CHAPTER 17
UNIVERSITY OF SOUTH ALABAMA

School of Engineering
Department of Mechanical Engineering
Engineering Classroom Building 212
Mobile, Alabama 36688

Principal Investigator:

Cecil H. Ramage (205) 460-6168

An Alternative to a Full-Size Power Wheelchair

Designed By: Charles Busby and Ku-En Tan
Client Coordinator: Robert Perry, Rehabilitation Engineer
Supervising Professor: Dr. Edmund T. Tsang
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

In order to provide a higher level of independence for a twelve year old Cerebral palsy client during school hours, a detachable drive device for a manual wheelchair was requested. Therefore, in cooperation with the child's parents and Scarbourgh Middle School the client's existing manual wheelchair has been adapted to accept an add-on drive unit and the unit has been constructed.

A battery, motor and drive train have been mounted in an aluminum housing that fits beneath the chair. Steering is provided by an independent linkage to the chair's front wheels that have been slightly modified by the addition of vertical forks. The controls for the drive motor are located on the steering column and connected to the motor housing by a single cable.

SUMMARY OF IMPACT

The recipient of this device, a twelve-year-old child with spastic quadriplegic Cerebral palsy and a student at Scarborough Middle School, will now be able to move about in her classroom and change rooms independently.

Previously this child has been unsuccessful in using a joystick for wheelchair control, but the add-on power unit built by these students may reveal that the natural damping of the mechanical steering system combined with a feeling of real steering will be the key to overcoming her mobility predicament.

TECHNICAL DESCRIPTION

A device has been designed and constructed which will enable independent operation of a manual wheelchair by a person with very limited upper body muscle control. The main components of the apparatus are outlined below.

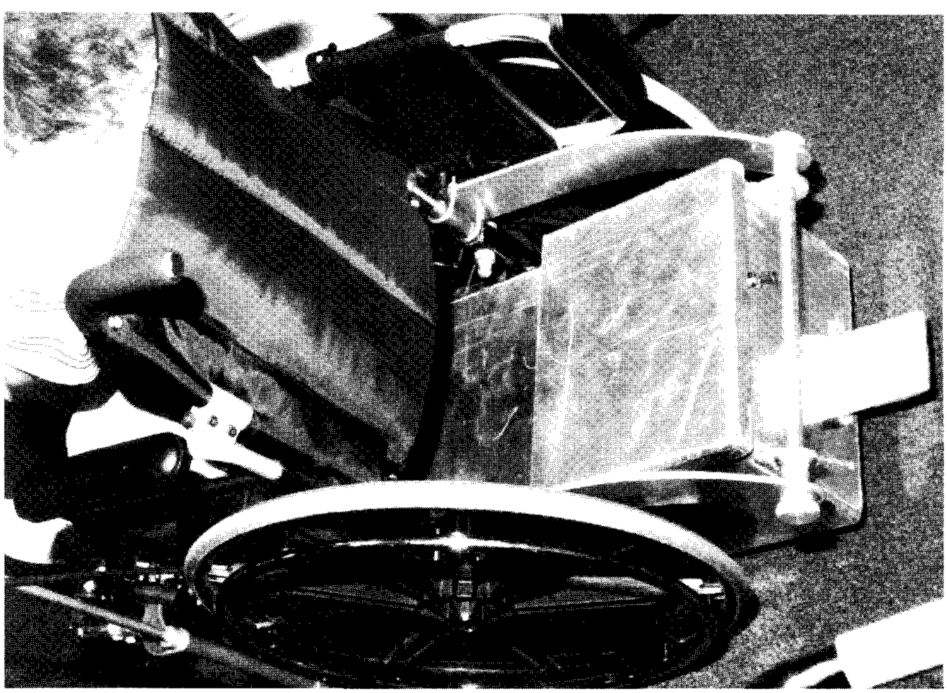

Fig. 17.1. Modified Full-Size Wheelchair.

Steering - The front forks of the wheelchair have been replaced with forks that do not track the wheelchair's direction of motion. A steering linkage has been attached to the front wheels. A pitman connects the linkage to a vertical steering column. The top of the steering column is attached to a horizontal rod that runs parallel to the chest of the operator across the chair. This arm has a 270 degree angle of vertical rotation that allows it to hang next to the vertical rod when not being used and to be self supporting when in position for steering. Any horizontal movement of this rod by the operator will result in change in the direction of the wheels thus allowing for steering of the chair.

Battery - The device has been equipped with a 12 volt GEL-CEL battery which is rated for 6 hours at a discharge rate of 20 amps. This will provide for 2 hours of actual operation between charging and still remain in accordance with manufacturer's recommendations of only 33% discharge.

