CHAPTER 20
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DEVELOPMENT OF AN ACCESSIBLE AND ADAPTABLE YOUTH GOLF CART

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INTRODUCTION

The objective of this project was to modify a standard power cart for use on a golf course by a young boy, who has limited use of his legs. An Invacare Lynx-L3, shown in Figure 20.1, was modified in order to allow this "client" maximum independence and accessibility while providing all of the necessary features for a golf cart. To accomplish this, two main modifications to the power cart were made: a redesign of the rotating seat to incorporate a tilting function and a safety harness, as well as a redesign of the front axle of the cart to change it from a three wheel design to a more stable four wheel design. An electric actuator mounted at the bottom of the seat base was used for the tilting mechanism. The design features two bar parallel linkage on each side of the seat that allows the backrest to remain vertical while in the tilted position. The steering system of the front axle design includes a bracket on the steering column, tie rods and spindles. The tie rods attach to the bracket and connect it to the spindles which allow the cart to steer. New larger off-road tires were also added to provide the appropriate traction for maneuvering the golf course. A golf bag holder was also added to carry the essential golf items. The adapted golf cart is depicted in Figure 20.2.

SUMMARY OF IMPACT

People with disabilities have little access to activities such as golf due to limited wheelchair accessibility or the need for assistance from other people when participating in the activity. This is unfortunate, because activities such as these can be very therapeutic for an individual, allowing them to play the sport they love. Eric Rine, a ten year old boy with spina bifida, currently loves to play golf, but has very limited access to play because he uses a manual wheelchair which cannot maneuver on a golf course. There are several adaptive golf carts on the market

Fig. 20.1. Invacare Lynx LX-3.

Fig. 20.2. Adapted Gold Cart.

today, such as those available from EV Rider, GolfXpress and SoloRider, but these carts are designed for adults and are difficult and unsafe for smaller people to operate. These carts are also very expensive, ranging in price from $3,990 to $9,950.

A mobility cart, an Invacare Lynx-L3, was modified to allow Eric to play golf, accessing all areas of the golf course with complete independence. The adapted golf cart allows its user to efficiently maneuver about a golf course and to golf while remaining seated. Figure 20.3 depicts Eric using the cart and Figure 20.4 depicts Eric along with the members of the design team.

Because Crosswinds Golf Club has a youth program in which several children with physical disabilities are involved, the golf cart will be kept there, where it will be available to any child with a physical handicap to use. Therefore the golf cart will have a positive impact on the lives of many children in the greater Toledo area no matter their physical ability.

TECHNICAL DESCRIPTION

The objective of this project is to adapt a power cart to efficiently maneuver about a golf course and allow the user to golf while remaining seated. The main design criteria are safety, ease of use, reliability, comfort, and usability. The adaptation of the power cart required adding a seat tilt function to allow for a better swinging motion for the user, and to change the cart design from three wheels to four wheels to add stability. This required the redesign of the cart seating and steering systems.

Fig. 20.3. Client using the Adapted Golf Cart.

Fig. 20.4. Client and design team members.

Seat Design. Modifications performed to the seat include the addition of a tilting function as well as a safety harness to hold the passenger securely in place while golfing. The added tilting function allows the user to golf from a position that will drop their knees and enhance their swinging motion. Electric actuator, hydraulic cylinder, and a manual lever designs were considered to actuate a linkage that would raise the rear of the cart's seat. Using a House of Quality, the electric actuator design was chosen for its ease of use, its limited space usage, and an infinite number of inclination angles for the user to position the seat within its motion range. This will allow the user to position the seat in the most comfortable position from which to swing. The hydraulic system would require the user to pump a lever to tilt the seat and use a release valve to lower the seat, which is more complicated and harder to use than the electric system. The manual system tilting system would be the most cost-effective method. However, it would use one lever on each side of the seat attached directly to the tilt linkages and the seat would lock into several predetermined tilt positions as it was raised. The manual system would thus require more user effort to operate and is not as adjustable as the hydraulic or electric systems, due to the limited number of locking positions.

A linear electric actuator was mounted at the bottom of the seat base and connected to the center of the rear of the seat bottom. The design of the seating system also features a two bar parallel linkage on each side of the seat that adds stability to the seat and allows the backrest to remain vertical while in the tilted position. A diagram outlining the electric tilt mechanism is shown in Figure 20.5.

