CHAPTER 11
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BIONIC GLOVE FOR PERSONS WITH QUADAPLEGIA

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Client Coordinator: Keith Parsons and Dr. Everett Hills
Penn State Hershey Rehab Hospital
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INTRODUCTION

Our team created a Bionic Glove that will allow our sponsor, Keith Parsons, to work out with weights more easily and independently. Keith Parsons sustained a spinal cord injury resulting in an inability to perform gripping actions with his hands. Since he still has muscle control in the upper portions of his arms (biceps, triceps, shoulders, etc.) he is still able to enjoy the act of weightlifting; however, his limited gripping ability makes this activity difficult to perform independently.

Keith currently uses Action Life gloves, which use Velcro straps to fasten various pieces of weight-lifting equipment to his hands. The gloves are difficult for him to take on and off without assistance.

In our design, we added thumb loops to the Velcro straps to secure the glove to the user. Linear actuators were used to provide the mechanical action for opening and closing the glove (see Figure 11.1). Voice recognition hardware was installed allowing for operation of the glove via voice commands. The power supply and microcontroller were located on the forearm sleeve to evenly distribute weight.

SUMMARY OF IMPACT

By making the modifications and adjustments to our Bionic Glove, the sponsor will be able to work out more easily and independently. He will be able to grasp a conventional dumbbell for strengthening exercises for his arm muscles. He will also have a reduced set up time for each upper body exercise he wishes to perform.

Dr. Everett Hills said the Bionic Glove design incorporates features of previous prototypes to create a unit that fits the user's hand, spreads the weight across the forearm to provide better balance, and uses voice recognition to control the duration of grasping

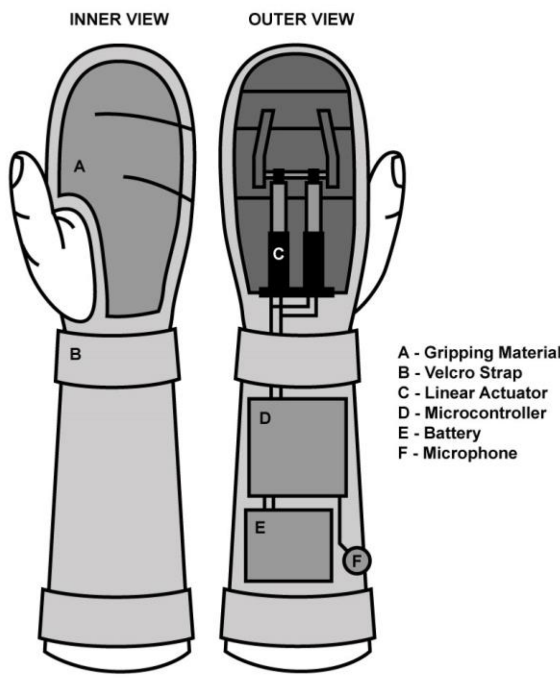

Fig. 11.1. Glove Diagram.

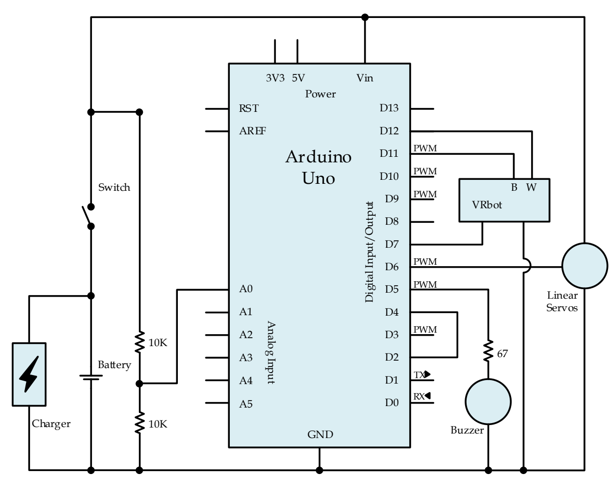

Fig. 11.2. Circuit Diagram.

an object. With this Bionic Glove, the user doesn't need to purchase special equipment for weightlifting; he can use traditional equipment in a gym.