Drive Motor and Circuit - A one-quarter horsepower, permanent magnet, 12 volt DC motor was used. The motor is of commercial grade high torque design and operates at 1750 rpm. The motor is controlled by a momentary push-button to control starting and a two position rocker switch to control direction. Both of these operators are mounted on the steering column. The push-button activates a single pole single throw (SPST) relay which in turn delivers power to the motor. The rocker switch controls two double pole double-throw (DPDT) relays which can reverse the polarity of the power to the motor and thus reverse its direction.

Drive Train - A right angle, worm reduction gear with a speed ratio 10:1 was used to turn the drive wheel at 175 rpm. The drive wheel is eight inches in diameter and made of solid rubber. It is coupled directly to the half inch output shaft of the reduction gear. The eight inch diameter wheel turning at 175 rpm provides a top speed of 4.2 mph.

Enclosure - Quarter inch aluminum plate was used to construct the floor and sides of the enclosure while its top is made of one eighth inch aluminum plate. Its dimensions are designed such that it does not add appreciably to the overall dimensions of the wheelchair. It is equipped with a caster platform at the rear to prevent possible tipping of the chair. The enclosure attaches to the chair by means of pivoting brackets attached to the back of the enclosure and bolted to the frame of the chair.

Further work should be addressed in an attempt to decrease the size of the drive enclosure. The method of steering may not be feasible for all clients capable of using a power wheelchair. Finally a motor speed control should be added to provide variable speed capability and reduce the high accelerations encountered when starting and stopping the chair. The final cost of the materials for the project was approximately $740.

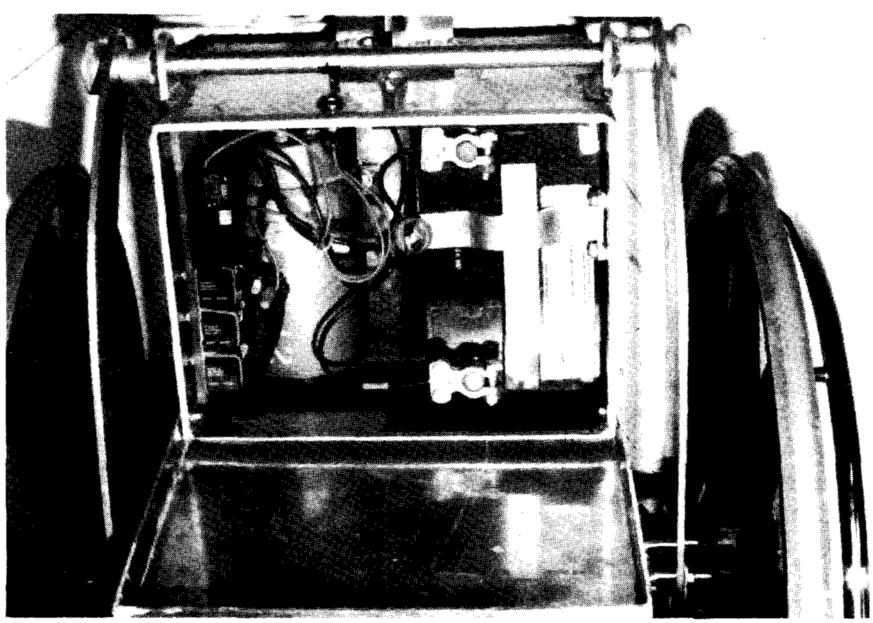

Fig. 17.2. Close-up of Modified Full-Size Wheelchair.

Computer Interface

Designers: Richie Richardson, Scott Parker, Bruce Snyder
Client Coordinator: Robert Perry
Supervising Professor: Dr. Cecil Ramage
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

Christy, a girl with Cerebral palsy, is unable to operate a computer. In order to solve Christy's problem, the design team looked at two possible solutions. The first was a wheel and button system and the second a voice activation system.

The wheel and button system consisted of a movable wheel indicating computer key symbols. An arrow on the wheel is aligned with the desired symbol and a submit button pressed to send the selection to the computer. The wheel would be 10 inches in diameter to allow the key symbols and letters to be quite large and easily seen.

Typically speech recognition systems are quite expensive ($9000+). These systems recognize an almost infinite user vocabulary. During research, the group found an inexpensive speech recognition system called Hearsay 1000. Although the system limits the number of commands to 64, the system could be used to input letters just as if they were typed on a keyboard. The system was also capable of speech synthesis which is an excellent feature for the visually impaired.

The group was uncertain which solution was best for Christy. Since the wheel and button system would require considerable hand/eye coordination it was decided to test the speech recognition system.

