CHAPTER 14
STATE UNIVERSITY OF NEW YORK AT STONY BROOK

School of Engineering and Applied Sciences
Department of Mechanical Engineering
113 Light Engineering Building
Stony Brook, New York 11794-2300

Principal Investigators:

Yu Zhou

(631) 632-8322

yuzhou@notes.cc.sunysb.edu

Qiaode Jeffrey Ge

(631) 632-8305

Qiaode.Ge@stonybrook.edu

Lisa M. Muratori

(631) 444-6583

Lisa.Muratori@stonybrook.edu

T.R.E.A.T. (THERAPEUTIC AND RECREATIONAL ELECTRO-ASSISTED TRICYCLE)

Designers: Mehdi Iratni, Matthew Otto and Baljit Singh
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

A rehabilitative tricycle was designed and constructed to promote rehabilitation and mobility for individuals with debilitated lower-body strength. Through a multi-mode system, the rider has the option to pedal the tricycle, drive it solely on electric power, or use assistive pedaling to reduce manual effort. This tricycle also incorporates an advanced therapy mode that further promotes physical improvement, by providing increasing pedaling resistance for lower-body muscle strengthening. While there are many electric tricycles on the market, none accommodates the rehabilitation of individuals with an impaired lower-body. Our tricycle helps these people recuperate and rebuild strength.

SUMMARY OF IMPACT

Mobility and physical activity can be challenging for people with impaired lower-body strength. Currently, most apparatuses that facilitate mobility result in a further decrease of the user's strength and fitness. For instance, electronic wheelchairs provide a means of mobility, but they tend to reduce the user's physical activities. While wheelchairs may be the only solution for certain disabilities, they can be disadvantageous to those individuals that retain some portion of their lower-body strength. On the other hand, rehabilitative devices that increase the user's overall fitness tend to be constrained to a fixed location. Our design of the rehabilitative tricycle combines these two concepts and provides an accommodating solution for the aforementioned individuals. It can have a great impact on the lives of these individuals, by offering them both short-term and long-term solutions - mobility and rehabilitation.

TECHNICAL DESCRIPTION

The overall system works partly like a standard tricycle. In this respect, the user may use leg power to rotate the pedals, which in turn, propels the tricycle. When the user's leg power is not sufficient to propel the tricycle, a DC motor, connected to the back axle through a chain-sprocket system, turns on and aids the rider in reaching a desired speed. This motor is mounted in an enclosure, which is in the place of a standard tricycle's rear cargo basket. In this dual-function mode, the motor either solely powers the tricycle or complements the user input.

Fig. 14.1. Prototype of T.R.E.A.T.

Fig. 14.2. Chain and Sprocket System.

The other mode of this system is the advanced therapy mode. In this mode, the motor functions as a generator. The user can vary the inherent resistance of the generator by altering the position of a throttle. This produces a resistance that varies with respect to the actual magnitude of regenerative braking. The power that the user inputs is captured and charges a battery which powers the motor and electrical components in various modes.

To accomplish the proposed functions, the mechanical system of the rehabilitative tricycle was designed and fabricated by customizing a Schwinn Meridian Tricycle. An Arduino Uno microcontroller was used as the central controller to receive input from components, including thumb throttle, brake levers and switches, run the control flow, and command the motor through the motor controller.

The cost of the parts and supplies for this project was $1275.

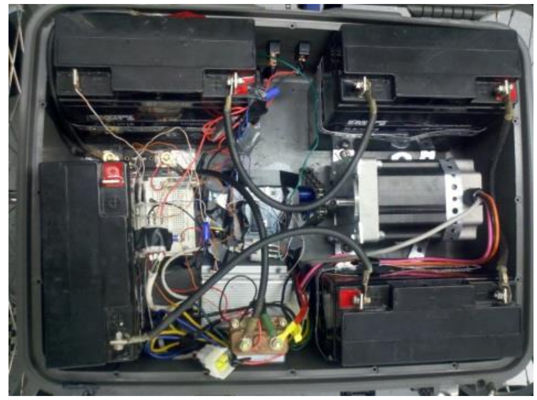

Fig. 14.3. Control System in Rear Enclosure.

