-3-4. The device also incorporates engineering standard 60812 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

One of the largest constraints to our project is the budgetary constraint. Many similar robotic arms currently on the market cost thousands of dollars; however, the budget allotted to this design project is 750 dollars. This is a major concern and may limit the quality of the parts that comprise the robot arm as well as the functionality of the device. The budget also does not leave room for buying spare parts, which can be used as backup if some of the primary parts get damaged during the construction of the assistive robotic device.

Environmental

Our project also faces environmental constraints such as variations in weather and temperature. The robotic arm must be able to withstand spills and dirt that accumulate during everyday use. In addition, the assistive robotic arm must be able to function in an elementary school environment, which means that the device must be durable and resist being damaged in playground. The device should be designed to resist malfunction and wear and tear under these normal circumstances and should be able to function in humid temperatures as well as frigid temperatures. The assistive robotic arm will be mounted on the client’s wheelchair so it must not heat up or cause any thermal agitation to the client. The devices must not take up too much of his space so that he can still efficiently maneuver his wheelchair as he did prior to obtaining the device.

Sustainability

The sustainability of the device is also a concern. The device should be durable and not require constant repairs. It should be able to withstand being constantly used and not be prone to malfunctioning. In addition, the weight of the materials should be limited to reduce the power requirements of the device. The rechargeable battery will last much longer if the assistive robotic arm is made of light material because it will require less torque to move the robotic arm and to pick up objects. Longer battery life is essential so that the assistive robotic arm can function for the length of the entire school day.
Manufacturability

The manufacturability is also a concern for this device as the arm would need to be customized to the individual purchasing the equipment. Our student has limited use of his right hand. If a different customer had use of only their left hand the manufacturing process should be adjusted to allow for changes. Also, other clients may 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. The device must also be able to mount on any electric wheel chair regardless of its size in order for it to sell in the market because this would enable it to have a much larger consumer base. This would also enable the assistive robotic device to be used in hospitals for patients in rehabilitation centers as a way for the patients to function independently.

Health and Safety

Health and Safety is a major concern that is restricts our progress. The robotic arm has to be safe enough for the customer and his classmates, considering that he has some disabilities. For example, the pressure that the device can produce is going to be limited in order to avoid any kind of accidents when he is trying to grab something; also, the device should have a releasing emergency system. The electronic part of the device should be completely covered and isolated in order to prevent a discharge to the client, or in case he accidentally spills a liquid into the robotic arm.

Socially

Socially, the client does not want to stand out from all his peers. The assistive device must be aesthetically pleasing and not cause the client embarrassment. Young children usually fear things that are different; therefore, if the assistive robotic arm is has a grandiose and flamboyant design, it will inhibit the client from effectively interacting with his peers. In addition to a subtle design, the noise induced by the assistive robotic arm must not interfere with the activities in the class. If the design produced a lot of noise it would disrupt the client’s teachers and his peers.

Politically

It is of vital importance that all Food and Drug Association (FDA) and the Occupational Health and Safety Administration (OSHA) safety regulations be followed in the creation of this robotic arm. All of the materials must also be safe for use in a public school system, so that they do not harm any of the young elementary school children or the faculty. The other political concern is that of patent infringement. Research must be done to ensure that no patents are being too closely replicated and that the design is original and can be put out into the market without any hindrances.
4 Safety Issues

Electrical

The assistive robotic arm is designed to be safe and easy to use for the client and should not contain any safety concerns. To protect the client from any risks associated with the electronics, the wires will all be hidden from plane view and stored in the base of the robotic arm so as not to pose a threat to the client. The base is a much safer place for the wires to be stored because it is not within reach of the client and is not prone to drink spillage. The wires will be protected because they are hidden, this will mitigate the probability of the wires getting damaged and decreasing the probability of short circuiting the assistive robotic arm. It will make the design more efficient and much safer for the client to use and not pose a threat to his aide or anyone that he may see on a day to day basis.