Christy was able to use the Hearsay 1000 system. The system allows Christy to easily and quickly input data into an IBM XT/AT compatible computer. The speech synthesis feature proved valuable in overcoming Christy's visual problems. The system will speak the letters as they are entered. It will also read text on the screen out loud. Since the Hearsay 1000 system was so successful, plans to build the wheel and button system were canceled.

SUMMARY OF IMPACT

The recipient of this device, a twelve year old girl with spastic quadriplegic Cerebral palsy and a visual impairment, can now access the computer keyboard independently and quite efficiently using only her impaired voice.

Previously this child was able to use a computer only with a key guard. This method was extremely slow and tedious and virtually impractical.

Because of this project, the parents have purchased a computer for home and are very encouraged by their child's new ability through the use of this technology. This will greatly enhance her life in the areas of education, and recreation. In the future, the means of computer access developed in this project may lead to vocational prospects that will substantially increase her independence.

TECHNICAL DESCRIPTION

The Hearsay 1000 system consists of an internal IBM XT/AT compatible card. It comes with a microphone/speaker headset and supporting software. The system will work with any program or compiler that uses Interrupt 16 for keyboard services. The included software is menu driven and compensates for background noise.

The voice recognition system accepts 64 voice commands. This is enough to allow input of the 26 letters of the alphabet, numbers O-9, enter, backspace, space bar and other important computer keys. Each command is trained to the user's voice. A template of the user's voice is made for each command during the voice training process and stored in a disk file.

The commands are placed into macro pages containing 16 commands each. Each command in the page is assigned a key sequence that will be executed when the corresponding command is recognized. The key sequence may be any series of keys on the standard keyboard including function keys, enter, control, alternate, etc. They are executed just as if they were typed on a keyboard. Macro pages are stored in a disk file.

Only one 16 command macro page is allowed in memory at any time. This requires the user to switch back and forth between pages. The command to switch pages takes up space in the 64 command list.

Since the voice commands and macros are stored in a disk file, the system may be trained for different users or for different command lists. The command and macro files may be loaded when the TSR program is loaded or by using the menu provided in the program.

The words used as commands must be selected carefully. The system has difficulty in distinguishing between soft sounds such as "s" and "p" and explosive sounds such as "t" and "k". Commands with more than one syllable also have better results.

The Hearsay 1000 system was purchased for $185.70.

Design Of A Headstick Manipulator

Designers: David Budlong and Steven Guinn
Client Coordinator: Robert Perry, Rehabilitation Engineer
Supervising Professor: Dr. A. J. Wilhelm
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

A manipulator device was designed and built for Daryl. Daryl has Cerebral palsy that severely affects the dexterity and coordination of his muscoskeletal system. This causes object manipulation to be limited and difficult. The manipulator will allow increased use of toys and other small objects. Daryl uses a head pointer to operate a digital voice simulator. The gripper is interchangeable with the head pointer.

SUMMARY OF IMPACT

The recipient of this device, an eight-year-old gifted student with athetoid quadriplegic Cerebral palsy, will now have another way to manipulate and interact with his environment.

This child is a typical eight-year-old boy and is constantly needing, and eagerly striving for, play stimulation and interaction with playmates and his surroundings. The manipulator has given this child another mechanism for this interaction and has inspired the investigation into further use of his head for activities such as computer access.

Fig. 17.3. Headstick Manipulator.

TECHNICAL DESCRIPTION

Daryl clearly stated his expectations when he said that he wanted an "arm mounted on his head with a hand that could grab things." The three main things that Daryl would like to pick up and manipulate are dominoes, building blocks, and toy army men. The heaviest toy that Daryl has is a toy truck that weighs 0.5 pounds. Daryl's parents requested that the manipulator be capable of grasping items up to 2.5 inches in width.

The manipulator designed consists mainly of two parallel arms which are restricted to an arc movement on each side of a center member. A cable pulls the two parallel arms through an arc away from the center member. When the cable is released a spring connected between the two parallel arms, pulls them back together. The cable will be activated by leaning on a lever attached to the right or left side of the wheelchair. This system will allow Daryl to grasp and manipulate objects independently.

Daryl can lift a maximum of 4.5 pounds at the end of his 12 inch pointing rod. He can generate a maximum of 5 pounds force with his arms pushing downward or to the rear. Using this information, the design configuration was analyzed to determine if Daryl would have the strength to operate the manipulator. A spring constant of 0.222 pounds per inch was calculated to lift the 0.5 pound object. It was found that with a spring constant of 0.222 pounds per inch the manipulator requires less than 10% of his arm strength to open the gripping surfaces. It was calculated that if a 2.4 pounds per inch spring constant is used a force of 4 pounds is required to open the manipulator. Using this spring constant the manipulator can hold a 5 pound object that is 2.5 inches in width. This allows Daryl to manipulate objects well over the design requirements.