TECHNICAL DESCRIPTION

The bionic glove is constructed from a modified Action Life glove. The glove was altered to extend the glove to the forearm. This reduces the weight on the users hand by evenly distributing the components onto the sleeve. The main components are a battery pack, microphone, buzzer, microcontroller, linear servos, and gripping mechanism. The Arduino Uno microcontroller board controls the operation of the glove. A VRbot voice recognition module is connected to the board and receives voice commands through an external microphone. A 2.048k Hz Piezo buzzer is used to inform the user when a command is accepted or starting. Everything is powered by a rechargeable 7.4V lithium-ion battery pack that provides around 3 hours of operating use.

A gripping mechanism constructed of durable, lightweight metal is attached to the backhand side of the glove. Similarly to a mechanical claw, a hinge that simulates the pivoting of knuckles allows the glove to open and close the user's hand. Mounted to the back plate, two Firgelli L12 –R linear servos power the gripping force. The high 210:1 gear ratio provides a gripping force of around 100N and a back drive force of 300N.

Once the power switch of the glove is turned on, the glove waits and listens for a command. The main voice commands are "Glove", "Open", "Close", "Stop", and "Battery." The trigger word "Glove" is used to activate the glove. If successful, one quick beep will sound and then the glove will wait for a command. When the open and close commands are issued, the servos are powered to retract or extend respectively releasing or tightening the grip. The stop command cancels the previous issued command. The battery command reports the life of the battery through a series of beeps. Three beeps represent fully charged, two beeps means halfway, and five quick beeps is when the battery should be charged before continued use.

Fig. 11.3. Bionic Glove Prototype.

BIONIC GLOVE

Designers: Kyle Chen, Josh Eisenhardt, Andre Umali, Bill Brandt
Client Coordinators: Keith Parsons and Dr. Everett C. Hills, MD, MS,
Penn State Hershey Rehabilitation Hospital
Supervising Professors:
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INTRODUCTION

Our team has created a glove capable of manipulating the wrists and fingers of an individual with paraplegia to grip both free weights and handles on common weight-lifting machines. The sponsor, Keith Parsons, has limited motor skills within his hands and wrists. Due to this, he is not able to completely close his hands and therefore cannot grasp objects.

As a team, our primary objective was to demonstrate the principles of effective design by inventing a new 'bionic glove' that our sponsor can use to lift weights and increase his upper body strength. Our goal was to create a simple glove enabling our sponsor to lift approximately 50 pounds. We will measure the simplicity of our design by how easily the sponsor can put the glove on and how he can use it. The effectiveness will be measured by how tightly the glove closes around a given weight and how independent the glove enables the sponsor to become.

SUMMARY OF IMPACT

The Bionic Glove team's final design is known as the Wrist Reel Glove (WRG). The WRG allows the user the freedom and independence to enjoy activities requiring grip strength such as lifting weights and shooting pool. The concept uses a motor to wind the strap tight, securing the weight in place. The motor is activated by voice automation removing Mr. Parson's dependence on outside assistance. The WRG is powered by three rechargeable 9-volt batteries making for a readily available and inexpensive power source.

The foundation for our design is the reference glove provided by our sponsor. The reference glove is a simple, leather design with a Velcro strap used to close it. The wrist-reel design works in a similar manner, except it strives to eliminate the inconvenience associated with closing and opening the glove by automating processes that were previously difficult or awkward for the user.

To open and close the glove, the user inserts his hand into the glove and tightens the wrist strap. Then the user gives a voice command picked up by the microphone located in the lower wrist of the glove. At the command, the glove will close and the switch will trigger the motor to begin winding the reel. As the reel winds, the hand naturally begins to close around the weight lifting bar. Left unrestricted, the motor will continue winding the reel until it reaches its locked position.

Once the user is finished and wishes to disengage the glove, the user simply flips a directional toggle switch. Once the microphone picks up the word "open", the voice activated switch triggers the reel to begin to unwind. The reel will continue to unwind until the hand reaches its original open position, unless interrupted by "shut the emergency stop toggle switch off".

Dr. Hills watched as the sponsor demonstrated the device. Both agreed the glove offered independence for its user. The sponsor, Keith Parsons, liked the efficiency of the rechargeable batteries. It had an initial expense, but was cost effective in the long run.

TECHNICAL DESCRIPTION

In analyzing the final design and speaking with the sponsor about the long-term performance of previous designs, the team identified several areas of the design where analysis was warranted: the points where the voice relay and motor housing connect to the glove body, the strap reversal point, and the reel shaft itself.