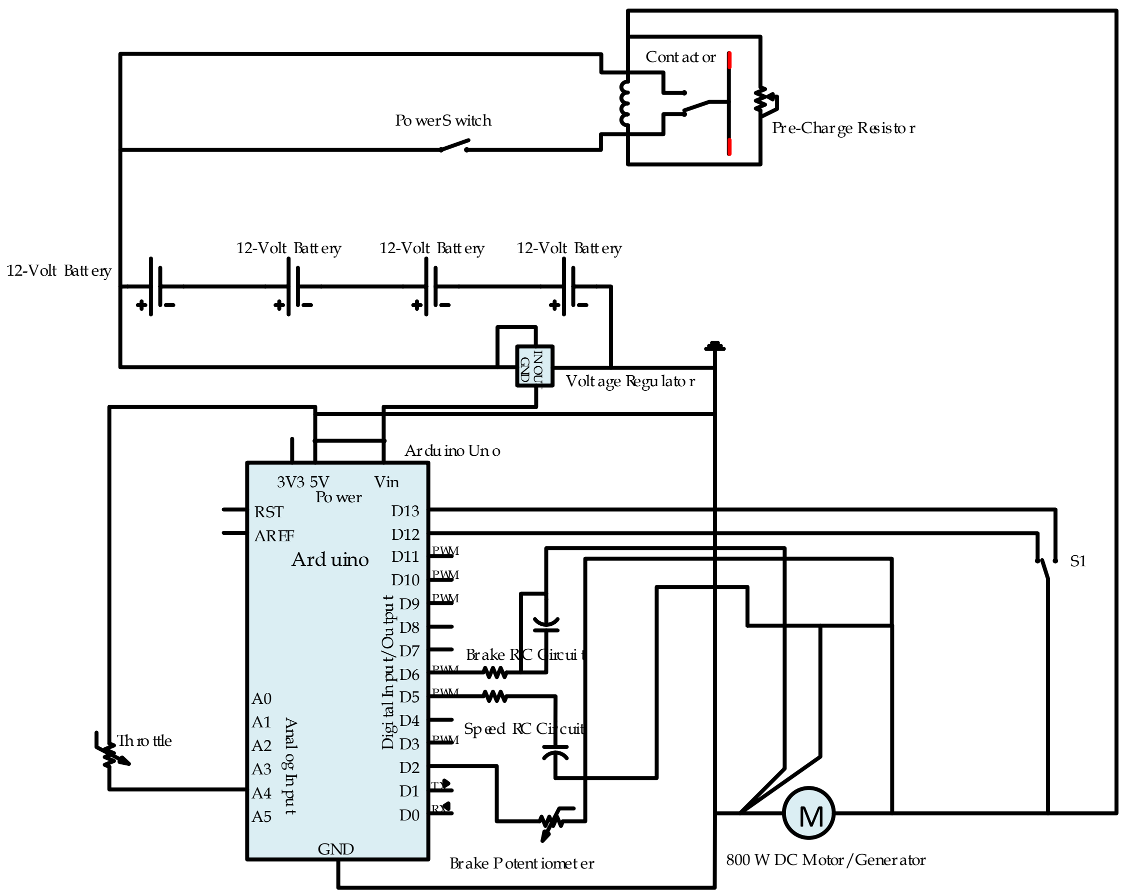

Fig. 14.4. Control Circuit.

ANKLE EXOSKELETON

Designers: Teng Lin, Ka Wing Ng and Ying Ying Cui
Supervising Faculty Professor: Dr. Lei Zuo and Dr. Yu Zhou
Department of mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

An ankle exoskeleton was designed to help people who lose their walking ability, due to ankle weakness, to regain walking ability. Statistics show that 1.7 million people in U.S. (about 0.57% of the 3 billion total population) are suffering from weakness in their lower extremities and cannot lift their feet to walk. This motivated the design of the ankle exoskeleton. In operation, the designed ankle exoskeleton is attached to the leg and foot of the user, and generates force to support the foot and assist the walking action, according to the Electromyography (EMG) signal from the lower limb muscles.

SUMMARY OF IMPACT

The prototyped ankle exoskeleton succeeded in generating motion and force outputs to assist walking according to the user's intention recognized from the EMG signal generated by the user's muscles. It provides a conceptual prototype for studying the EMG-based control for walking assistance. It will lead to an effective solution for people with ankle weakness to regain their walking ability.

TECHANICAL DESCRIPTION

This project focused on the design of the mechanical system of the ankle exoskeleton, assuming that the control decisions have been made by EMG signal processing.

The ankle exoskeleton has a stepper motor as the actuator, a flexible shaft as the power transmission, a jointed foot mechanism to achieve the desired motion, and a light weight and long-lasting battery as the power source.

The mechanism is mainly made of 6061 Aluminum. The foot mount and base are made of aluminum plate. The materials were cut to custom fit the user's leg and foot. The mechanism is connected to a stepper motor through a flexible shaft which transmits the torque. Since the leg joints are not stationary when the user walks, a flexible mechanism must be selected to transfer the power. The flexible shaft, along with ball screw and bearings, provide an easy and economical solution. The ball screw is used to reduce weight while reach high energy efficiency, boosting the torque and eliminating the necessity of including a gear train. The bearings are used to make the mechanism move smoothly and reduce energy loss in friction. The stepper motor is controlled by the post-analyzed signals which are initially collected from the user's muscles and then processed by an EMG system to identify the user's intention.

The future work will include reducing the weight and adding more degrees of freedom to the mechanism.

The total cost of the parts and supplies for this project was $900.

Fig. 14.5. Ankle Exoskeleton.

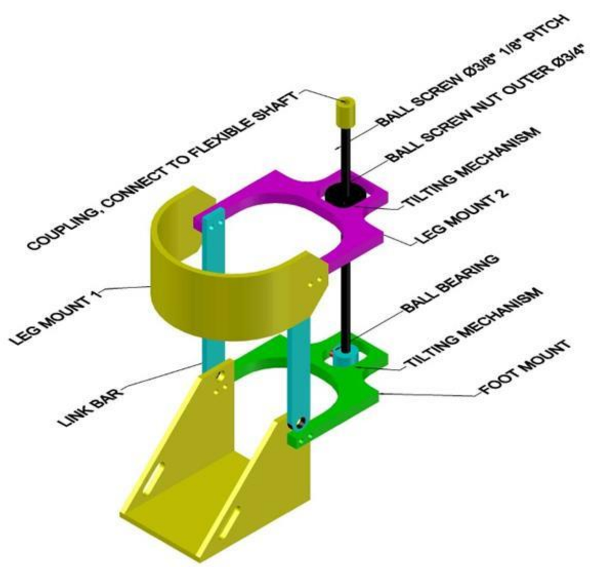

Fig. 14.6. Mechanism Design.

ELEVATING WHEELCHAIR RELOCATOR

Designers: Kevin Chen, Ross Garrett and Cora Walter
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

An elevating wheelchair relocator was developed, designed and manufactured to lift a wheelchair user. Typically this is a process that involves either great upper body strength by the wheelchair user to elevate himself, manual lifting of the individual by assistive care professionals, or the use of sling lifts. We notice that, when the personal upper body strength is not available, assistive care professionals often sustain injuries from lifting wheelchair users, and the use of sling lifts requires excessive time and cumbersome equipment to relocate paraplegic individuals. To design an improved method, we propose to integrate a mechanism into a wheelchair for the user to lift and relocate himself onto a platform. The prototype consists of an offset rotating platform mounted atop a hydraulic lift. Once the platform is positioned atop the elevated surface, the user can manually slide himself on and off the surface with minimal effort. It eliminates the need of a separate machine or other assistance, and the user would have full control over the process.

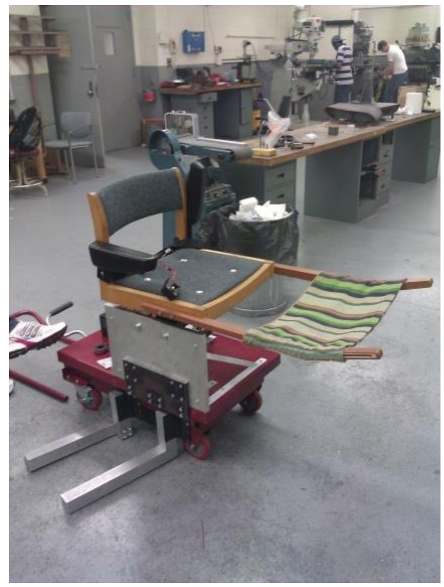

Fig.14. 7. Prototype of Elevating Wheelchair Relocator.