The gripper is made of one-eighth inch thick aluminum with rubber pads. The members are connected using one-sixteenth inch shoulder screws. The activating lever is also made of one-eighth inch thick aluminum and is connected to the wheelchair by use of a hose clamp. This allows the manipulator to be removed and placed on a new wheelchair when needed. The cable is standard bicycle cable.

The total cost for the manipulator is approximately $225.

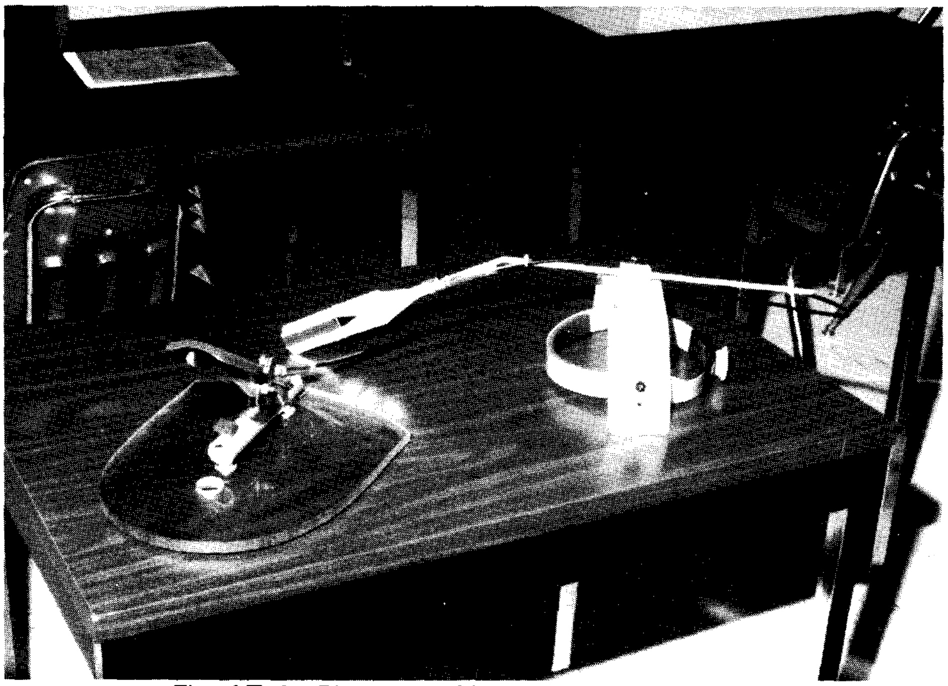

Fig. 17.4. Close-up of Headstick Manipulator.

Design of Handicap Access System

Designers: James Noyes, Wes Gerhardt, Steven Guinn
Client Coordinator: Robert Perry, Rehabilitation Engineer
Supervising Professor: Dr. Cecil H. Ramage
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

In January of 1991, our three member design team was introduced to Pat, a quadruple amputee. Pat has lived in her present home for a number of years, and up until early 1990 was able-bodied. At that point due to pneumonia complicated by diabetes, both legs were amputated at the hip, one arm was amputated at the shoulder and the other arm amputated slightly above the elbow, thus confining her to power wheelchair.

Pat has no desire nor the financial means to move from her present home. Her bedroom however, is located two steps (14 inches) lower than the main living area of the house. The relatively small size of the room makes the use of a conventional handicapped wheelchair ramp impossible. Nor are there any other types of small lift systems available to use in place of a ramp. The purpose of this project was to design and construct a lift system that would fit in the relatively small area adjacent to the bedroom door and allow Pat access to her bedroom.

SUMMARY OF IMPACT

The individual receiving the ramp, a quadruple amputee, will now be able to enter her own bedroom independently, greatly enhancing her quality of life.

This design will give her the privacy of sleeping in the bedroom (previously inaccessible) instead of in the living room and, possibly more importantly, allow her to cool only her bedroom using a window air-conditioner, instead of having to cool the entire house.