For the voice relay and motor housing, a contoured aluminum plate was sewn with high-tensile Kevlar fiber to the leather base glove. The strap reversal point is simply a leather loop that is a component of the base glove. Both the Kevlar fiber and the leather strap were constantly observed as weight was increased to detect signs of fraying or wear.

The third component is the reel shaft itself. The team knows, from the product specifications, that the nylon strap that will wind itself around the reel is capable of supporting approximately a thousand pounds of force. From the design specifications of the glove, the largest weight that the sponsor requires the glove to hold is a 50 lbf weight. With the design of the strap, reel, and strap reversal point, the glove can be approximated as a one-pulley system with the weight attached to the pulley. For motor selection initially, we did a rough estimate of a maximum 25lb-in (3 N-m) holding torque is required when the weight is pulling on the string. That estimated number was then multiply the factor of safety to become our specification holding torque. The specified holding torque was 175 lb.-in; that number doubles equal to 350 lb-in. After the specified holding torque was determined, we searched for a motor that has higher holding torque than we specified. We found one with holding torque 64.5 N-m (570 lb-in). Since the distance of travel was short, we needed a motor that has low rpm and small size with the holding torque required. We looked at adding a gearing stage to reduce the speed of the motor as well. However, such motor configuration has a large size. Also, since the voice activation relay runs on 24Vdc, we picked the motor to run on 24 VDC as well. This enabled us to eliminate a potentiometer that reduces the 24Vdc to the desired voltage. With one less component, the glove is much lighter and smaller.

Instead of picking a large rechargeable battery pack as our power supply, we decided to use 3 9V rechargeable batteries to save space, and it would be a lighter battery pack wrapped on the arm. Also, backup batteries will be available for replacement. A 9 volt battery charger will be provided in the product package when mass production takes place.

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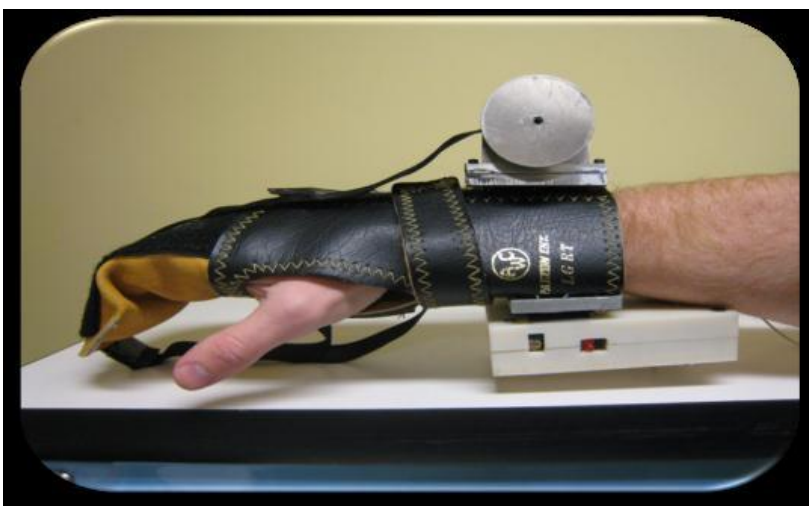

Fig. 11.4. Photo of final product.

DESIGN OF A HANDCYCLE FOR CRAIG DIETZ

Designers: Bello Galadanchi, Dave Friedman, Kristen McKee, Ashley Pachter, Murtaza Raza
Client Coordinator: Gretchen Kaag, IM ABLE Foundation
Supervising Professor:
Dr. Margaret Slattery
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INTRODUCTION

The IM ABLE team project is to design a safe, durable, operational cycle for a man with no hands and legs. Craig Deitz, a man from St Mary's, PA, was born with neither hands, nor legs but will stop at nothing to be physically fit. Craig would like to participate in the IM ABLE Got the Nerve 2011 triathlon race, however, without a cycle for a person with his disability, he can only participate in the swimming leg of the race.

For people with no upper or lower extremities, there are limited options to participate in sports. These people will either have to pay a large sum of money to have custom equipment made or just not exercise with a bike for their entire life. Our team will take the existing prototype and redesign it to accommodate the disabilities of Carl Deitz.

SUMMARY OF IMPACT

This project has opened a new window of opportunity for Craig. As an active man, he strives to push all boundaries and engage in any type of strenuous activity of which he is capable. Developing a handcycle that Craig can operate, allows him to explore a new activity and to show others that disabled people do not have to constantly live with limitations.