SUMMARY OF IMPACT

By mechanizing and motorizing the process that once would have required intensive physical labor, the elevating wheelchair relocator minimizes the effort of the wheelchair user and mitigates the risk of injury to assistive care professionals. Moreover, the use of a separate and expensive device, such as sling lift, becomes unnecessary, and the time to move onto a platform is largely reduced. Overall, the quality of life of the paraplegic user is improved as he would have more control over getting on and off a raised surface instead of depending upon assistance.

Fig.14. 8. Rotating Mechanism of Elevating Wheelchair Relocator.

TECHNICAL DESCRIPTION

A 660-pound capacity hydraulic scissor lift table was chosen as the base for the project as it provided a sturdy base capable of elevating and was compact enough to fit through standard door sizes. The capacity satisfied the 250-pound lifting weight expectation, with a safety factor included.

Components were attached to the lift table to incorporate the other features of the proposed design. Atop the table, an aluminum plate was vertically mounted using bolts and brackets. Two pillow blocks were bolted onto the plate and a steel shaft was placed within these blocks such that they could guide the shaft's rotation. This shaft sat atop a thrust bearing embedded in a block of aluminum bolted onto the tabletop. Between the two pillow blocks and around the shaft, a large diameter sprocket was located. A chain was wrapped around this sprocket as well as another smaller sprocket mounted onto the output shaft of a DC Leeson right angle motor. This was done to both reduce the speed output and increase the torque output of the motor.

A flat steel plate was welded on top of the shaft, with the shaft positioned along one of the edges of the plate. This was done so that the plate rotation would be offset, allowing for lateral movement of the user atop the plate while the shaft rotated. With a seat mounted on the plate for comfort, flip-up armrests were added for safety and ease of sliding onto an elevated platform. A seatbelt was also utilized to keep the user secure, and elevated leg rests were mounted onto the chair so that the legs would be kept parallel to the floor and away from obstacles during the rotating process.

Base extensions were mounted to the bottom of the lift table to increase the footprint of the device and prevent tipping during operation. A handheld control box was fitted with a DPDT switch with a momentary push button switch so that the user could alternate between the rotating directions. The chair would only rotate if the push button was physically pressed down, as a safety measure.

The cost of the parts and supplies for this project was $1210.

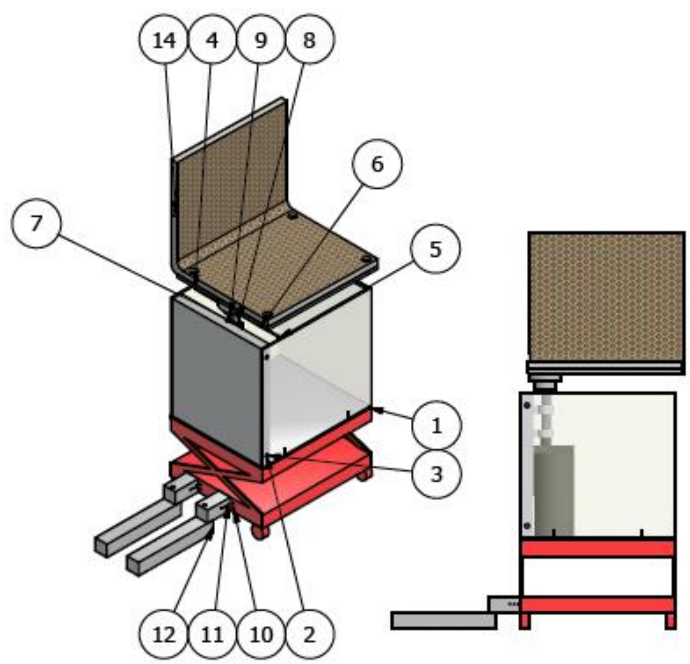

Fig.14.9. Design of Elevating Wheelchair Relocator.

CR WHEELCHAIR

Designers: John Havlicek, Robert Parra and Kirill Shkolnik
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

A special wheelchair was designed to reduce the operational effort of manual wheelchairs. Very few commercial wheelchairs are available for the same purpose, and the available products often aim at an increase in speed rather than a decrease in user's effort. To address this problem, a four-bar linkage and sprocket-chain system was used to provide the user with comfort and reduce the effort.

SUMMARY OF IMPACT

The proposed design of wheelchair provides the user with an increased comfort by allowing the arms to function in a more natural position, and reduces the user effort greatly through the use of a sprocket-chain system and four-bar linkage. This design can easily be expanded to include multiple sprockets and other customizable features to accommodate more needs and provide a more flexible system that could more easily deal with various terrains and user needs.

TECHNICAL DESCRIPTION

A standard hospital-style folding wheelchair was customized to accomplish the proposed functionality, with a consideration of the design and fabrication effort.

To accommodate the linkage and sprocket-chain system, the wheelchair frame was modified and fitted with threaded inserts for shoulder screws to carry the driving handles and sleeves added to the frame to house the shaft and bearing assembly for the crank of the linkage. Furthermore the rear wheels were modified to carry a plate that mounted a large sprocket that would be driven by the linkage.

The linkage was designed to create a natural comfortable arcing motion for the user to move the handles through and furthermore to transfer the motion easily to the sprocket-chain assembly. A Grashof crank-rocker four-bar linkage was selected and designed because of its simplicity and its ease of customization. The sprocket-chain system allows for the wheel and driver sprockets to be freely placed and connected through the chain, and furthermore provides significant mechanical advantage to the user through the transmission ratio of the two sprockets.

Fig.14.10. Prototype of CR Wheelchair.

The system is simply driven by rhythmically pumping the two handles simultaneously, which turns the crank and drives the sprocket-chain system. Turning is achieved by pumping one handle while allowing the other to idle, in much the same manner that one would turn a standard manual wheelchair.

The cost of the parts and supplies for this project was $600.