Mechanical

Mechanical risks are also mitigated in the design of the assistive robotic arm. By storing the large gears that cause the motion of the assistive robotic arm, in the base of the design they are shielded from any sort of spillage and are less likely to get jammed. There will be a small belt mounted on the wrist but it will be shielded in a casing so that it is also spill proof and will not get jammed. Because the belt is encased it will not injure the client or anyone that he comes in contact with, thus making it safe for everyday usage. The casing will protect the belt from any sort of debris that may inhibit its rotation as well as the rotation of the motors. By encasing the moving parts the client can rest assured that if any gear or motor comes loose the encasing will prevent it from flying out of control making it safer for both himself and everyone he associates with. By firmly encasing the rotating mechanical components in the assistive robotic arm, the design is safer and can be used in the classroom or in almost any environment that the client resides.

Thermal

The assistive robotic arm design also accounts for thermal hazards that might arise due to the spinning of the belts and the motor. The motors and belts will be lubricated in order to lessen the friction between the rigid bodies so as to elongate the life expectancy of the parts as well as provide a more efficient and easily flowing motion. The lubrication is essential so that the constant rubbing of the metal does not cause injury to the design components and therefore the assistive robotic design does not overheat. It is essential that the assistive robotic arm run at room temperature so that it does not irritate the client and so it does not cause any damage to the components that comprise the assistive device. By lowering the temperature that the assistive robotic arm operates, the client has a safer and longer lasting device that can help him for many years.
5 Impact of Engineering Solutions

The assistive robotic design will act as a third limb, enabling the client to function more independently despite his cerebral palsy. The device will enable him to convert his gross motor functions into fine motor functions that he lacks due to his disorder. The assistive robotic arm will allow the client to perform everyday tasks that most people take for granted such as opening doors, writing, typing and stabilizing arms. The client currently functions with help from an aide but would like to be more independent and able to support himself. The client is a very bright young adult and it is only fair that he be granted his independence. The assistive robotic arm will enable our client to become more independent when facing everyday challenges and enable him to lead a more fulfilling life. The client is a young child in elementary school who is diagnosed with athetoid cerebral palsy. This implies that he has a difficult time controlling his muscles especially with regard to fine movement. This condition requires that he have an aide to assist him during school.

The assistive robotic arm will enable the client to require less assistance from his aide and pursue more challenges with his new found confidence. This device will be specifically tailored for the clients needs and will be attached to his wheelchair. The arm will be constructed so that it is not flamboyant and does not cause the client to be ostracized from his peers. The robotic arm will enable him to have a more positive experience in the classroom and in all his future endeavors. This device should aid our client by enabling him to grasp eating utensils and writing utensils as well as helping him to use a keyboard. The robotic arm will serve to compensate for his lack of fine motor skills; therefore it will increase his confidence and raise his self-esteem. The assistive robotic arm will give him the confidence to be more active in class and in his extracurricular activities. It will enable the client to partake in everyday events that most people take for granted. The client is very intelligent and will utilize the robotic arm to advance his situation and will finally be released from the shackles of dependence.

Many companies in industry are starting to build assistive robotic devices to help individuals with disabilities to function more efficiently in society. These devices are of great help to the individuals and enable them to become more independent and assimilate with their peers as well as limiting the frustrations that they must deal with on a day to day basis. The devices on the market however are very highly priced and most require the client to purchase an entirely new wheelchair with the attachments built in. These devices are also very ostentatious and draw attention to the client, which can cause the client to be alienated by his peers. Young children do not always respond kindly to things that they are not familiar with, that is why the assistive robotic arm is designed to be as subtle as possible so as not to cause client to stand out from his peers.

The assistive robotic arm is also very economical; its price will not be anywhere near the exorbitant price range of other commercially available assistive devices. The assistive robotic arm will also be designed so that it can be easily controlled by the client despite his lack of motor skills. The assistive robotic arm is not merely aimed at increasing the clients motor skills but rather aid him in all his future endeavors, whether in the classroom or at home. The sense of independence that the client will obtain will help him with dealing with all his future endeavors. It will enable the client not only to
enjoy going to school a lot more but will enable him to persevere through all the trials and tribulations that life has to offer.

