CHAPTER 9
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CRAWLER TO ASSIST A CHILD WITH DISABILITIES

Designer: Patrick S. Allen
Client: The Tammy Lynn Center, Raleigh, NC
Supervising Professors: Drs. R. P. Rohrbach and P. L. Mente
Department of Biological and Agricultural Engineering
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Raleigh, NC 27695

INTRODUCTION

For this project, a crawler was designed to assist children who are unable to crawl independently. The frame is rectangular and has an attached sling to support the child. Swiveling castors are attached to the frame, enabling the device to move in multiple directions. Each of the castors has a brake that allows the device to be immobilized. The sling is constructed of nylon and climbing webbing, and it is attached to the frame via climbing webbing and climbing buckles. The buckles are used to adjust the sling. The crawler was designed for use in a therapeutic setting under close supervision.

SUMMARY OF IMPACT

Some children are unable to support their own weight and cannot correctly position themselves to make walking and crawling possible. The device designed for this project will enable them to begin to learn to crawl by eliminating the need to support their own weight. This crawler (see Figure 9.1) makes it possible for a therapist to assist a child in learning to crawl. The crawler allows the child to be correctly positioned so that he or she can move about without having to support his or her own weight. As the child becomes more proficient at crawling, the therapist can increase the amount of weight the child must support by adjusting the sling. This allows the child to progress toward independent crawling.

TECHNICAL DESCRIPTION

The crawler was designed for use in a therapeutic setting where an adult closely supervises the child. The main design requirements were that the project: 1) enable a child with disabilities to crawl; 2) allow the child to move in all directions; 3) not cause any discomfort for the child or therapist; 4) be able to vary the supported weight; 5) be sturdy and durable; and 6) have a brake that will prevent the crawler from moving when this brake is set.

Each component of this project is constructed from 6061 T6 aluminum. This was done to reduce the weight of the crawler while maintaining structural integrity. The frame is composed of aluminum tubing with an outer diameter of ¾-inch. The inner diameter of this tubing is 0.568 inches. The two pieces of tubing connecting the opposite frame pieces together are composed of the same material. The cross members welded onto the top of the frame are built of 2-inch wide and ¼-inch thick aluminum flat. Several ¼-inch diameter holes are drilled into the aluminum flat to provide attachment positions for the support sling.

The sling is constructed of double-layered nylon and another layer of polartec fleece. The fleece is to ensure that the sling is soft and comfortable for the child. The sling is stitched together using heavy-duty cotton thread. Five 2-foot pieces of climbing webbing are stitched into the sling. The opposite ends of the webbing have buckles attached to them so the sling's length can be adjusted. The sling may be removed for washing. A swiveling castor was attached to the frame at the base of each of the four legs. These castors make movement in all directions possible and inhibit motion when the brake is applied.

Several issues warrant more consideration. The strength of the frame is greater than necessary. Increasing the inner diameter of the aluminum tubing may be a feasible option to reduce the weight of the design. Lastly, the implemented castors are made of a hard plastic material. A softer plastic or rubber would be preferable for the castors to further reduce the slipping of the design when the child is using it. The approximate cost of the crawler is $300.

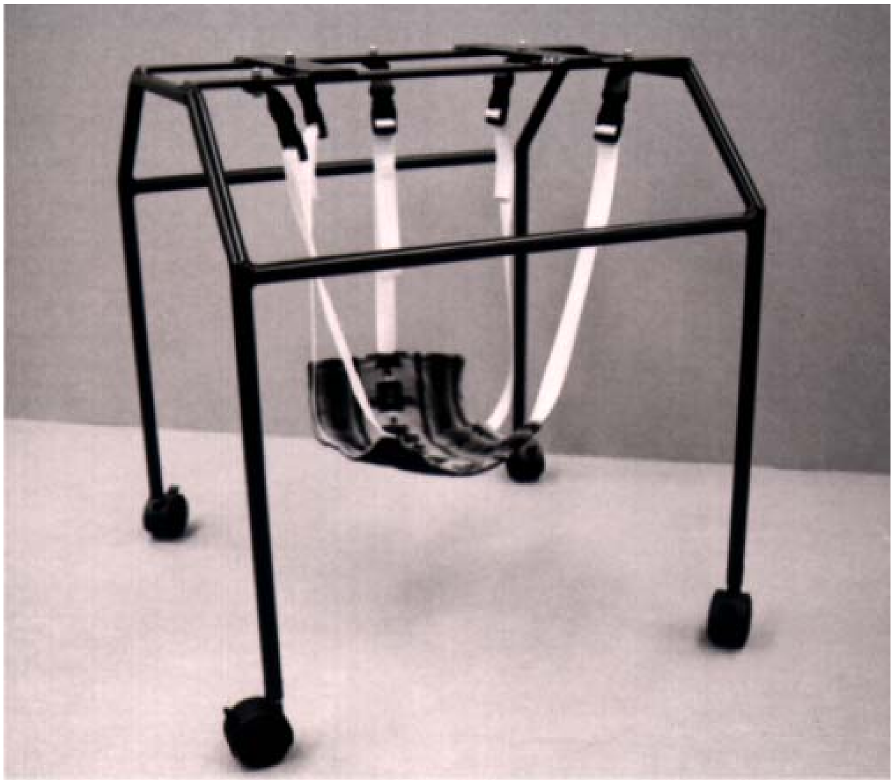

Figure 9.1. Device for Helping Children Learn to Crawl.