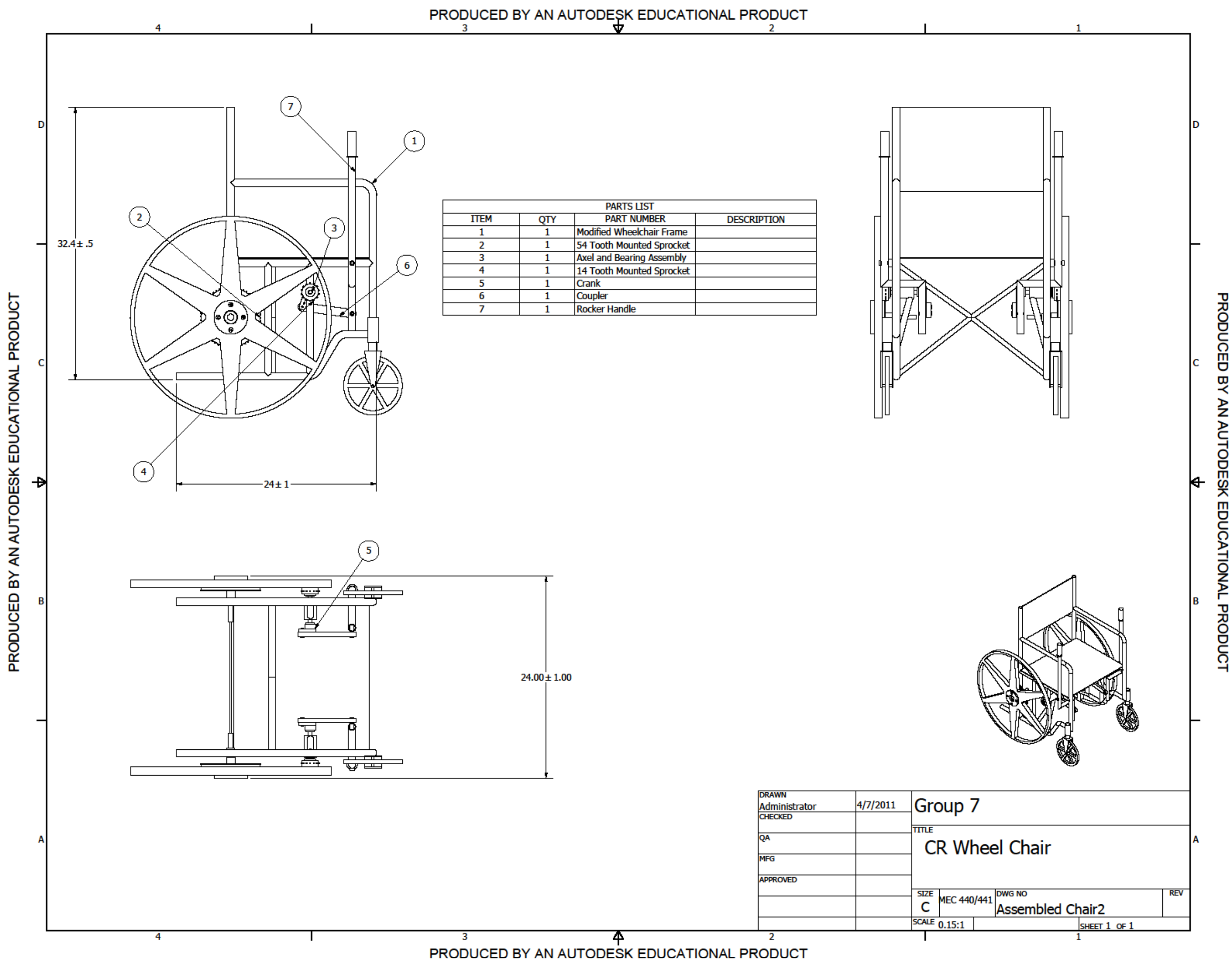

Fig. 14.11. Design of CR Wheelchair.

CURB CLIMBING WHEELCHAIR

Designers: Leo DeMino, Alex Felce and Gennaro A Manna
Supervising Professor: Dr. Yu Zhou and Dr. Chad Korach
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

The curb climbing wheelchair serves as a solution to a common problem that many wheelchair users face on a daily basis. The device allows a user to traverse a curb in the absence of a handicap accessible ramp. The mechanism is capable of both climbing and descending a curb in a safe and fluid manner. Since the climbing system is supplementary to the wheelchair's primary function, the weight of the additional system is kept to a minimum. Safety is clearly paramount to our design considerations. Due to this consideration, the design keeps the angle of the chair approximately parallel to the ground throughout the process. The main challenge is to control the center of gravity of the system, thus avoiding any tipping and ensuring that the forces are distributed correctly. Ultimately, the design provides an inexpensive and elegant solution to traverse a curb, and consequently gives wheelchair users greater freedom, safety and peace of mind.

SUMMARY OF IMPACT

The curb climbing wheelchair can have a large impact on the targeted market. During the market research and user needs analysis, we found that wheelchair users, who did not possess the strength to ascend and descend a curb without assistance, felt intimidated by the possibility of encountering curbs without a ramp. The only device on the market is far too expensive for average wheelchair users. If the design could go into production, it would have a serious impact on society because its design is simple and affordable. Moreover, one of the key objectives of this project was to add a simple, light and safe retrofit device onto a wheelchair, thus giving the user peace of mind that they did not need to search for a ramp if one was not readily available. This goal has been achieved.

TECHNICAL DESCRIPTION

The user will activate the device through a three way switch fixed on the wheelchair, and the lifting process will be run on a DC battery. The driving force of the system comes from a linear actuator. Its power is transferred to lift and lower the wheelchair through the use of linkages, chains, sprockets and gears. The lifting process takes roughly 14 seconds and is able to lift the user in a safe and controlled manner while keeping the user horizontal. For the drive system, the user will be able to continue using the big wheels on the wheelchair even when they are off the ground to move forward or backward to get either over the curb or away from it. After the wheels get to their desired orientation with the curb, the user reverses the actuator and the wheelchair is lowered down and the wheelchair is able to continue on its way.

Fig.14.12. Prototype of Curb Climbing Wheelchair.

To make sure everything was safe for the user, the materials were carefully selected to ensure that they were both light and strong enough for the application. We used a combination of 4130 aircraft steel for shafts that dealt with high forces and 6061-T6 aluminum for the other components where the forces are less. We used an assortment of bushings and bearings to ensure that all the parts were moving smoothly and easily to prevent material breakdown.

The cost of the parts and supplies for this project was $1200.