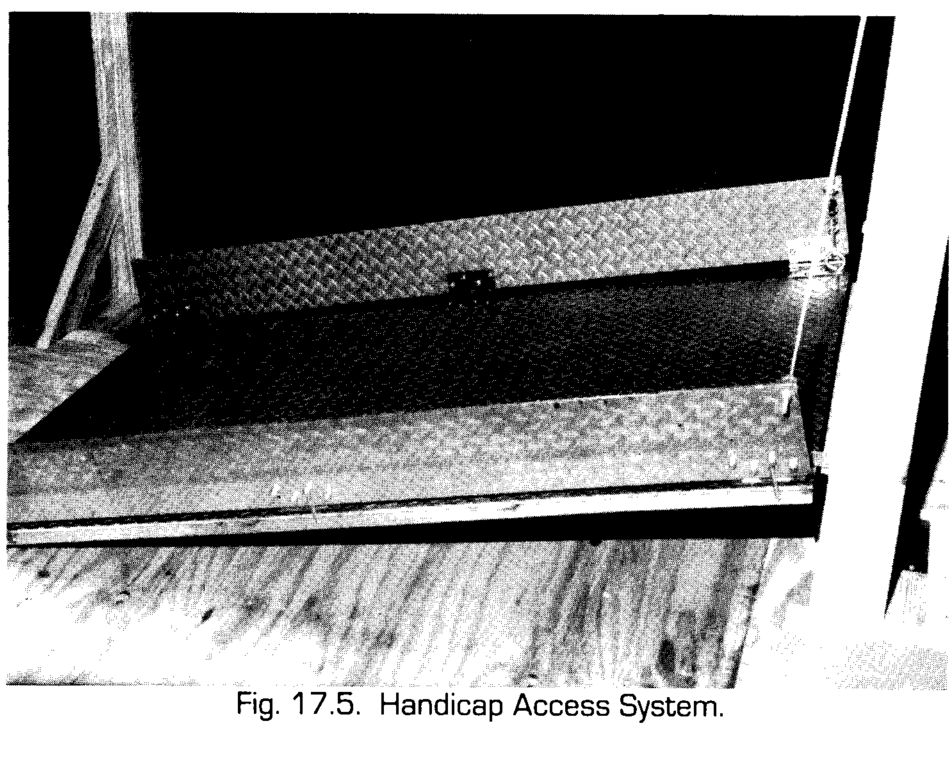

Fig. 17.5. Handicap Access System.

TECHNICAL DESCRIPTION

The ramplift is primarily composed of two major components, the winch, which includes the controls necessary for its' operation, and the moveable ramp that provides the driving surface for the wheelchair. All components of the system were designed and/or selected based on a weight load of over 500 pounds, which is much more than the combined weight of an occupied power wheelchair. The winch has a built-in clutch-brake that insures no motion unless the switch is energized. The ramp has six inch safety sides on each side which are automatically pulled to the upright position when the ramp is off the ground, and down flat only when the ramp is in the extreme down position. This prevents the wheelchair from rolling off the side of the ramp when it is in its up position.

The operation of the ramplift has been made as uncomplicated as possible. When Pat is in the upper section of the house, the ramp is in the up position supported by the winch brake and safety stops allowing her wheelchair access into the bedroom. When she desires to be in the bedroom, she simply drives the wheelchair down the ramp into the room. Once in the bedroom, she positions the wheelchair adjacent to the ramp controls located on the wall at the base of the ramp. To lower the ramp, she first retracts the safety stops by depressing a large push-button switch. She lowers the ramp using the "ramp position" control, a double push-button switch (with large mushroom heads for easier operation), by pushing the "DOWN" button. This activates the winch and lowers the ramp all the way to the floor. The entire bedroom is now wheelchair accessible.

When Pat wishes to leave the bedroom, she again positions her wheelchair at the controls on the wall at the base of the ramp. She pushes the "UP" button on the ramp position control. This activates the winch and raises the end of the ramp flush with the upper floor level. When the ramp reaches this point, it contacts one limit switch that turns the winch off and two other limit switches (one on each side of the ramp) which engage the two safety stops. The ramp is then secure in the up position with Pat positioned at the base ready to drive the wheelchair up out of the bedroom.

The total cost was approximately $900.

Swing-Away Communication Board

Designers: James P. Parr and Richard Rabenau
Client Coordinator: Robert Perry, Rehabilitation Engineer
Supervising Professor: Dr. Edmund Tsang
Mechanical Engineering Department
University of South Alabama
Mobile, AL 36688

INTRODUCTION

The physiologically handicpped tend to improve or deteriorate in their disability as a function of their capacity to act independently of others. That is, when an individual can function with little or no help from others, then that person develops a better mind set thus giving them a psychological boost to overcome their disability.

Therefore, when a "Touch-talker" (an augmented communications device) is needed for an individual to communicate with others in his or her surroundings, it is a blow to their psyche every time someone in the environment has to put the device into place so that it may then be used. Especially, if this is in a school setting where the teacher has to momentarily stop class so the handicapped individual may become involved. This also brings unwanted attention.