Although the handcycle is specifically designed for Craig, there are many aspects of the project that could be implemented in cycles for others. For instance, the headrest brake design could be applied in handcycles meant for people living with many types of disabilities. Additionally, the propelling mechanism that is capable of converting vertical movement into rotational movement can be a universal design used in cycles for people with disabilities.

The team translated the customer requirements into a final design and was able to meet all of our project objectives. Our handcycle design uses Craig's most capable limbs for the two functions that require the most force, steering and propelling, and requires no limb usage for braking. The handcycle is durable with a dependable and accessible brake, controllable steering, and is both safe and comfortable.

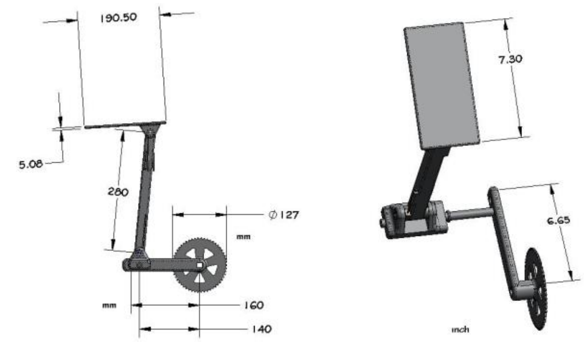

Fig. 11.5. Bionic Knee Design.

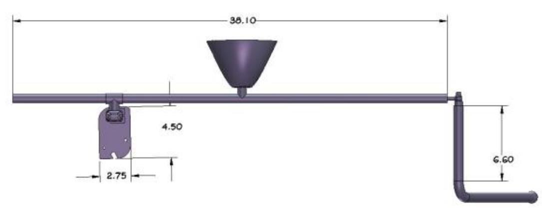

Fig. 11.6. Enhanced View of Steering.

TECHNICAL DESCRIPTION

The recumbent seating included in our final design allows Craig's weight to be evenly distributed throughout the seat and Craig's center of gravity to be lower. This seating is much safer because it is lower to the ground than a traditional cycle.

Craig propels the bike with his strongest limb, his leg, by moving his leg in a linear motion and converting it to rotational motion using the bionic knee design (shown below in Figure 11.5). Because the cranks work in a circular motion, the springs need to push and pull the crank set over top dead center and bottom dead center of the circle. The forward push is achieved from two torsional springs. (Torsional springs are small and strong, requiring only a small amount of deflection). The spring mechanism that pulls the pedal back during the transition from the downwards pedaling to upwards pedaling is a conventional, longer spring. The replicated knee is attached to a mold of Craig's leg.

The steering, (shown in Figure 11.6), is operated using his right arm limb. He inserts his limb into a prosthetic which is attached to a rod placed to the right of his seat. This rod is connected to the steering column.

Since both of Craig's most capable limbs are being used to propel and steer, it was best to use designs that do not require limb usage for both shifting and braking. For this reason, the team chose a headrest braking mechanism where Craig leans his head back into the headrest in order to initiate braking.

It was initially thought that automatic shifting would be utilized in our final design. After working with the new trike, it was decided that automatic shifting was not suitable and an alternative design concept would have to be included in our final design. Therefore, the team chose to implement the other design concept generated for the shifting application. This design concept involves placing shifting levers on Craig's arm.

Also included for safety purposes, specifically to prevent tipping, support wheels were added. The total cost of parts and supplies is approximately $825.00.

Fig. 11.7. Photo of Prototype.

SELF PROPELLED WALKER

Team Members: Proma Debnath, Kasha Kultys, Will Novak, Eric Soring
Client Coordinators: Hershey Rehabilitation Center, Dr. Everett Hills, Dr. Sergio Chacin, Mrs. Nancy Ehrlich
Supervising Professors: Dr. Mary Frecker and Dr. Maggie Slattery
The Pennsylvania State University
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INTRODUCTION

The self-propelled walker was designed to aid patients with insufficient body strength. These patients would greatly benefit from a self-propelled walker to reduce the amount of energy required from the user. Many patients with neuromuscular conditions do not possess sufficient upper body strength to operate the current walkers available. The simultaneous action of grasping the walker and pushing it forward can prove to be burdensome.