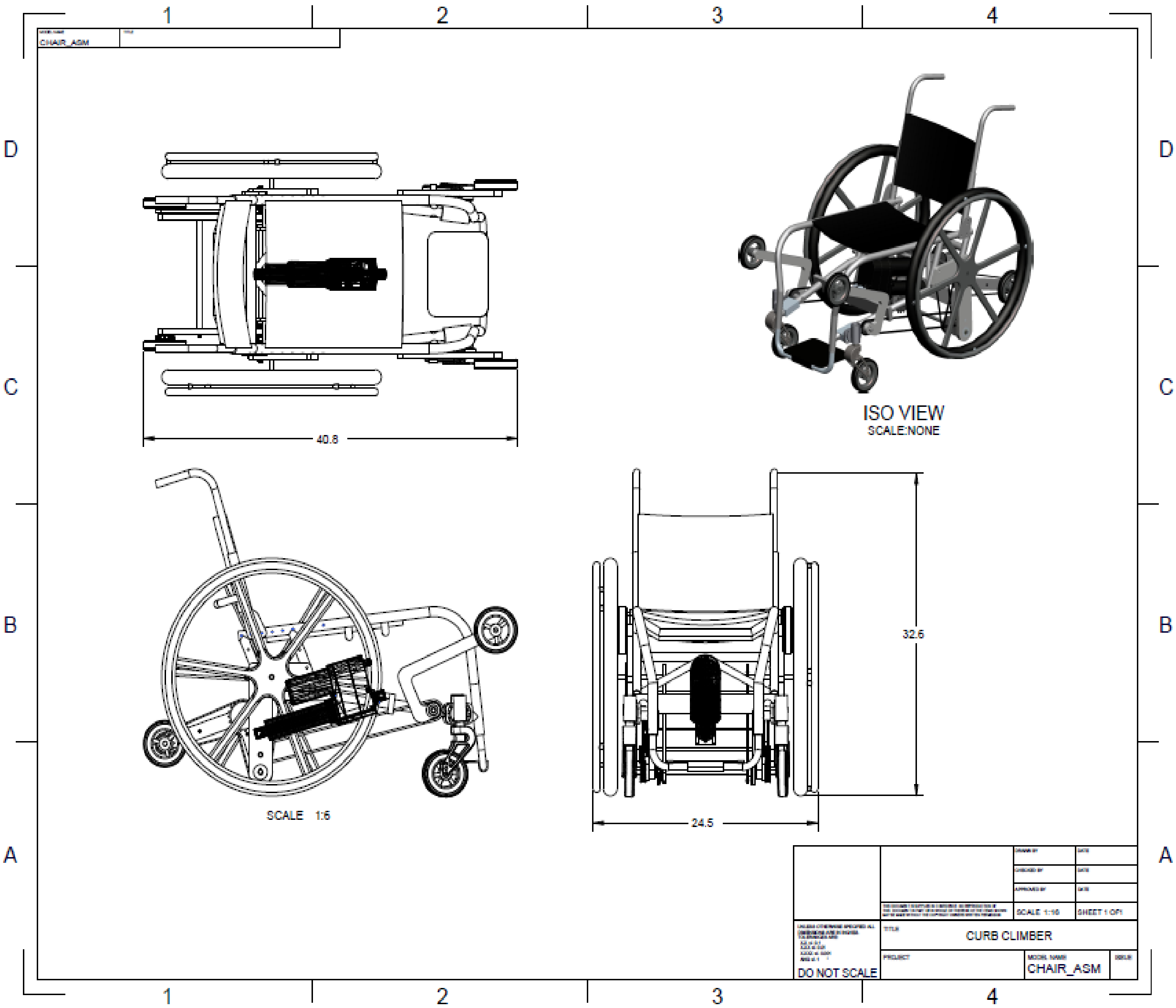

Fig.14.13. Design of Curb Climbing Wheelchair.

ALL-TERRAIN TRAVELING BASE

Designers: Chuancai Zou, Rui Wang and Nan Qin
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

The All-Terrain Traveling Base was designed to provide a way for wheelchairs to travel on various terrains, including sand, hard surface, grass, incline surface, bumpy terrain and stairs. The motivation of the project was to design a capable base for wheelchairs, which can climb stairs and travel on different types of surfaces independently, because very few current products are applicable. A combination of a belt and wheel system was chosen as our solution. Under wireless control, the traveling base can move forward and backward, adjust the seating level, turn left and right, and overcome different terrains.

SUMMARY OF IMPACT

The designed traveling base provides an effective and economic solution for electrical wheelchairs to climb stairs and overcome rough terrain. It will offer many wheelchair users more independence and freedom. For instance, in New York City, many subway or train stations do not have elevators. By replacing the regular wheelchair base with the All-Terrain Traveling Base, wheelchair users would never worry about the availability of elevators or travel a long distance for a handicap path. They can use the shortest path to arrive at the platform, just as other people. Moreover, we notice that the proposed technique can also be applied to a broader range of vehicles, e.g. all-terrain mobile robots.

TECHNICAL DESCRIPTION

The designed traveling base consists of four major subsystems: driving, transmission and motion delivery, body connection and control system. The overall shape of the base resembles a spider with all the electrical components contained inside its body. The prototype base is controlled through a four-channel remote controller.

The base can transform into different poses by adjusting the active length of the linear actuators. In the driving position, linear actuators are fully extended, and the base reaches its highest level. The gear motor delivers force through the sprockets and shafts to the body wheels. By rotating the belt, the force is delivered to the driving wheels which directly contact with ground, and the whole base is travelling. In the case of climbing stairs, the linear actuators shrink until the belt holder is parallel to the ground. In this way, the contact surface between the belt and the ground is large enough to drive the base upward or downward by the friction force.

Fig. 14.14. Driving Position of Prototype.

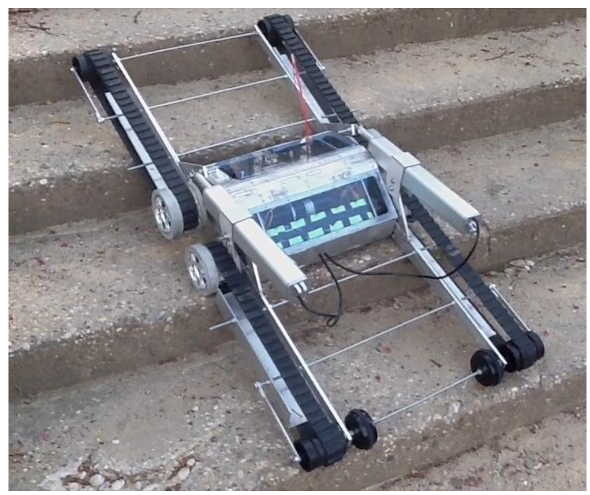

Fig. 14.15. Climbing Position of Prototype.

Due to the constraints in manufacturing and cost, a scale-down prototype was fabricated. The body material used 6061-Aluminun, the actuator holder was made of 4130-Steel sheet, the wheels were made of plastic, and the belt was made of rubber. As a result, the allowed external load to the prototype is about 60 pounds in the normal driving position. A full-scale base would be able to support a payload of 250 pounds.