A mechanism was designed to provide a means by which a "Touch-talker" could be placed in a stored position when not in use and brought up into a usable position when needed by the handicapped individual. The user of this device has limited upper body strength and muscle control. The device did not add significantly to the overall dimensions of the wheelchair and did not impair its' use as a wheelchair. The device is aesthetically pleasing as well as being designed not to hinder the individual in any way during his daily activities. And, although independent operation was of primary importance in designing this device, ease in maintenance was also a consideration.

SUMMARY OF IMPACT

The recipient of this device, a four-year-old child with Cerebral palsy, was not able to use both his communicating device and his power wheelchair joystick independently. The "Touch-talker" can now be moved to give unlimited access to the joystick.

Because of this device's aesthetic appearance and simplicity, several therapists and parents have asked how they can obtain one for other clients.

TECHNICAL DESCRIPTION

The apparatus consists of three major components: the frame, the arms and the power system.

The Frame - The frame was made from two pieces of 2x2 square tubing mounted to an angle base. Bronze bushings were inserted near the top of the tubing to act as bearings for a stainless steel drive shaft to move the arms. This frame is attached to the back of the wheelchair.

The Arms - The two arms are made out of seven-eighths inch stainless steel tubing. They are connected to the drive shaft with 90 degree Tee connectors. The upper and lower segment of each angle are connected with 110 degree angle connectors. The lower ends of the arms are connected to the "Touch-talker" mounting frame with 90 degree Tee connectors.

The Power System - The power system consists of a 12 volt DC right-angle, worm gear drive motor that transmits torque through a chain driven gear reducer attached to the stainless steel drive shaft. The motor is powered by a 12 volt battery controlled by a monitoring switch that the user must push and hold in the ON position to move the "Touch-talker" to and from its stowed position. Once the switch is released, the "Touch-talker" stops. The extreme positions arms "Touch-talker" are controlled by limit switches and mechanical stops.

The cost of the apparatus was approximately $472.

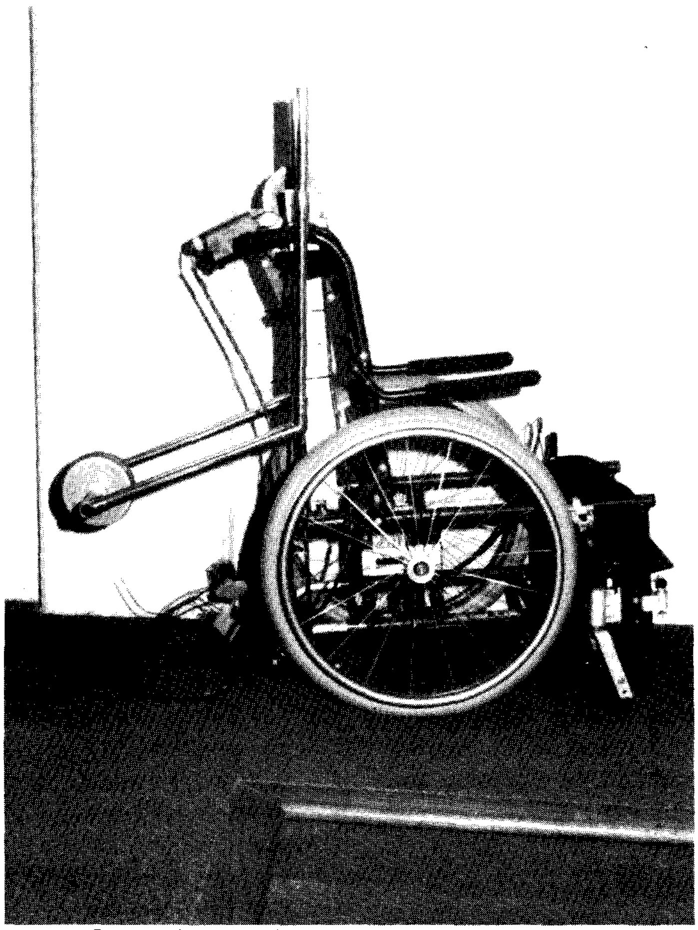

Fig. 17.6. Swing-Away Communication Board.

Design of a Control Device for a Power Wheelchair Using Available Leg Motions

Designers: Monica Garsed, Scott Parker, Tony Price
Client Coordinators: Robert Perry, Rehabilitation Engineer
Susan Perry, Physical Therapist
Supervising Professor: Dr. Cecil H. Ramage
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

Katina is a seventeen year-old high school student who has spastic Cerebral palsy. This condition does not permit her to control a power wheelchair by conventional means. Katina has specific physical motions that will enable her to control a power wheelchair. She has limited control over her left knee and foot. Movement of her left knee, from left to right, is possible when her foot is fixed. She can also pivot her foot upward and downward about the ankle joint. According to her physical therapist, these are the only motions she can perform consistently without muscle spasms. Thus, the aim of this design was to utilize these specific physical motions to control a power wheelchair.