FOOT POWERED MECHANISM FOR PADDLING A CANOE

Designer: Kevin R. Johnson
Client: NC 4-H Youth Development
Supervising Professors: Drs. P. L. Mente and R. P. Rohrbach
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INTRODUCTION

A foot-powered mechanism for paddling a canoe was developed for children with disabilities. The mechanism (see Fig. 9.2) consists of the following three main components: an axle with an attached pedal, a U-shaped paddle arm, and a right angle gear box that connects the axle and paddle arm. The unit mounts on the inside of the canoe with braces attached by bolts. These bolts run through the sides of the canoe. Force from the child's foot on the pedal causes the paddle arm to sweep in an arc toward the back of the canoe. A spring pulls the pedal and paddle back to their original positions. During this process, a hinge folds the paddle back to decrease water resistance. This device was designed for use in a specific make and model of canoe used by the 4-H camps but could be used on other models depending on their dimensions.

SUMMARY OF IMPACT

Children with disabilities are sometimes not included in activities requiring physical involvement. For example, children with a disability of the upper body may find it difficult to paddle a canoe. This disability could be as temporary as a broken arm or as permanent as a degenerative muscular condition. If a child can participate in paddling the canoe rather watching others paddle, self-esteem will improve because the child will feel included in the activity. This mechanism allows participation in the paddling of a canoe by someone who cannot use his or her arms to paddle by the conventional method.

TECHNICAL DESCRIPTION

There design was required to: 1) provide a feeling of participation, but not necessarily contribute substantially to propulsion; 2) be removable so it could be taken off the canoe and stored when not in use; 3) be light, so that it does not hinder the movement of the canoe; 4) be durable in a wet environment; and 5) be safe for children to use.

The major components of this machine (See Fig. 9.2) are made entirely of aluminum to avoid any corrosion problems due to water contact. The axle and paddle arm are constructed of aluminum tubing with an inner diameter of 1″ and an outer diameter of 1-1/8″. The two braces, pedals and pedal links are all made from a ¼″ thick aluminum plate. Nyliner bearings, 1-1/8″ inner diameter, are used to decrease friction during the rotation of the axle and paddle arm. A canoe paddle, cut off 10″ above the blade on the aluminum shaft, is attached to the paddle arm using a universal joint. This joint is made of steel with a black oxide finish. It is pinned to the shaft of the paddle on one end and the paddle arm on the other. A piece of 1-1/8″ inner diameter tubing is welded to the back of the paddle arm to restrict joint movement in the forward and lateral directions.

The paddle arm is 18″ long and extends down at a right angle for a distance of 8″ and connects to a right angle gearbox. The other side has a 4″ piece at a right angle to pin to the universal joint. The right brace is 12″ long, 2 ½″ wide, and has a bracket that is 2 ¼″ deep. This brace supports the axle and attaches the mechanism to the right side of the canoe. The left brace has similar dimensions, but also adds a 4″ by 3 ¾″ mount for the right angle gearbox and two supports for the paddle arm as it rises from the gearbox. The use of an enclosed gearbox eliminates the safety risk of having open gears exposing pinch points. The pedal is 4″ wide and 6″ long and is held 8″ from the axle. This was done to increase the mechanical efficiency of the pedal.

Force applied to the pedal causes the axle to rotate forward. This rotates the paddle arm in a counterclockwise direction from the front of the canoe to the rear. A spring is attached between the pedal and an eyebolt on the right brace. When the pedal is depressed, the spring is extended. The spring contracts as force is removed from the pedal, and the paddle is pulled back to its original position. During the return stroke of the paddle, the paddle hinges at the universal joint and can be pulled forward at an angle of up to 80° to reduce water resistance.

The final cost of this paddling mechanism is approximately $250.