The assistive robotic arm will have a profound effect on medical instrumentation and rehabilitation engineering. This device is custom made for the client and contains all characteristics that he desires. Similar devices on the market try to accommodate a wide variety of different clients but in doing so fail to satisfy most of their clients needs. The designs are too generic as well as very expensive and flamboyant. The assistive robotic arm is humble in its design and does not draw attention and does not engender a lot of noise or disruption. The assistive robotic arm is very subtle so that the client does not feel that he is different from his peers and is also not treated differently from his peers. The devices currently on the market would ostracize their clients from the rest of their associates and would not serve their purpose. It is difficult for anyone to have to live with a cerebral palsy especially a young child, which is why it is of the utmost importance that the design of the assistive robotic arm does not further differentiate him from his peers. The purpose of the arm is for him to be more independent and coincide with his peers, so if the assistive robotic device has an ostentatious design then this will not only negate its intended function but worsen the client’s current state and further alienate him from his peers.

Similar devices on the market are also more that triple the price of this design’s allotted budget. The exorbitant prices of the products are due to the many unnecessary components that the commercial arms contain that are not only superfluous but sometimes even inhibit the optimal functionality of the assistive robotic devices. The current assistive robotic devices on the market are far too expensive for the average patient to afford and if they are not covered by medical insurance are unattainable by most of the individuals that require them for support. The proposed assistive robotic arm serves as a promising alternative that not only functions more efficiently but is more cost effective than the current models available for consumers to purchase. It will revolutionize the current medical instrumentation industry and help many clients with physical disabilities obtain the independence, increasing their likely hood for success and enabling them to function in everyday life.

Cerebral palsy does not coincide with mental retardation, this implies that the client is incredibly bright and does well in school. The assistive robotic arm will serve to less the severity of the gradient that exists between his physical and mental abilities. The device will help him reach his optimal potential not only in elementary school but in all his future endeavors. It will enable him to persevere through many trials and tribulations and could possibly in the future enable him to obtain a job and function normally within society. The potential good that the assistive robotic arm can engender is unparalleled and will revolutionize rehabilitation engineering as well as the bioinstrumentation industry.
6 Life-Long Learning

In designing the assistive robotic arm a lot of knowledge was acquired about electromechanical devices and the components that are required to create such devices. Many different types of electric motors exist that could have been utilized in the design of the assistive robotic arm. For example, a stepper motor is a motor that can divide a full rotation into a large number of steps and when commutated electronically with a microcontroller, the motor’s position can be controlled precisely without any feedback mechanism. A linear motor however instead of producing a torque, produces a linear force along its length by setting up a traveling electromagnetic field. Learning the different types of motors is essential because it enables designers to discover the various options they have to design their device. Servos motors function when pulse width modulation signals are sent to them and are then translated into position commands by electronics inside the servo.

The central processing unit of an electromechanical device is almost always some sort of microcontroller. A microcontroller is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single semiconducting integrated circuit (IC). Microcontroller can have C code or assembly language uploaded onto them and can process the information inputted into it either through a joystick or a button on the assistive robotic arm’s controller. The Microcontroller is much more efficient that using logic gates to control the device and is very inexpensive and was chosen to be a major component in the assistive robotic arm’s design. In comprising the first alternative design for the assistive robotic arm, not only were all of these components discovered but also how they functioned individually and together. Knowledge was gained in dealing with the integration of the electrical and mechanical components of the assistive robotic arm and how robots are designed and what factor they require in order for the mechanical components to communicate with the microprocessor.

An important factor of senior design is teamwork. Working constructively together in unison is important and helped facilitate the design of the assistive robotic arm. Equally portioning the workload and making sure that every member contributes equally and on time has helped ease the design of this device. Besides portioning the workload, compromising with each other is of vital importance. It is important because although two people might have varying opinions on how something can be done and both ideas might be feasible both cannot be utilized. For the group to function compromises must be made about the design of the device and this senior design project has helped this group learn how to function as a cohesive unit which is an essential trait that we will utilize in the future.
## Budget and Timeline