SUMMARY OF IMPACT

Dr. Hills and Dr. Chacin were extremely happy with the design and prototype of the self-propelling walker. Not only can the walker be a very useful device for someone with a neuromuscular condition, but it would also be very helpful for patients who are in a rehabilitation process and need a stepping stone between a wheel chair and a standard, non-powered walker. The device kept all features of a regular walker such as maneuverability, portability, and the ability to fold up and be placed in a small space. In addition, it proved to be strong enough that someone could transfer a significant amount of their body weight for balancing issues and still progress forward using the DC motor attached to the front shaft. The combination of these features will make life much easier for patients using the walker. The low amount of energy needed to use the device will allow a patient to exert their energy in other ways throughout the day.

TECHNICAL DESCRIPTION

The device consisted of modifications made from a walker already on the market, the Medline Rollator. All wheels, the breaking system and other attachments were removed from the Rollator, leaving a bare frame, from which the group used as their beginning design. A front shaft extended from the original two front legs housing the driving mechanism, an 18V DC motor. The motor was connected directly to an 8 inch “never flat” foam based wheel. Wires were run from the motor to the trigger device, which was mounted on the left handle of the device. Wires were then run from the trigger to the batteries, located underneath the folding seat. Omni directional wheels (not shown in Figure 11.8) for the two rear legs will be included in the final manufactured product. To prevent tipping when improperly used, two small caster wheels were added on the front of the walker. The beta prototype produced passed all tests to ensure safety and functionality and the group was able to stay within the $1000 budget while meeting all of the customer needs. The total cost to produce the walker was around $180.00, which will correspond to a market price of about $750.00.

Fig. 11.8. CAD drawing and photo of final product.

ASSISTIVE RIFLE TRIGGER PULL

Team Members: Leonard Weber, Eric Weidert, Ben Roscoe, Michael Thompson, Jim Vomero
Client Coordinator: Travis Oldhouser and Dr. Everett Hills
Penn State Hershey Physical Medicine & Rehabilitation
Supervising Professors: Dr. Mary Frecker and Dr. Margaret Slattery
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INTRODUCTION

The Trigger Pull Assist Device (TPAD) was designed to provide trigger squeeze sensation to a rifleman with quadriplegia, in order to operate and discharge his firearms more independently. The device focuses on finger dexterity limitations associated with certain spinal cord injuries but which are essential in pulling the trigger of a rifle or pistol. Design criteria utilized for concept generation and selection were determined based on customer needs generated from the input of the project sponsor. The criteria include ease of use, traditional operation, steady operation, platform independence, device durability, weatherproofing and overall cost. The current products available require the user to blow or bite into a tubing placed in their mouth. Biting or blowing into the tube activates the device, setting the machine into motion causing a rapid trigger pull.

Our sponsor, who comes from a military background said, "That is not how you fire a gun." It was the intent of the design team to exceed the design criteria set by our sponsor and create a device that is novel allowing him to pull the trigger of his rifle. The loss of hand or finger dexterity complicates daily tasks, as well as, participation in many recreational activities. The TPAD (see Figure 11.11) was designed so the sponsor could participate in firing his guns and begin to participate in competitive shooting.

SUMMARY OF IMPACT

Design criteria utilized for concept generation and selection were determined based on customer needs generated from the input of the project sponsor. The criteria include ease of use, traditional operation, steady operation, platform independence, device durability, weatherproofing and overall cost. The TPAD is an accurate and effective design permitting a traditional trigger pull sensation for a rifleman with quadriplegia. After testing the device, Dr. Everett Hills was impressed and thought the device would be very useful. The TPAD met the objectives set by the sponsor and is in use by Travis Oldhouser.

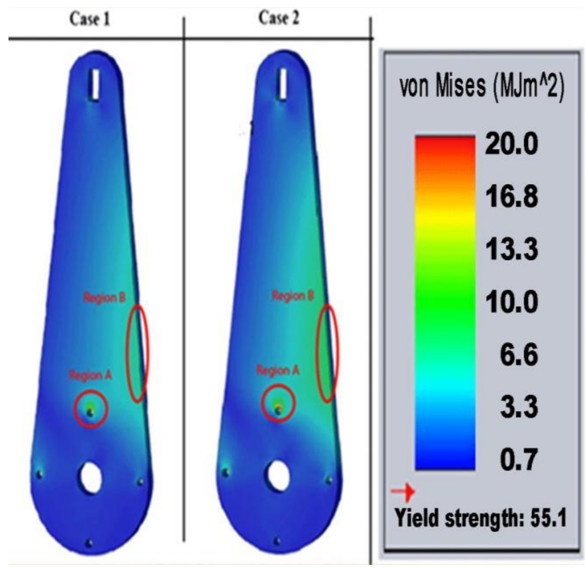

Fig. 11.9. Finite Element Analysis Model of the device arm.