After a rather long process of idea generation and evaluation, a design was chosen. The controller consists of a foot pedal, a knee guide, and two low-friction control cables which connect the foot pedal and the knee guide to a joystick, mounted at the rear of the wheelchair. The knee guide components control the left and right movement of the wheelchair. The foot pedal will control the forward and reverse movement of the wheelchair.

SUMMARY OF IMPACT

The recipient of this mechanism is a high school student with severe spastic Cerebral palsy having virtually no use of her arms or hands and *very* limited controlled movement of her head. Because of the severity of her disability, she was not considered a good candidate for powered mobility. It was later discovered that this young lady had very good movement and control of her left leg and foot.

The foot-leg joystick activator allows this student to efficiently operate a joystick and will be used as an incentive for the rehabilitation service to further examine her ability to use powered mobility. It will also provide a means for her to access a computer or electronic games, greatly enhancing her life in the areas of education and recreation. As she learns to use the controller it is hoped that her vocational possibilities will be improved.

TECHNICAL DESCRIPTION

The system is designed to allow a seventeen year-old Cerebral palsy client to control a power wheelchair with only limited motion of her left knee and left foot. The system consists of a foot pedal and a knee guide to control the forward and reverse and left and right motion, respectively, of a single joystick. The force from the foot pedal and knee guide are transferred to the joystick through control cables.

Foot Pedal - A foot pedal was attached to the left foot support of the power wheelchair. The pedal was spring-loaded such that when the client placed her foot on the pedal the joystick remained in a neutral position. When the client pressed down on the forward portion of the pedal the cable was activated in such a manner as to push the joystick into forward motion. When the client pressed down on the rear of the pedal the cable was pulled into the position of reverse motion. The pedal was balanced in such a manner, with a brace in the center of the pedal and springs under the front and rear portion, as to allow a small general application of force in either the front or rear portion of the pedal to produce forward or reverse motion, respectively. The cable was attached to the pedal with a linkage designed to provide proper alignment between the pedal and the cable.

When no attempt at motion was made the pedal returned the joystick to a neutral position.

Knee Guide - A thin, horseshoe type brace was mounted behind the client's calf. When the client moved her leg to the right, the cable was activated and the joystick was pushed to the right. When the client moved her leg to the left, the cable pulled the joystick to the left.

Joystick Alterations - The joystick modifications needed for this design were minimal. The joystick was relocated to a position behind the power wheelchair. The cables were attached to an extension of the joystick handle.

The completed cost of this design system was less than $100.

Fig. 17.7. Control Device for a Power Wheelchair.

Evaluator Skills for the Adaptive Driving Program

Designers: *Gay Carnley* and Morris Spann
Client Coordinators: Robert Perry, Rehabilitation Engineer
Warren E. Weed, Occupational Therapist
Supervising Professor: Dr. Cecil H. Ramage
Department of Mechanical Engineering
University of South Alabama
Mobile, AL 36688

INTRODUCTION

In the State of Alabama a person confined to a wheelchair who wishes to drive must enroll in an Adaptive Driving Program. This program is only offered in Birmingham, Alabama at the Lakeshore Rehabilitation Facility. The abilities required to enter this program are sufficient arm strength and endurance and range of motion to drive a specially equipped vehicle. Many people go to Birmingham with the intention of enrolling in this program only to find out that they are not physically ready to do so. The problem is to develop a device that will test whether Hank, a prospective driver's training candidate, has these minimum required skills, and that will also allow him to monitor the progress of his physical therapy to determine when he is physically ready to enter the driving program. This device will provide a means by which any person can evaluate their own ability to enter the Adaptive Driving Program. By doing this a person can eliminate the need for multiple trips to the training site.

SUMMARY OF IMPACT

Hank, the young man that will benefit from this apparatus, a nineteen-year-old quadriplegic, is a senior in high school and a vocational rehabilitation service client.

The ability of a quadriplegic to drive, thus allowing him enough independence to obtain substantial employment, is sometimes uncertain. The determination of this ability is very expensive for the VRS counselor and time-consuming for the client, requiring him to relocate for several weeks to an evaluating center located 266 miles away.

Fig. 17.8. Evaluator Skills for the Adaptive Driving Program.

This device will not only be a confidence builder, but will allow the recipient to measure his strength and endurance before attempting the evaluation, resulting in fewer failures.