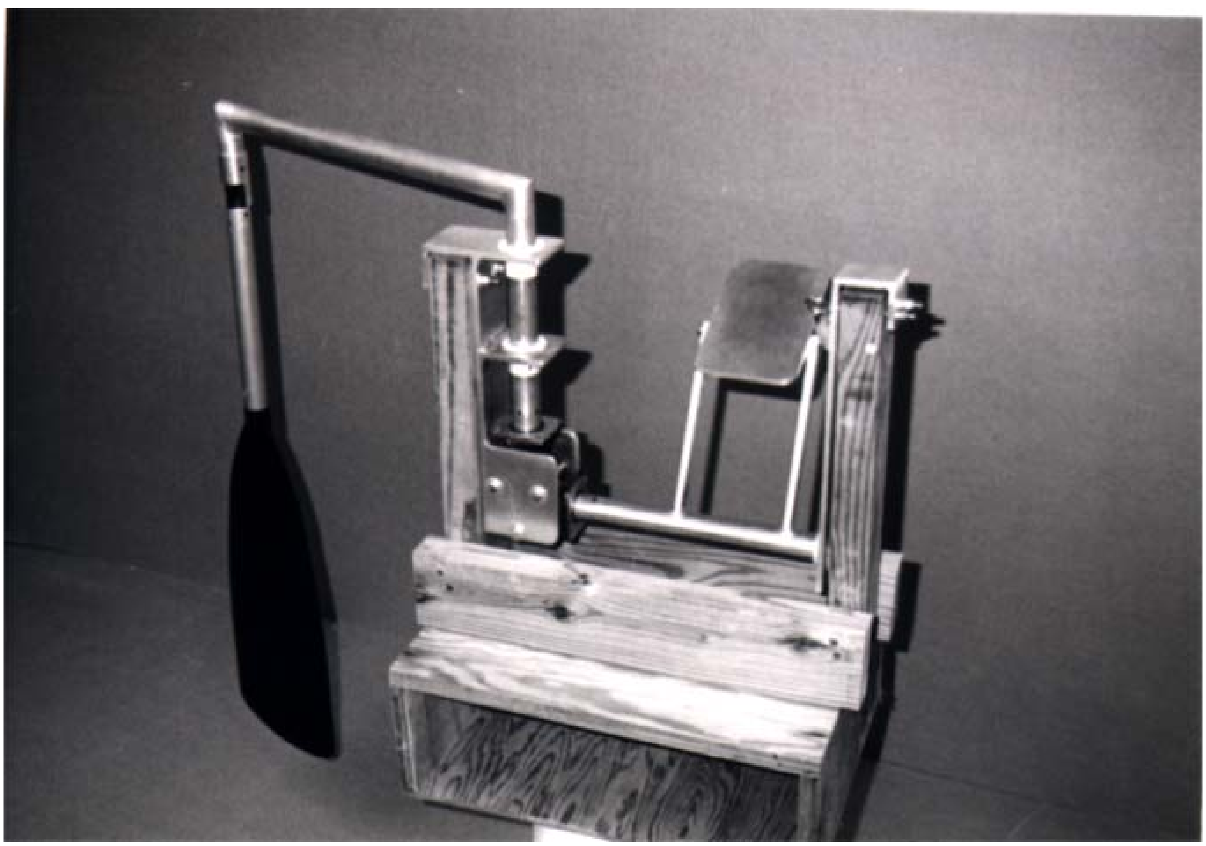

Figure 9.2. Canoe Paddling Mechanism in Wooden Frame.

LOWER EXTREMITY SENSORY PROSTHETIC

Designer: Keith R. Martin
Client Coordinator: David Patridge, CP
Raleigh Prosthetic and Orthotic Clinic
Supervising Professor: Dr. P. L. Mente
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INTRODUCTION

A lower extremity prosthetic for a person with an amputation below the knee has been designed to provide sensory information to the wearer. Force sensors embedded in the foot of the prosthesis provide a signal to electro-mechanical actuators (vibrating motors) that are molded into the socket of the prosthetic. These actuators vibrate in response to the sensors, providing stimulation to the residual limb. This stimulation is in proportion to the force encountered by the sensors, allowing the wearer to sense the amount of force encountered by the foot. The signal is further monitored and adjusted through feedback to ensure proper function. The added sensory information improves mobility, balance, and proprioception.

SUMMARY OF IMPACT

Currently, lower extremity prostheses offer no provisions to aid users in overcoming adaptation issues with regard to mobility. Many people who wear lower extremity prostheses have difficulty maintaining balance on uneven ground, walking up and down stairs, and detecting obstacles with their feet. These problems present additional and unnecessary challenges to overcome and can have a large effect on quality of life.

The overall objective of this project was to directly address these issues, develop a solution through engineering design, and evaluate the appropriateness of this solution. This was achieved by close interaction with a person who has had an amputation, assistance from a certified prosthetician (CP), and guidance from engineering consultants.

TECHNICAL DESCRIPTION

Anthropometric data from one specific person was used to design the prosthetic. This could be done for other people as well. The main design requirements were that the device: 1) provide lower extremity sensory feedback to the wearer; 2) be lightweight and practical; 3) be durable and comfortable for extended use; 4) be watertight to prevent electrical shock to the wearer; 5) have sensors to detect weight increments of 1/4 lb in order to distinguish between the different magnitudes of forces encountered; and 6) have sensors positioned at pressure locations of the gait cycle to aid in mobility. In addition, the sum of electrical components must weigh no more than 1-1/4 lb to prevent a pendulum effect, the added swing of a prosthetic leg caused by excess weight.

The sensor array is located in the foot of the prosthesis, which is embedded in the shoe. In-line connectors allow removal of the shoe, if necessary, and tuck out into the shoe itself for discretion. Three sensors each detect forces ranging from 0-100 lbs. These sensors are positioned at pressure locations for the heel-strike, mid-stance, and toe-off stages of the gait cycle. Their corresponding actuators are aligned vertically against the residual limb. They are in close enough proximity to one another to allow the wearer to feel the weight transfer from sensor to sensor while walking. Each sensor-actuator pair is able to operate independently.

Five sensors, operating in the 0-25 lb range, are located along the outer edges of the shoe to allow detection of obstacles against the foot. Their corresponding actuators are placed against the residual limb in a way that provides position correlation with little learning. Therefore, the wearer can relate a position on the calf with an equivalent position on the foot, respecting lateral, medial, anterior, and posterior relations.

The control circuit (Figure 9.3) consists of eight operational amplifiers. Each of these amplifiers has a negative feedback loop and offset compensation, a voltage regulator, eight actuator drivers, and collective hysteresis comparators. These are all built onto a single circuit board mounted inside the structural frame and hermetically sealed. A replaceable 9-volt power supply and main control switch are accessible to the wearer. Offset compensation allows each sensor to be adjusted to provide a zero-stimulation base point to remove any forces created by mounting. The operational amplifiers provide initial signal conditioning, and the actuator drivers and hysteresis comparators initiate function. The latter are integrated into a series of two IC chips. If the current provided to the second chip rises too quickly or to high, separate hysteresis loops provide feedback information to the first chip. This in turn cycles the chips on and off at 20 Hz until normal operation is restored. This prevents actuator stall and overload, reduces the risk of heating and failure, and ensures a proportional response from the actuators to the sensor input.

Operational tests were performed in which known incremental forces were applied to the sensors and the current at the actuators was measured in response. It was concluded that the device functions as intended and is adequate for use. Final sensor and actuator placement were done according to wearer preference and required no further adjustment.

The total cost for the project, excluding donated items, is approximately $260. An estimated cost including donations is $1800.