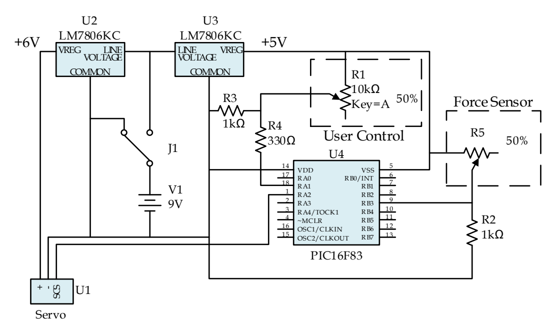

Fig. 11.10. Circuit Diagram of the microchip.

TECHNICAL DESCRIPTION

The most important elements of our final design include an RC Servo for torqueing the lever arm, an aluminum lever arm to apply a backwards force to the finger strap, a Velcro finger strap to restrain the operator's finger, and a Force Sensing Resistor (FSR) to actuate the device. Selecting these components required careful consideration of overall size, ability to inter-connect, and device compatibility. Figure 11.9 displays the groups Finite Element Analysis (FEA) of the device's arm. The analysis helped determine what material to use for the arm and how to design it. Figure 11.10 details the circuit diagram for a microchip – electronic board assembly the team constructed. The microchip – electronic board assembly was the heart of the device; it allowed the device to have a pressure sensitive trigger pull. These components helped the device to successfully provide sufficient force to pull the trigger while minimizing overall size. Manufacturing the device was a five step process that required fabrication and assembly of the lever arm, leather strap, housing, housing mount, and electrical components and circuitry. The overall cost to create this device was $809.81. We estimate the market value price to be $100.00.

Fig. 11.11. Photo of final product.

WII™ REMOTE FOR MAN WITH QUADRIPLEGIA

Designers: Alice Cheng, John Dzikiy, Marisa Hicks, Madubuike Okafor James Peters
Client Coordinator- Dr. Everett Hills
Penn State Hershey Rehabilitation Center
Supervising Professor- Dr. Margaret Slattery
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INTRODUCTION

This project was to combine rehabilitation with enjoyment of the Wii™ system. The Wii™ is a system that uses an accelerometer to detect motion, which then transfers the motion data to the game. This project potentially promises to bridge the gap between self-rehabilitation and enjoyment. There are many articles on the prospect of "Wii-habilitation." "Wii-habilitation" has been proven to show an increase in range of motion of the wrist, and possibly increase connectivity of neurons through repetitive motion. Applying the notion of "Wii-habilitation" to the broader scheme shows that it can be useful for many types of rehabilitation.

Mr. Bob Yorty is man with a C-6 injury resulting in quadriplegia who would like to use a Wii™ controller to play Wii™ video games for rehabilitation purposes. Mr. Yorty has wrist extension and elbow flexion, but does not have finger movement, elbow extension or wrist flexion. Therefore, he does not have enough control of his hands to grip or control the Wii remote. Mr. Yorty would like to use the Wii™ controller to play Wii™ Sports for rehabilitation and leisure purposes.

Adaptive Wii™ Remotes exist on the market but are expensive and less thrilling. A common device used by disabled patients, entails an intricate wiring system which includes a head set used to utilize their head movement abilities. The team believed this deprived Mr. Yorty of the excitement of the game, so we strived to create a more traditional remote that would include only the arm movements.

SUMMARY OF IMPACT

We wished to optimize and customize the device making it patient specific while keeping both function and comfort within acceptable tolerances. During the development process, we analyzed and pushed the limits to Mr. Yorty's range of motions to

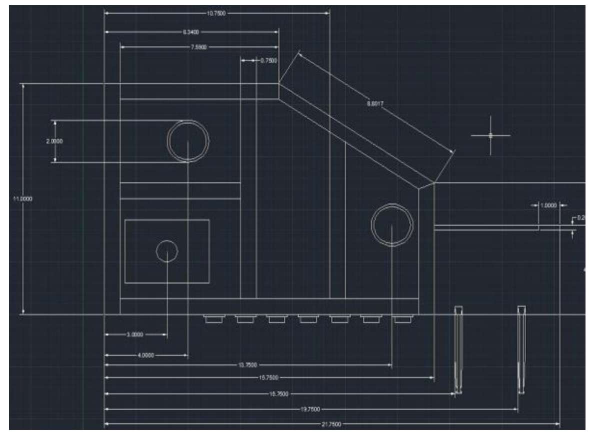

Fig. 11.12. CAD Drawing.