### 7.1 Budget

Table 1: Budget for the assistive robotic arm

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Actuator</td>
<td>1</td>
<td>130</td>
<td>n/a</td>
</tr>
<tr>
<td>Brushless motor</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Touch Sensor</td>
<td>1</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Gripper + Servo</td>
<td>1</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Assembled Power Servo with 5:1 Titanium Gears</td>
<td>1</td>
<td>215</td>
<td>215</td>
</tr>
<tr>
<td>Round Servo Arm</td>
<td>1</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Elbow Servo</td>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Servo Horn</td>
<td>1</td>
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<td>8</td>
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<tr>
<td>Digital Joystick</td>
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<td>11.25</td>
<td>22.5</td>
</tr>
<tr>
<td>Deep Cycle Battery</td>
<td>1</td>
<td>178</td>
<td>178</td>
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<tr>
<td>Microprocessor</td>
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<td>5</td>
</tr>
<tr>
<td>Raw Materials</td>
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<td>50</td>
</tr>
<tr>
<td>PCB Board</td>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>Total $638.50</strong></td>
<td></td>
</tr>
</tbody>
</table>

The budget allotted for the assistive robotic arm is $750. The total cost proposed for the design is currently $638.50. This leaves the design group with $111.50 left in the budget to spend on purchasing other materials that the design team might not have noticed and to replace parts that maybe damaged in the learning process. The price of the linear actuator has been neglected from the total budget because the group was able to obtain a linear actuator from the senior design that lab that meets the specifications for the assistive robotic device.
8 Team Member Contributions to Project

Alon Dagan
   Alon has been responsible for the theoretical development of the Cartesian to Angle system as well as the general concept for x/y control. In addition, he has investigated numerous motor control systems ranging from stepper motors to optical encoders before deciding on servo control. Alon has designed the mechanical elevator system integrating the linear actuator. He has also developed the concept of arm accessories and designed the various accessory components.

Aaron Hernandez
   Aaron has been responsible for the structural stability and durability of the robotic assistive device. He has worked to calculate the static forces the arm will undergo including forces and moments in loaded and unloaded scenarios. Aaron was also responsible for the initial concept of a rotating base with elevator system. Aaron has worked to develop Visio representations of various aspects of the system.

Michael Khalil
   Michael has been responsible for microprocessor research and selection. In addition, he has worked with LabVIEW to prepare a preliminary testing module. Michael has also researched various servo components and developed a budget that includes all necessary products for under budget. Michael was also responsible for battery analysis and selection. Michael has also played a role in the analysis of safety concerns and realistic constraints. In addition he has worked to evaluate the impact of the engineering solutions. Michael has also been responsible for gripper selection.
9 Conclusion

The assistive robotic arm will enable our client to become more independent when facing everyday challenges and enable him to lead a more fulfilling life. The client is a young child in elementary school who is diagnosed with athetoid cerebral palsy. This implies that he has a difficult time controlling his muscles especially with regard to fine movement. This condition requires that he have an aide to assist him during school. The assistive robotic arm will enable the client to require less assistance from his aide and pursue more challenges with his new found confidence. This device will be specifically tailored for the client’s needs and will be attached to his wheelchair. The arm will be constructed so that it is not flamboyant and does not cause the client to be ostracized from his peers. The robotic arm will enable him to have a more positive experience in the classroom and in all his future endeavors. This device should aid our client by enabling him to grasp various items and writing utensils as well as helping him to use a keyboard. The robotic arm will serve to compensate for his lack of fine motor skills; therefore it will increase his confidence and raise his self-esteem. The assistive robotic arm will give him the confidence to be more active in class and in his extracurricular activities. It will enable the client to partake in everyday events that most people take for granted. The client is very intelligent and will utilize the robotic arm to advance his situation and will finally be released from the shackles of dependence.