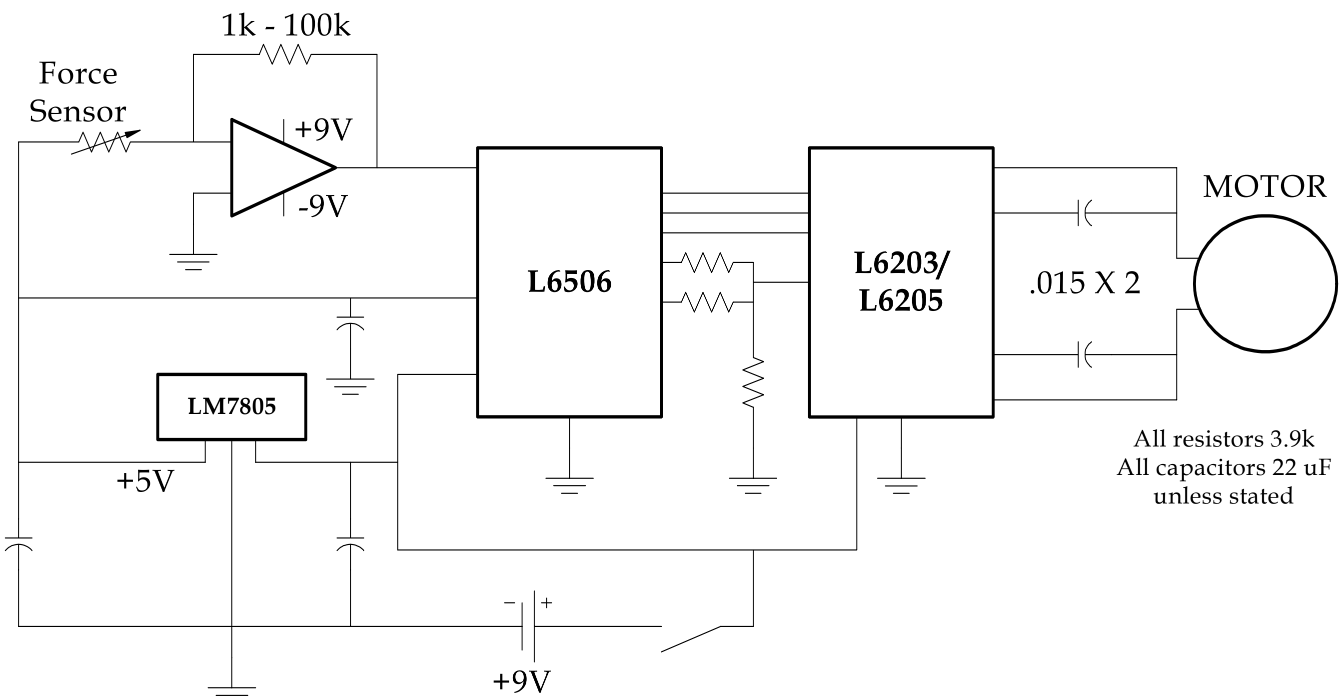

Figure 9.3. Circuit Schematic.

GO-CART FOR A CHILD WITH SPINA BIFIDA

Designer: John R. (Obie) Sullivan
Supervising Professor: Dr. G. R. Baughman
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INTRODUCTION

This go-cart (Figure 9.4) was designed and manufactured for a three-year old child. The child has a wheelchair, but he cannot keep up with his brothers when they go outside to play. The go-cart is built from an existing go-cart frame, but the frame was reduced to fit the child. Two 12-volt batteries power the go-cart by an electric motor obtained from a modified scooter. The motor has an electric mechanical brake. A switch that activates the brake is mounted on the handlebars. The motor is connected to the wheels by a chain and sprockets. The go-cart travels at a top speed of 11 mph and weighs 158 pounds. The device is equipped with both forward and reverse. Handlebars for steering and a thumb-throttle for speed control the go-cart. A small lever that is pushed by the child's thumb adjusts the speed. The lever propels the go-cart forward when it is pushed forward and backward when it is pushed backward.

SUMMARY OF IMPACT

This go-cart allows the child to become more independent and play with his brothers. The go-cart can be easily loaded into a pickup truck or van. This child can now participate in outdoor activities with his family. The go-cart is electric and can be used indoors if enough space is available.

TECHNICAL DESCRIPTION

The go-cart was built from an existing go-cart frame. The frame was shortened in width and length, 3 feet by 4 feet, to better fit the child. It was also designed with a smaller width, so it can fit through a standard doorway. Two 12-volt batteries were connected in a series to produce a total of 24 volts to power the electric motor. The motor was connected to the wheels by number 40 chain and sprockets. The sprockets were sized in order to produce a top speed of 11 mph. The drive sprocket is 8 inches, and the follower sprocket is 4.5 inches.

Figure 9.4. Modified Go-Cart.

The motor has an electrically operated mechanical brake. There is a spring that pulls the brake pad against the internal motor surface. When electricity is provided to the brake circuit, the brake releases. The brake circuit is energized through the main power supply to the motor. When the go-cart is turned on, the brake automatically releases. A push button switch is used to operate the brake. When the switch is pushed, the electric circuit is broken, and the brake is initialized.

The go-cart is equipped with both forward and reverse capabilities. Handlebars for steering and a thumb throttle for speed control the go-cart (see Figure 9.5). A small lever connected to a potentiometer controls the voltage to the motor. The throttle assembly has a mechanical barrier to maintain the go-cart at slow speeds while the child is young. As he gets older, this barrier can be adjusted in order to allow faster speeds.

A 155-pound student tested the go-cart. The performance of the device satisfied all design objectives and specifications. The go-cart was then given to the child who will be using it for more testing. It was initially too fast, so the speed was adjusted. At first the child did not know how to drive the go-cart. After some initial instruction, he learned the basics within the first hour. He did not understand how to avoid obstacles. He ran into curbs and other rigid objects. As he grows older, he will learn to avoid these obstacles. Driving the go-cart is an enjoyable activity for him.

The cost of the go-cart, excluding donations, was $559. The final cost of the go-cart, including donations was approximately $2,000.