The cost of the parts and supplies for this project was $1250.

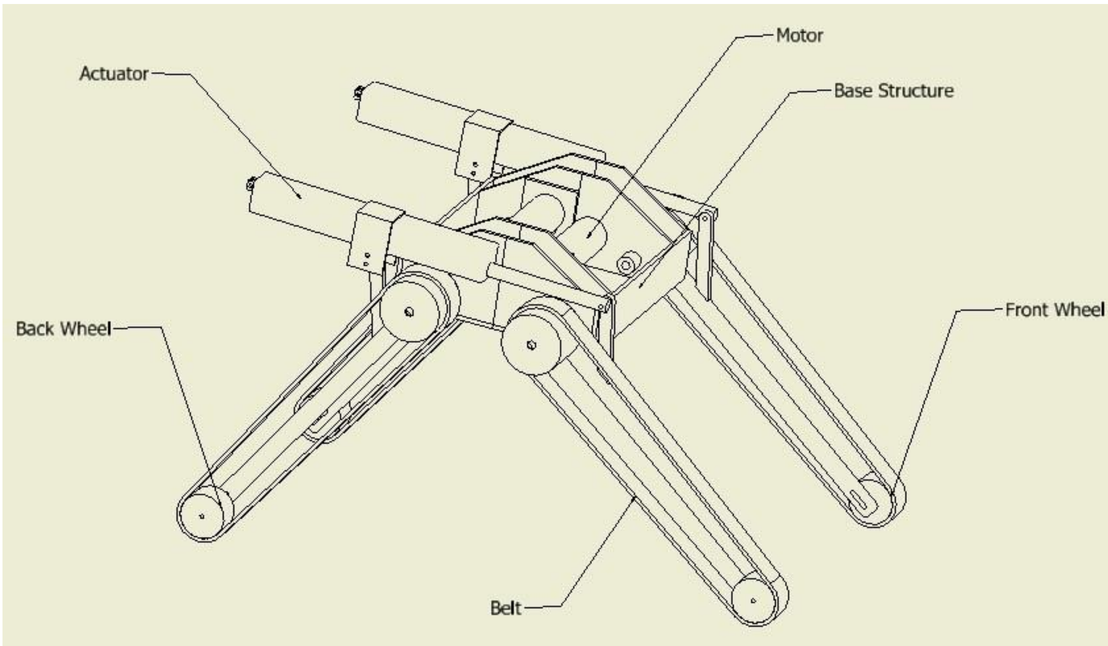

Fig. 14.16. Design of All-Terrain Traveling Base.

VARIABLE-RESISTANCE ARTHRITIC ORTHOPEDIC

Designers: Troy Douglas and Naveed Khan
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

The objective of this design project is to design a device that reduces the effect of mild arthritis and aids in leg injury rehabilitation. The device has two main features. Firstly, the device will act as a knee brace to support the joints. It takes the excessive pressure off the knee which would otherwise be experiencing the effects of vertical forces. It will result in less wearing of the cartilage in the knee, and the user will not feel as much pain. The second feature is the resistance mechanism which will add resistance against the motion of the knee joint to help strengthen the muscles and ligaments surrounding the knee. The resistance can be adjusted, depending on the effort needed for effective use.

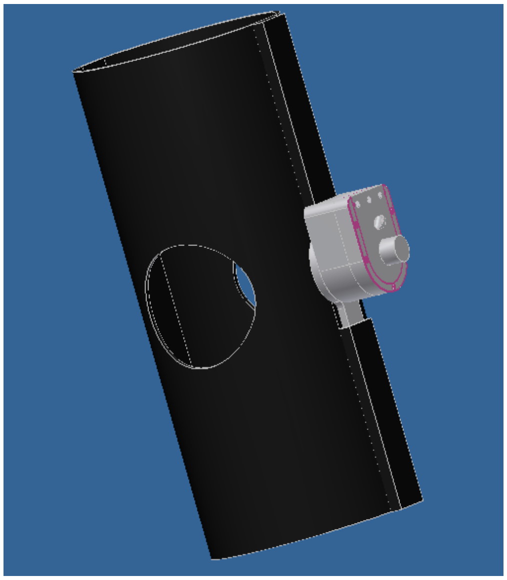

Fig. 14.17. Variable-Resistance Arthritic Orthopedic.

SUMMARY OF IMPACT

People who suffer from knee arthritis experience discomfort as a result of excessive vertical forces on the knee. In most knee arthritis cases, the muscles and ligaments of the leg are too weak to support the knee. This can cause knee joint to wear and a considerable amount of pain. By acting as a knee brace, the device provides support to the muscles and ligaments surrounding the knee. On the other hand, used as a resistance training device, it builds muscle and ligament strength. By increasing the strength of muscles and ligaments in the leg, the knee will be better supported.

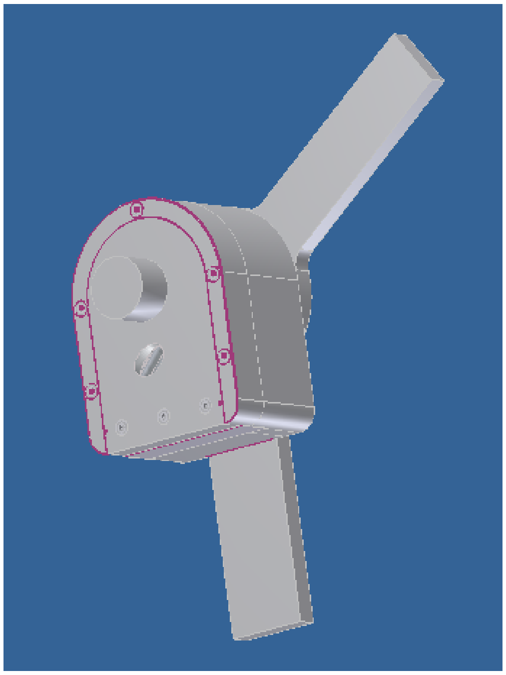

Fig. 14.18. Resistance Mechanism.

TECHNICAL DESCRIPTION

A resistance mechanism is attached to a knee brace in place of a standard hinge. The user can select the appropriate force range by turning a handle and then locking the mechanism with a thumbscrew. Thus, as the user walks, he will feel a resistance to the motion of the knee.

The key component to the resistance mechanism is a spiral torsion spring that has its center fixed to a hexagonal shaft. The outer edge of the spring is constrained to the lower leg, attached to the user's upper calf. As the knee is flexed, the end of the spring undergoes deflection and the resulting force acts in the opposite direction to the movement of the calf.