make the device as customized as possible. The device is a unique way to allow Mr. Yorty to integrate rehabilitation into home entertainment. According to Mr. Yorty, "when you see the potential benefit of what a Wii™ device has to offer, but only marketed to the "abled" not the "disabled" it's a huge disappointment - both in physical activity, and, generally speaking, being left out." Dr. Hills was questioned about "Wii-habilitation" and he replied, "Sometimes these rote physical tasks in traditional rehab can become so boring and take a long time for benefits to appear that the patient loses interest or enthusiasm for the rehabilitation program. This adaptive Wii device will allow the patient to perform therapeutic exercises that feel fun to pursue repetitively while enhancing the patient's physical skills and giving them an immediate sense of accomplishment." Our project is a great way to overcome both of these obstacles. Mr. Yorty said he is looking forward to playing against his girlfriend's daughter in boxing.

TECHNICAL DESCRIPTION

Our team capitalized on the original Wii™ remotes virtual grounds. We mounted passively open buttons on a manufactured acrylic deck. All the ground wires in the micro switches were soldered to the main ground in the Wii™ remote. Each passively open button on the deck was soldered to the positive terminal of the respective button on the Wii™ remotes circuit board. Our finally deck included all the buttons on an original remote. The geometry of the board was designed according to Mr. Yorty's anatomy and his wheelchair's specifications. The final design includes two C-clamp vise grips and a carrying strap that will enable Mr. Yorty to easily mount the board onto his wheelchair himself (These items are not shown in Figure 11.13). The device cost approximately $425 to manufacture, but with mass production we would expect this device to drop below the current market products which range around $350.

The team needed to determine how much force a human hand applies when dropped from a 45 degree angle relative to the elbow joint. The weight of an average human hand is 1.25 pounds. The average length of a human forearm is nine inches. The height of the button is about one-third of an inch. The diameter of the A and B buttons is two inches. The height for the hand to drop onto button from a 45 degree elbow orientation was calculated to be approximately 6 inches. The pressure that would be applied to the button (weight of hand/area of button) was found to be approximately 0.4 psi. The actual pressure required to depress the buttons was the pressure applied by 400 grams of mass which is about equal to 0.27psi. From this analysis we have determined that an average person should be able to operate the buttons on the deck only using the weight of their hand.

The figure below shows the final versions of the "top view" of our device. Dimensions have been added to the CAD drawings to avoid any miscalculation in the manufacturing process.

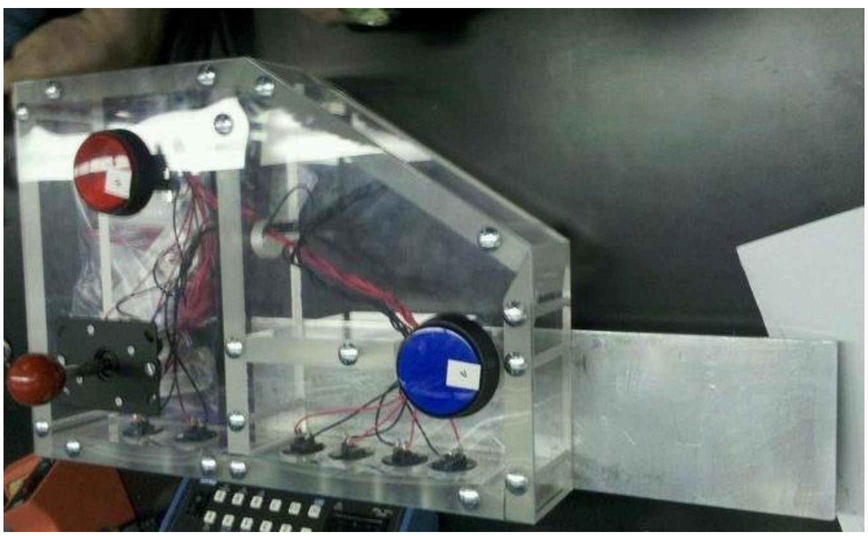

Fig. 11.13. Adaptive Wii™ Remote.