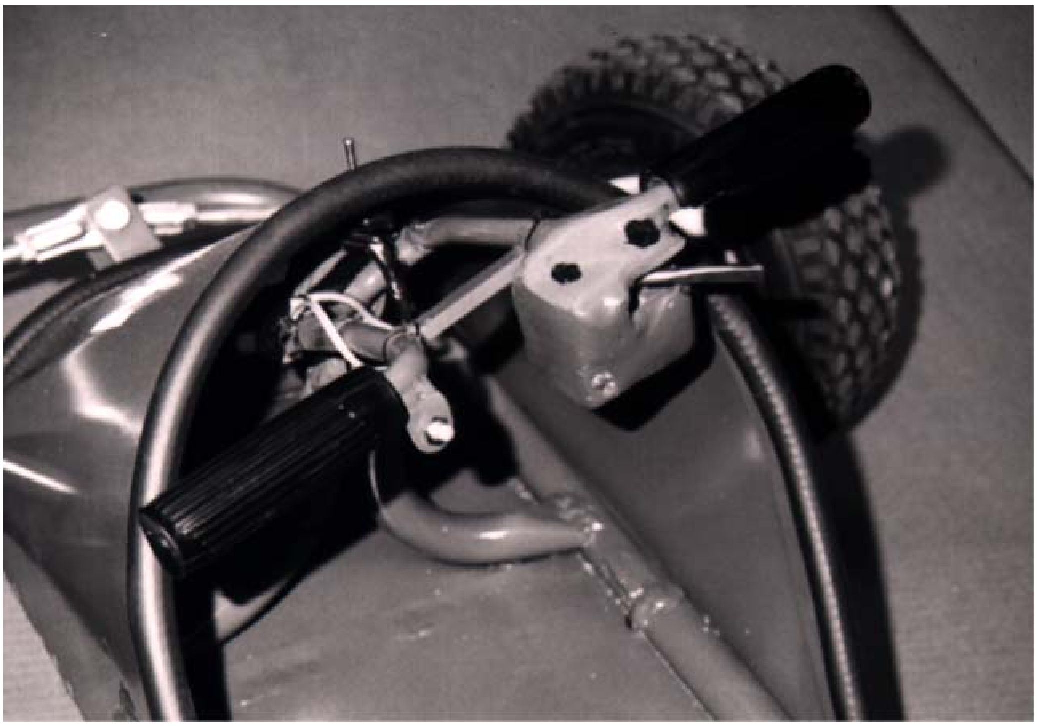

Figure 9.5. Thumb Throttle and Handlebars for Modified Go-Cart.

FLOOR CHAIR FOR CHILDREN WITH REDUCED MUSCLE CONTROL

Designers: Niki Wynne and Amanda Kirby
Client Coordinators: Stacy Crowder, PT
The Tammy Lynn Center for Developmental Disabilities
Supervising Professors: Drs. C. M. Sommerich and R. P. Rohrbach
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INTRODUCTION

A floor chair (Figure 9.6) was designed for children with poor muscle control due to physical disabilities. The chair consists of a basic frame, tray, headrest, harness, and seatbelt. The chair frame includes an upholstered seat bottom, a backrest, a piece to prevent tipping, armrests, and poles to support the backrest and armrests. The device is portable, as the entire chair weighs less that 50 lb.

SUMMARY OF IMPACT

Many children with physical disabilities are not able to sit upright on the floor for therapy sessions. This is true of the children for which this device was designed. Their therapists must hold the children in their laps and use a mirror to view the children's reactions to various objects placed in front of them. This is difficult for the therapists because they have no free hands to work with the children. Therefore, a floor chair was designed to fully support the children and enable them to sit on the floor by themselves.

TECHNICAL DESCRIPTION

The floor chair was designed with a particular child in mind, but it could also be beneficial for other students. The main design objectives were that the chair: 1) allow a child with disabilities to sit upright on the floor alone; 2) not tip over when a small child leans back; 3) give the child access to the floor; 4) the be constructed from materials that are easily cleaned and disinfected; 5) be lightweight and portable; 6) be sturdy and safe; 7) have armrests that accommodate all children who will be using the chair; 8) have a headrest that is adjustable and easy to use; 9) have restraints and supports that are comfortable for small children; and 10) have a removable tray that is lightweight and capable of clipping to the armrests without slipping. In addition, the chair must support the weight of a 50-lb child.

The design of the chair is similar to a stadium or booster seat, and the restraints must also accommodate a 50-lb child. The armrests and headrest must accommodate a child of a minimum of 3 feet and a maximum of 4 feet in height.

Dimensions and data from the children who would be using the device were taken and evaluated. It was decided that adjustable armrests were unnecessary because all the children were close to the same size. The width and height of the chair was also determined from the dimensions of the children. It was determined with assistance from the children's therapists that the optimum angle of inclination for the chair was 110°. A tip-over analysis was also conducted on the chair by determining the maximum possible force placed on the back of the chair and changing the moment arm. The maximum force was determined by anthropomorphic data. Without the back piece, the chair would tip at 10.55 lb, and it would tip at 31.65 lb with the back piece in place. The maximum possible force is 28.9 lb. The braces used to attach the back piece to the chair also help prevent tipping. A stress analysis was conducted to ensure the straps would not fail when the maximum load of the upper body weight was applied. The stress applied is 231.2 psi, and the ultimate stress for nylon is 6000 psi.

Several different students were placed in the chair under the supervision of the therapists and instructed to perform various tasks while in the chair. The chair exceeded expectations.

The estimated cost for labor and materials is approximately $200. Professional upholstery added an additional cost of $65. The headrest and harness were donated.