TECHNICAL DESCRIPTION

The subject of this report is a compact and affordable physical therapy device to be used by any person who wishes to test or improve their strength and endurance. One device will allow a person, whether working with free weights at home or working with a cable and pulley system in a rehabilitation facility, to monitor their strength and endurance.

The main components of the device are outlined below:

Strength and Endurance Testing Sensors - adjustable wristband, attached to weights by 1/8" diameter plastic coated steel cable, is used to test strength. This exercise will be timed allowing endurance to also be monitored. The battery-power timing device will be activated by compression of a spring when the weight is lifted. The device will stop timing when the spring is no longer in compression.

Timing Device - The timing device is made up of three major parts.

1. A 12 volt DC power source is provided by a lantern battery.
2. A Model COS1, Clock Oscillator manufactured by Red Lion Controls provide pull down clock pulses of one volt at 10ma. The pulses are applied to the input of the counting device.
3. A Model Cubl, counter manufactured by Red Lion Controls is used as a timing device. The timing device is activated by a switch closure.

Evaluation of Test Results - A person wishing to enter The Adaptive Driving Program should have a muscle grade of at least 4+. Any person who can lift 7.5 lbs and suspend it, with the weight bearing arm extended perpendicular to the trunk of the body for 30 seconds, could be considered to have a muscle grade of 4+.

The design discussed in this report takes a major step in quantifying the testing procedure for strength and endurance. Due to the low cost and simplicity of the device it can be purchased for home use. This device is intended to be used with free weights in the home, and is also easily connected to the existing cable and pulley systems used in rehabilitation facilities. The possibilities for the use of this device in the rehabilitation field are endless. It is hoped that this device will be modified and used by anyone who can benefit from it.

The total cost of the project, including all items used for development, was approximately $185.

Design Of An XYZ Positioner

Designers: Dayeddine Al-Alami, Garland Borowski, David Budlong
Client Coordinator: Robert Perry, Rehabilitation Engineer
Supervising Professor: Dr. A. J. Wilhelm
Department of Mechanical Engineering
University of South Alabama
Mobile. AL 36688

INTRODUCTION

Athropalsy is a disease which causes the over-production of collagen. This abundance of collagen causes the muscle tissues of the body to lose its elasticity. With a lack of muscle tissue elasticity, the range of motion of an individual's arms, legs, hands, and feet are drastically reduced which limits the individual's independence. This was the difficulty in the life of Teresa Gurley. Teresa wished to be capable of reaching her phone, a computer keyboard, a small painting, a book, or other such random items without requiring the assistance of her nurse aide or husband. To meet this need in Teresa's life, a cantilevered table top was designed so that it was capable of movement along the x, y, and z coordinate axis. Through the use of a stick (an object that Teresa's uses comfortably), Teresa will be able to operate three-position toggle switches to activate motors that can drive the table top to any point within a three-dimensional envelope of movement.

TECHNICAL DESCRIPTION

A table top capable of movement in a three-dimensional envelope has been designed in order to increase the independence of a client with athropalsy. Main considerations were structural members and power train components as outlined below:

Structural **Members -** The basic frame consists of several sections of 2" box tubing and 1 3/4" box tubing. The 1 3/4" box tubing is inserted into the 2" box tubing with some reasonable clearance in order to allow for translation along the various axis of motion.

The structure is supported by two aluminum "feet" which are 2 1/2" wide and 1/2" thick. These feet are of a length such that a maximum load of 100 pounds will not be capable of causing the table to topple.

Deflections of the table top were of a concern, so triangular gussets of 4 1/2" x 4 1/2" x 1/2" were added to each foot in order to prevent deflection in that area (which had shown itself to be the cause of a majority of the deflection). Once the gussets were added, deflections were reduced to 1.1 inches under a maximum load of 100 pounds. Normally loading of 15 pounds resulted in a deflection of only 0.11 inch. This resulted in a slope of the table top of less than 1/3 of a degree.

Power Train Components - A series of relays, limit switches, toggle switches, and motors were considered on a ladder logic diagram and combined to prevent over-driving the system while also preventing any attempt to move the table top in opposing directions at the same time. A centrally located circuit box will house the relays and ladder logic. One hundred and twenty volts of AC power will be drawn from a house outlet to provide energy with which to drive the motors.

Toggle Switch Control - Due to Teresa's familiarity with a particular stick, it was necessary to provide control with which the stick's extended reach could be utilized. Three position toggle switches were decided upon. In the positive toggled position, the table top will move along a given axis in the positive direction. In the negative toggled position, the reverse is true, and should the switch be toggled to the center, it will render that axis of motion inactive until such time that it is need again. Three switches are provided, one for each axis of motion.

Final cost of the project is approximately $500.