A three dimensional working model of the current seat and all of its hardware was developed using

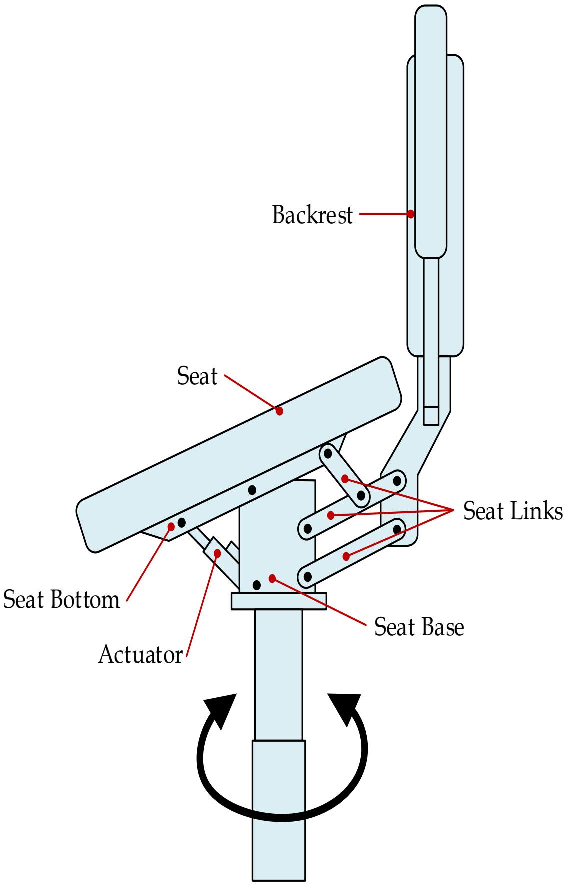

Fig. 20.5. Diagram of Electric Tilt Mechanism.

SolidWorks. An approximate tilt seat linkage was then modeled and adapted to the existing seat model. After a working assembly of the seat was created, dimensions of the various linkages were changed to produce the desired tilting motion. The actuator was then incorporated into the model. The seat assembly is shown in Figures 20.6 (Top) and 20.6 (Bottom) with the actuator fully retracted and then with the actuator fully extended, respectively. Figure 20.7 is a view from the back side of the seat which shows the final placement of the actuator.

With the desired kinematics modeled, calculations were performed to determine the maximum load that would be exerted on the actuator. To do this, the geometries of the seat base, seat bottom, and linkages were analyzed and the pieces were approximated as rigid beams. Using the various angles of the linkages and actuator relative to the seat base and assuming a rider weight of 250 pounds, the maximum rider weight for which the Lynx L-3 is rated, actuator reactions were calculated throughout the tilting range of the seat. Rider weight was approximated as concentrated force acting at the center of the seat. This process was iterative as calculations had to be performed based on geometries that would accommodate readily available actuators with a predetermined load rating and extension range. The maximum calculated actuator force was 93 pounds at an inclination angle of zero degrees. The actuator that was eventually chosen is manufactured by Firgelli Automations and provides two inches of extension (2″ stroke) while supporting loads of up to 150 lbs.

After determining an appropriate seat linkage and actuator selection, analysis was performed on the seat's various components. First, the shear stresses and bearing stresses were calculated for the pins on which the seat linkages pivot. Stresses were calculated using the maximum reaction force of 209 pounds calculated at the main pivot point between the seat bottom and the base. From the results of these calculations, the maximum shear stresses and bearing stresses were computed for the pivot pins and actuator mounting bolt. The lowest factor of safety found for the pivot pins was 14.571 and the lowest for the actuator mounting bolt was 22.174.

Next, Finite Element Analysis (FEA) was performed on various components of the seat. An assembly was made of the base and seat bottom and included a solid link to simulate the actuator. A 250 pound load was applied to the seat bottom and the analysis was used to verify the hand calculations for actuator load. Figures 20.8 and 20.9 depict the finite element model in the fully retracted and fully extended positions of the actuator, respectively.

The load calculated by the FEA analysis for the fully retracted actuator position was 93.1 pounds. When compared to the hand calculated value of 92.6 pounds, there is only a 0.54% difference. For the fully extended actuator position, the FEA analysis yielded a load of 72.9 pounds on the actuator compared to 70.2 pounds calculated by hand, which represents only a 3.7% difference and verifies the accuracy of the hand calculations.

The next analysis that was performed was on the new seat bottom. This is the piece that the actuator pushes on to tilt the seat. This piece was designed using 11 GA (.120 in) AISI 1008 carbon steel sheet. For the analysis, the seat bottom pivot point and the actuator

Fig. 20.6. SolidWorks Model Showing Tilting Motion of Seat, with the actuator fully retracted (top) and with the actuator fully extended (bottom).

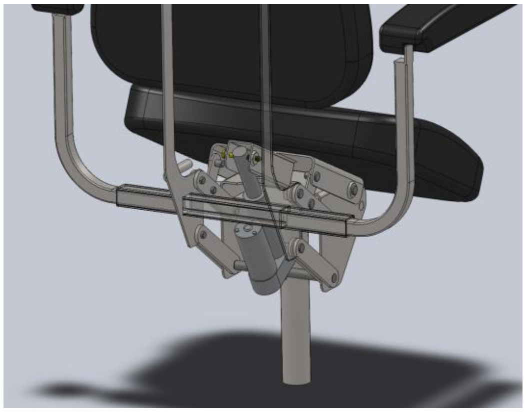

Fig. 20.7. Schematic view of the back side of the seat showing the final placement of the actuator.

mounting hole were both constrained as fixed hinges. This constraint allows rotation about each hole but does not permit translation in any direction as would be the case when the actuator is not moving. Then, a 250 pound load, representing the weight of the rider, was distributed across the top of the piece. The seat bottom was analyzed in the fully retracted actuator position as this would be the highest stressed case. Figure 20.10 shows the FEA model of the seat bottom for this tested condition. A minimum factor of safety for the piece was calculated as 3.32 and occurred just above the main pivot holes.