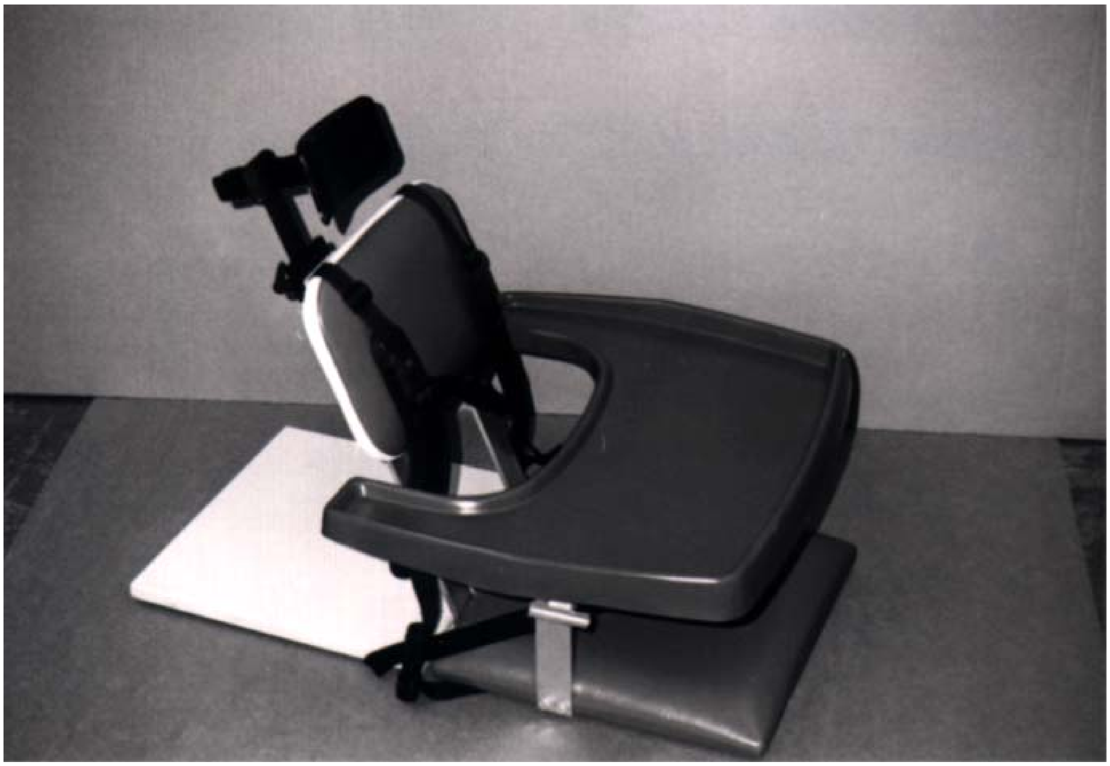

Figure 9.6. Floor Chair with Tray Attached.

MODIFICATION OF A POWER WHEEL TO MAKE FOR JOYSTICK CONTROL

Designer: Justin Carinci
Client Coordinator: Monica Cook, PT
Charlie Gaddy Center
Supervising Professor: Dr. S. A. Hale
Department of Biological and Agricultural Engineering
North Carolina State University
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INTRODUCTION

A device was designed to teach fundamental joystick skills to children who will someday use an electric wheelchair. The device consists of a modified Power Wheel (See Figure 9.7). A Power Wheel is a miniature vehicle that mimics a real car. It is powered by two rear motors and is controlled by a mechanical steering system. The mechanical steering column was removed and replaced by a linear actuator. The actuator was mounted underneath the Power Wheel and connected to the front axle. The system is wired with a joystick as the primary control.

SUMMARY OF IMPACT

This device was designed to provide an enjoyable way to teach joystick skills to children. In the eyes of a child, a Power Wheel is more appealing than a chair with wheels. Children are provided with a learning tool that is fun. This experience will then provide them with the skills necessary for operating an electric wheelchair.

TECHNICAL DESCRIPTION

A linear actuator and a joystick are the two main components that provide the Power Wheel with electrical steering. The linear actuator was mounted underneath the Power Wheel approximately 4.6'' in front of the front axle. Since the Power Wheel is made of plastic, sheet metal was used to increase the mounting strength. Wood was also used to provide further stability. The actuator connects to the front axle by a bolt. The joystick selected to operate the Power Wheel was the NES Advantage. It operates by a series of switches.

Figure 9.7. Modified Power Wheel.

There are four switches located in the joystick, each representing a direction (up, down, left, and right). Current is released when the joystick is moved in any of these directions, and motion occurs in the corresponding direction.

Figure 9.8 shows the wiring schematic that integrates all the components. The pair of switches and a square box containing magnet coils is a simplified representation of a relay. The joystick emits a small current that enters the relay. This amplifies the signal and activates a magnetic field that attracts the spring-loaded armature. Once the armature is closed, the current from the power source reaches the motors and either turns them on or off.

An analysis was performed on the bolt connecting the actuator to the front axle to determine the proper bolt diameter.

The ultimate stress of steel is 50 kip. The length of the moment arm connecting the linear actuator to the front axle is 4.6′′. The maximum amount of force exerted by the linear actuator is 250 lbs. The maximum moment applied was 1150 lb-in. Using these values, the diameter was determined to be approximately 5/8′′ diameter.

The final cost of the modified Power Wheel was approximately $530.