In order to control the preload on the spring, a ratchet mechanism is used which consists of a ratchet wheel, two pawls and a cam. The two pawls constrain the ratchet wheel from spinning in a certain direction. The cam engages with the pawls at four specific rotary positions, moving them in and out of contact with the ratchet wheel. Rotating a thumbscrew connected to the cam allows the user to choose between increasing the preload, locking the mechanism, decreasing the preload, and a zero resistive force mode. All of these components were made of 303-Stainless Steel.

The outer casing contains the spring as well as the ratchet components, and is made of 6061-Aluminum. It is attached to the two hinge plates via a press fit bushing. These hinge plates fit into sleeves on the side of the knee brace. The compact design allows it to fit on the knee brace in place of the preexisting hinge.

The cost of the parts and supplies for this project was $235.

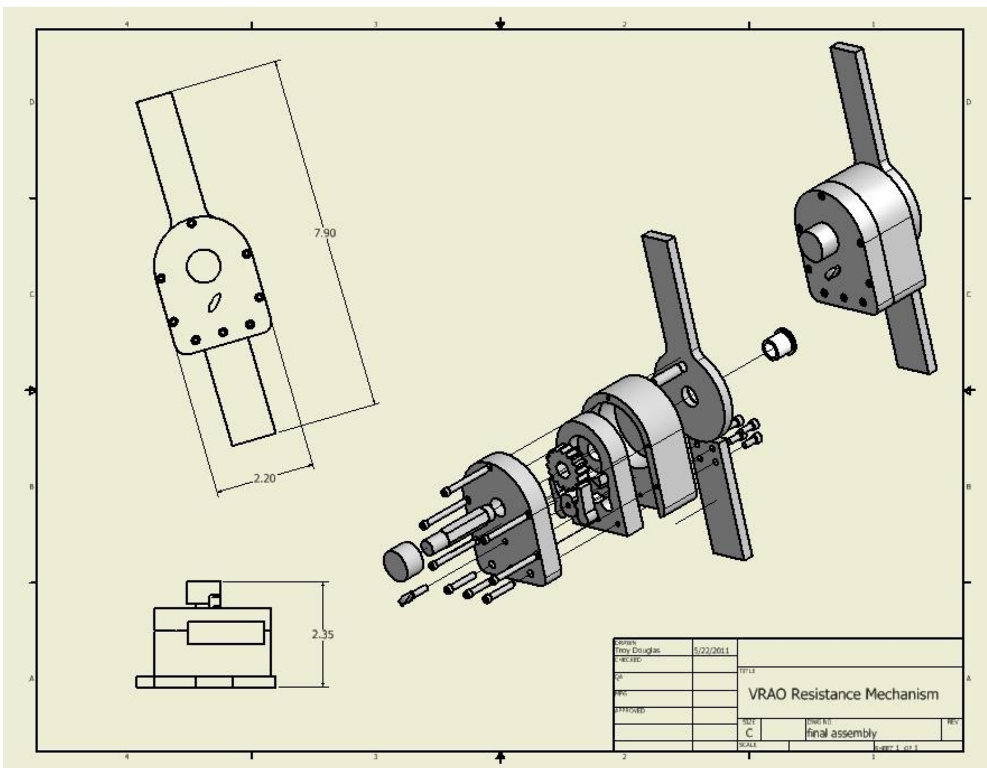

Fig. 14.19. Design of Resistance Mechanism

HAND DRIVEN TRICYCLE

Designers: Thomas Caldecutt and Lang Lang
Supervising Professor: Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

A hand driven tricycle was custom designed for a client to enforce the use of and thus exercise his weakened left hand and arm while providing mobility. An assistive device taking into account such types of imbalance is, in general, not available on the market. To provide a solution, a standard tricycle was modified with a new hand crank mechanism that enforces the engagement of the user's left hand and arm. The tricycle becomes drivable only when the left hand and arm applies sufficient force. In this way, the tricycle provides a rehabilitative function to the weak side of the user. While the tricycle is driven by hands, it is steered by feet.

SUMMARY OF IMPACT

Designed for the specific client, the hand driven tricycle will help to improve muscle mass and increase the strength of the user's left hand and arm to help the client recover from his weakness. This design can also be easily adapted to fit with people with right side weakness. It provides an effective and economic rehabilitative solution for this specific category of potential clients.

TECHNICAL DESCRIPTION

The entire system was designed and prototyped by modifying a Schwinn tricycle such that the client can use his arms and hands to pedal with a hand crank. The original pedals were removed. A hand crank and sprocket-chain set were added to the frame of the tricycle in front of the user, which work with the existing sprocket-chain set to transfer the power from the hand crank to the rear wheels. The hand crank has two handle grips for the user to hold. The input to the system will be the user rotating the hand grips. By turning the crank, the user will be producing the motion necessary to move the tricycle. This motion will be transferred, in sequence, from the hand crank to the rear wheels.

In order to enforce the use of the client's left hand, a left hand handle grip has been specially designed. For the left hand grip, the input will be the user pulling a slider to the left from its original position. This sliding motion will disengage the brake mechanism that acts against the driving system. The brake mechanism works by clamping onto the sprocket so that the friction safely slows the user down. Since this sliding motion alone does not exercise the users left arm, a spring is added to the slider, which constantly exerts a force to pull the slider back to its original position. In this way, the user will need to apply a constant force output which will help to build muscle strength. The spring constant is chosen so that the force required is substantial to the user but not so large that the user would become fatigued.

Fig. 14.20. Prototype of Hand Driven Tricycle.

The hand driven tricycle has a separate input for turning which is provided by the footrest attached to the front fork. The input to turn will be applied by the user pushing or pulling the left or right foot. The cost of the parts and supplies for this project was $400.