Many companies in industry are starting to build assistive robotic devices to help individuals with disabilities to function more efficiently in society. These devices are of great help to the individuals and enable them to become more independent and assimilate with their peers as well as limiting the frustrations that they must deal with on a daily basis. The devices on the market however are very highly priced and most require the client to purchase an entirely new wheelchair with the attachments built in. These devices are also very ostentatious and draw attention to the client, which can cause the client to be alienated by his peers. Young children do not always respond kindly to things that they are not familiar with, that is why the assistive robotic arm is designed to be as subtle as possible so as not to cause client to stand out from his peers. The assistive robotic arm is also very economical; its price will not anywhere near the exorbitant price range of other commercially available assistive devices. The assistive robotic arm will also be designed so that it can be easily controlled by the client despite his lack of motor skills. The client’s physical therapist informed the design team that the client is very adept at maneuvering a joystick. Because the client uses the joystick to control his wheelchair, the assistive robotic arm will also be maneuvered with a similar apparatus. The assistive robotic arm is not merely aimed at increasing the client’s motor skills but rather aid him in all his future endeavors, whether in the classroom or at home. The sense of independence that the client will obtain will help him with dealing with all his future endeavors. It will enable the client not only to enjoy going to school a lot more but will enable him to persevere through all the trials and tribulations that life has to offer.
10 References

11 Acknowledgements

This project has been generously supported by the National Science Foundation and the University of Connecticut Biomedical Engineering Department. We would also like to thank David Price and Dr. John Enderle for their advice and support.
Appendix

7.3 Updated Specifications

Shoulder Servo

HSR-5995TG Ultra Torque

Control System: +Pulse Width Control 1500usec Neutral
Required Pulse: 3.3-7.4 Volt Peak to Peak Square Wave
Operating Voltage Range: 4.8-7.4 Volts
Operating Temperature Range: -20 to +60 Degree C (-68F to +140F)
Operating Speed (6.0V): 0.15 sec/60° at no load
Operating Speed (7.4V): 0.12sec/60° at no load
Stall Torque (6.0V): 333.29 oz-in. (24kg.cm)
Stall Torque (7.4V): 416.61 oz-in. (30kg.cm)
Standing Torque (6.0V): 433.27 oz-in. (31.2kg.cm) 5 degree deflection
Standing Torque (7.4V): 541.59 oz-in. (39kg.cm) 5 degree deflection
Operating Angle: 90 Deg. one side pulse traveling 400usec
360 Modifiable: Yes
Direction: Clockwise/Pulse Traveling 1500 to 1900usec
Idle Current Drain (6.0V): 3mA at stop
Idle Current Drain (7.4V): 3mA at stop
Current Drain (6.0V): 300mA/idle and 4.2 amps at lock/stall
Current Drain (7.4V): 380mA/idle and 5.2 amps at lock/stall
Dead Band Width: 2usec
Motor Type: Coreless Metal Brush
Potentiometer Drive: 6 Slider Indirect Drive
Bearing Type: Dual Ball Bearing MR106
Gear Type: 4 Titanium Gears
Connector Wire Length: 11.81" (300mm)
Dimensions: 1.57" x 0.78" x 1.45" (40 x 20 x 37mm)
Weight: 2.18oz (62g)

Elbow Servo

HS-815BB Mega Sail Arm

Control System: +Pulse Width Control 1500usec Neutral
Required Pulse: 3-5 Volt Peak to Peak Square Wave
Operating Voltage: 4.8-6.0 Volts
Operating Temperature Range: -20 to +60 Degree C
Operating Speed (4.8V): 0.48sec/140° at no load
Operating Speed (6.0V): 0.38sec/140° at no load
Stall Torque (4.8V): 274.96 oz/in. (19.8kg.cm)
Stall Torque (6.0V): 343.01 oz/in. (24.7kg.cm)
Operating Angle: 70 Deg. one side pulse traveling 400usec
360 Modifiable: Yes
Direction: Clockwise/Pulse Traveling 1500 to 1900usec
Current Drain (4.8V): 8mA/idle and 700mA no load operating
Current Drain (6.0V): 8.7mA/idle and 930mA no load operating
Dead Band Width: 8usec
Motor Type: 3 Pole Ferrite
Potentiometer Drive: Indirect Drive
Bearing Type: Dual Ball Bearing
Gear Type: All Heavy Duty Nylon Gears
Connector Wire Length: 11.81" (300mm)
Dimensions: 2.59" x 1.18" x 1.26" (66 x 30 x 37mm)
Weight: 5.6 oz. (152g)

7.4 Purchase Requisitions and FAX Quotes

Purchase Requisitions and FAX Quotations will be included in budget due Wednesday December 5th.