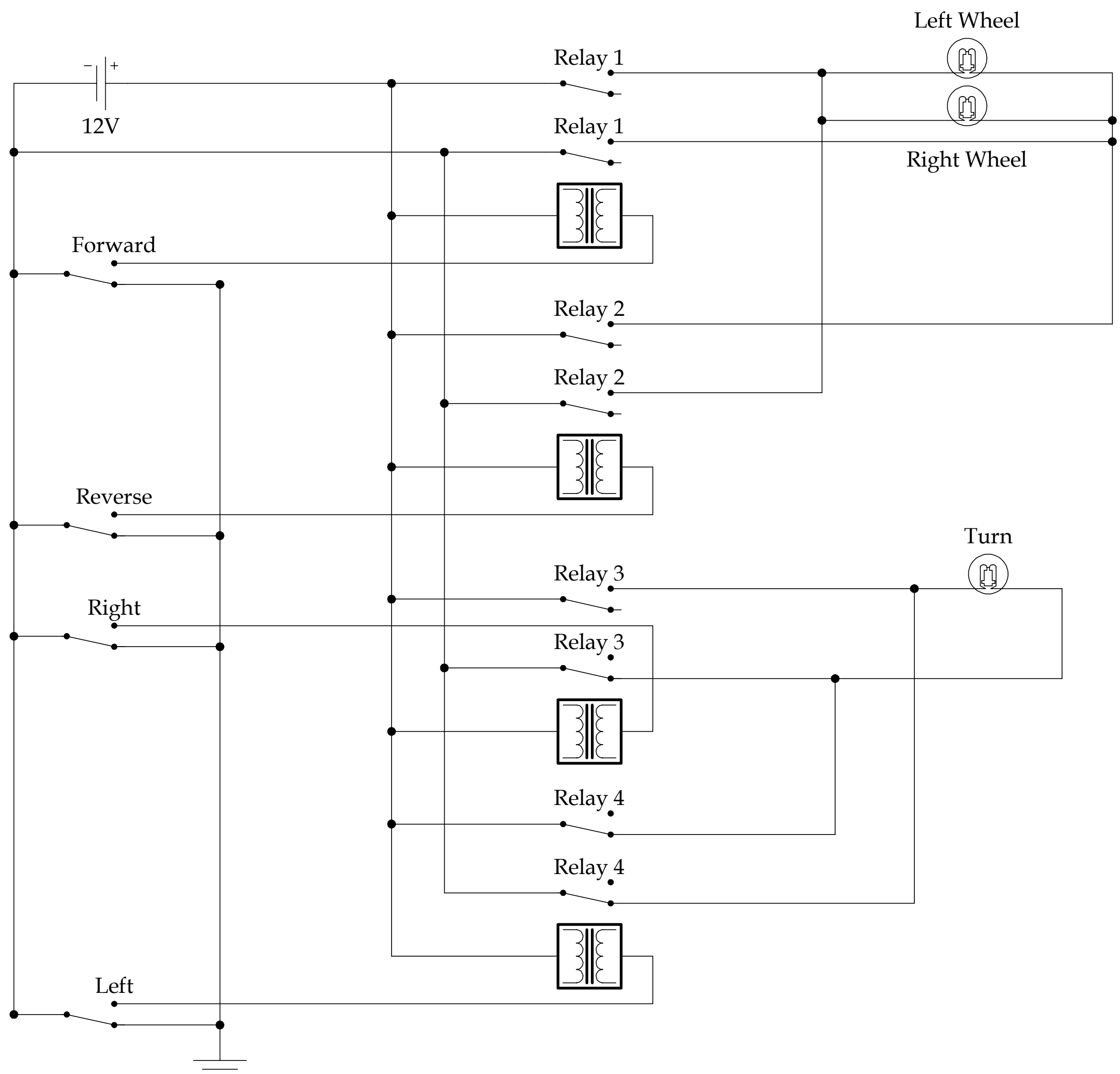

Figure 9.8. Circuit Schematic.

SWITCH CONTROLLED MOTORIZED FISHING POLE

Designer: Jeffrey Jones
Client Coordinator: Client's mother
Supervising Professor: Dr. R. P. Rohrbach
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INTRODUCTION

Many children who have cerebral palsy cannot go fishing because they are unable to coordinate the fine muscle movements this activity requires. The fishing industry has a narrow selection of rods and reels for people with disabilities. These rods and reels usually incorporate a switch-activated motorized mechanism to reel in the fishing line. However, most of these devices are tailored for people who have at least one fully functional hand. There is a need for a mechanism to drop and reel in the line of a fishing pole for a people who have cerebral palsy.

The device developed in this project (see Figure 9.9) is intended for a person who lacks skilled control of either hand. Some of the components of this prototype are an electric screwdriver, right angle gears and push buttons. The overall design is meant to create a safe and appealing product that allows people with disabilities to enjoy fishing.

SUMMARY OF IMPACT

This fishing pole design will allow a seven-year-old child who has cerebral palsy to participate in a new activity and gain independence.

Unplugging the pushbuttons allows the fishing pole to be easily carried separately along with the frame and pushbuttons. The child can handle the pushbuttons without having to worry about the rod or reel. The rod can sit inside a rod holder or be held by another person, and the reel and motor assembly sit on the ground. This setup creates the best scenario for the child to catch fish because he only needs to operate the pushbuttons.

TECHNICAL DESCRIPTION

A permanent adaptation was used to adapt the screwdriver for use by large switches. The original toggle switch on the screwdriver was rewired. Leads from the toggle switch were soldered to one-eighth- inch input jacks. The screwdriver is controlled using two double pole single throw switches. Any double pole single throw switch that is compatible with the input jack may be used to operate the screwdriver. The pushbutton switches were inserted into the jacks to activate the motor. In addition, the switches reel when they are held down.

The overall design was laid out on Pro-ENGINEER. Two right angle miter gears were used to connect the motor action of the screwdriver with the reel. The right angle gears meet at a brass bearing that stabilizes the gears in space. The reel system was directly attached to a miter gear by a component similar to a power nut driver used with drills. The other miter gear was attached to the torque action of the screwdriver through a hex chuck component. The screwdriver and reel were both mounted to a piece of steel, which serves as the base.

A site test was performed to evaluate the performance of the prototype. Two fish were successfully caught.

The total cost was approximately $250.