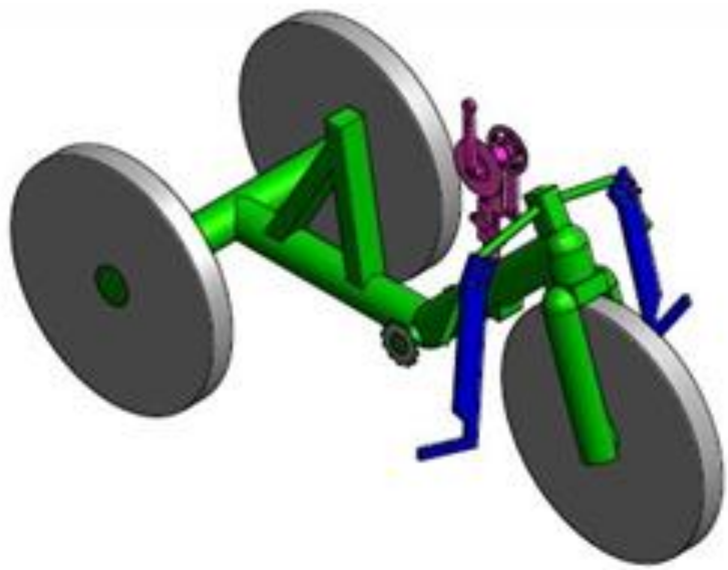

Fig. 14.21. Design of Hand Driven Tricycle.

MEDICAL STANDUP WALKER FOR CHILDREN

Designers: Sylvie Choucri, Peter Golaszewski and Huiheng Lin
Supervising Professor: Dr. Anurag Purwar and Dr. Yu Zhou
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION

Diseases such as polio, muscular dystrophy, multiple sclerosis and many more affect a child's ability to stand up and move around under one's own power, decreasing the ability to do many things other children take for granted. This project introduces a device that helps children with the above disabilities to stand up from a sitting position and walk around.

SUMMARY OF IMPACT

The standup walker we designed provides a valuable assistive device to children with difficulty in standing up and walking around. This device will make those children less dependent on caregivers. With little effort, they can stand up and move around on their own. This will have immense impact on the children's development, in particular enabling them to interact more with their peers and participate in more activities.

TECHNICAL DESCRIPTION

The principal mechanism of the device is two sets of four-bar linkage. The length of each bar (coupler, crank and rocker) is carefully calculated to imitate a natural standing up or sitting down motion path. The motion of each four-bar linkage is provided by a linear actuator attached to the frame and to the rocker. The user controls the lifting or lowering motion by a switch connected to a 12-volt battery, activating the linear actuators.

The frame is made out T6061 aluminum alloy for light weight, strength and machinability. It is adjustable by sliding bars and pins in the horizontal direction for different widths and lengths. The lengths of the bars of the four-bar linkages are also adjustable. The motion of the four-bar linkages may also be stopped at any height, providing for adjustability in the vertical direction.

Fig.14.22. Prototype of Standup Walker.

Four swivel wheels are attached at the bottom of the frame to provide mobility and are lockable for safety.

The support to the user is provided by a rock climbing harness, which is attached by S-hooks to the crank and fits kids ranging from 35 to 110 pounds.

The cost of the parts and supplies for this project was $810.

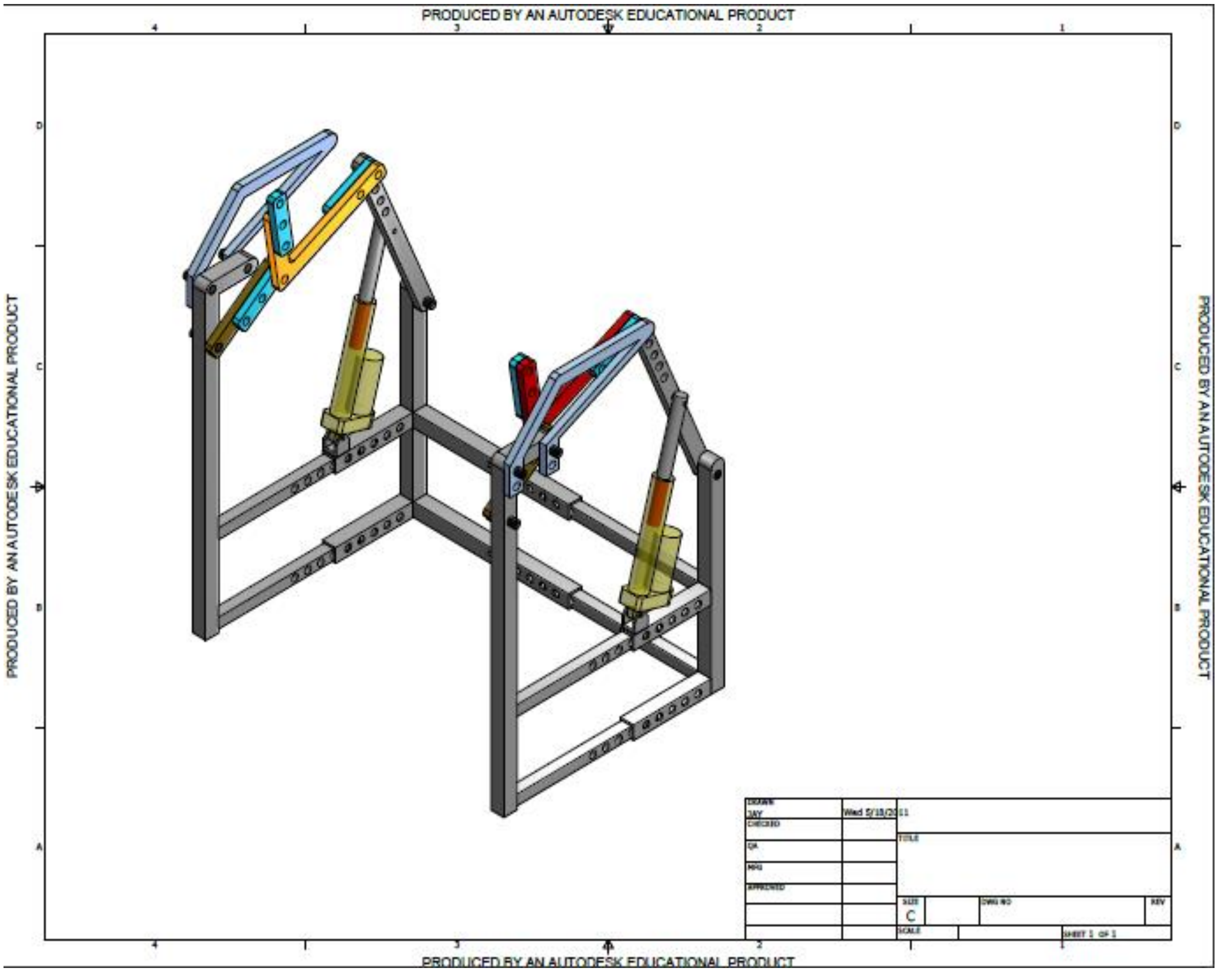

Fig.14.23. Design of Standup Walker.