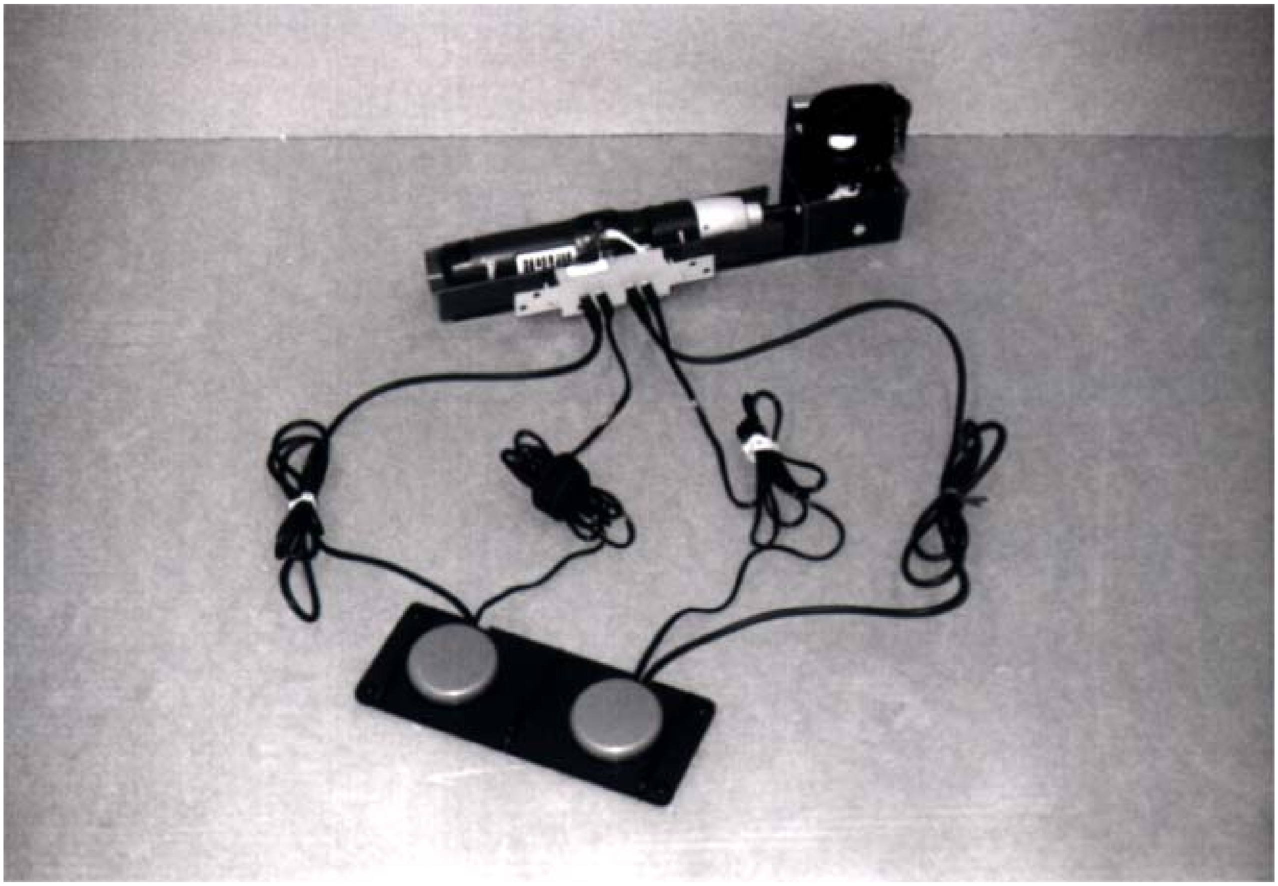

Figure 9.9. Switch Controlled Motorized Reel.

BICYCLE FOR A CHILD WITH SMITH-MAGENIS SYNDROME

Designer: Tong-Ying Wu
Client Coordinators: Kat King
Community Partnerships
Supervising Professors: Drs. R.P. Rohrbach, C.G. Bowers, S.M. Blanchard
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INTRODUCTION

Smith-Magenis Syndrome (SMS) is a chromosomal disorder characterized by a specific pattern of physical, behavioral and developmental features. Possible characteristics associated with SMS include developmental delay, learning disability, mental retardation, and low muscle tone. This special bicycle (Figure 9.10) was designed for a girl with SMS. The goal of this bicycle was to increase this child's muscle strength. The bicycle consists of the following main parts: two standard adult bicycles, a seat, and a pedaling mechanism. The two adult bicycles are linked together with the additional seat placed in the middle. All three sets of pedals are linked by bicycle chains to a common shaft.

SUMMARY OF IMPACT

This project can be used as a device to help people with minor disabilities gain leg strength. In the case of this 10-year-old girl, the project was aimed to enable her to ride a bicycle. This will provide her opportunities for more outdoor activities with her family.

TECHNICAL DESCRIPTION

One of the major concerns this project was the safety of the child during operation. After considering the girl's ability to ride a bicycle, it was decided that her parents should control the steering mechanism and that the bicycle can only be operated in low speeds.

The linkages between the two bicycles are constructed from standard black pipe, ASTM A-120 and Schedule 40. There are three locations for connecting the two bicycles: 1) front and upper sections of the bicycle frame, 2) rear and lower sections of the bicycle frame, and 3) the tube under the bicycle seats. The front linkage is achieved by using U-bolts and 1" pipe. Both of the linkages located at the rear and underneath the seat use 3/4" pipe. The frame for the additional seat has two parts. These parts are the frame itself and the seat. The frame is incorporated within the rear linkage and connected to the front linkage via U-bolts and 3/4" pipes. It is made of a 3/4" pipe and two 1/2" pipes welded in an "II" shape. The pedaling device is located in the front of the frame. The seat is made of 1/2" pipes and 3/4" wood boards and is tilted backward 25 degrees for comfort. The seat belts are incorporated within the seat.

The total cost for this special bicycle was $750.

Figure 9.10. Bicycle for Child with Smith-Magenis Syndrome.