In addition to the seat bottom, FEA analysis was also performed on the seat base. This piece, which fits into the original seat mounting post, serves as the attachment point for the seat linkages as well as the actuator. It is constructed from 11 GA AISI 1008 carbon steel sheet and also includes the pivot point for the seat bottom. In the analysis, the mounting post, which allows the base to rotate about its attachment post on the cart's frame, was constrained as fixed geometry, preventing it from rotating or translating in any direction. Then, the previously calculated loads (maximum calculated force of 93 lbs. acting on the actuator when fully retracted and maximum reaction force of 209 lbs. calculated at the main pivot point between the seat bottom and the base) were applied to the actuator mounting holes as well as the seat bottom pivot holes. Figure 20.11 shows the FEA model of the seat base for this tested condition. A minimum factor of safety was calculated as 1.77 around the weld of the main pivot post.

Analysis was not performed on the different links of the linkage system as they only serve to hold the backrest of the seat vertical throughout the tilting range of the seat. Because of this, the only load they will see is due to the weight of the seat back and any force the rider exerts on the backrest. With 8 links made from 3/16 inch thick steel flat bar, they will have no problem supporting this loading. As a final check, the bending stress in the actuator mounting bolt was checked. This check was performed because the actuator load is applied directly to the center of a 6 inch long bolt, creating a large bending moment. With a 3/8 inch SAE Grade 8 Bolt serving as the actuator mount a maximum bending stress of 26,950 psi was calculated providing a factor of safety of 4.825.

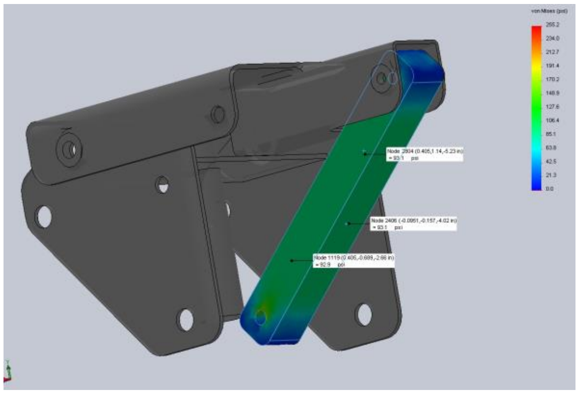

Fig. 20.8. Fully retracted actuator load FEA.

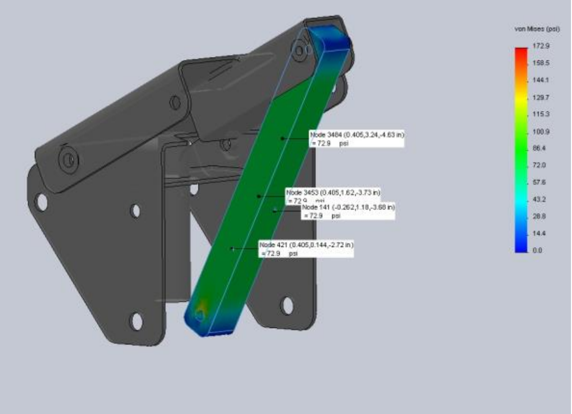

Fig. 20.9. Fully extended actuator load FEA.

Steel for the seat construction was donated by Custom Metal Works, Inc. in Norwalk, OH and the parts were fabricated by the team members. This fabrication included all of the linkages as well as the seat bottom and base. The pivot pins were machined by the University of Toledo machine shop and the actuator and control switch were purchased online through Firgelli Automations.

The safety harness used is a 2 inch lap belt connected to a 2 way anti-submarine belt to fully support the rider's weight. This setup was purchased through Crow Enterprises. During the final assembly, the seat was painted and the actuator was connected to wires spliced into one of the cart's two 12 volt batteries.

Front Axle Design. Three main design options were proposed in order to modify the front axle system: to install a wider front tire and otherwise keep the three wheeled design of the cart, to modify the front axle to accommodate two front wheels, or to add dolly wheels to the front sides while keeping a single wheel in the front.

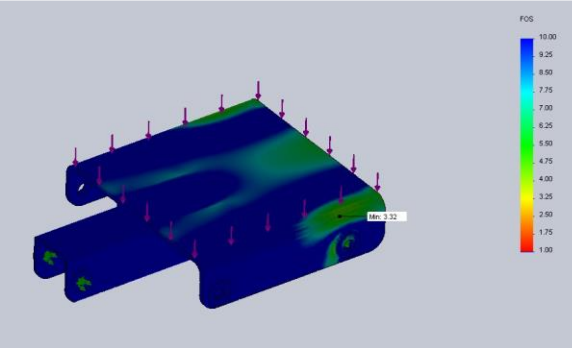

Fig. 20.10. FEA factor of safety plot for seat bottom.

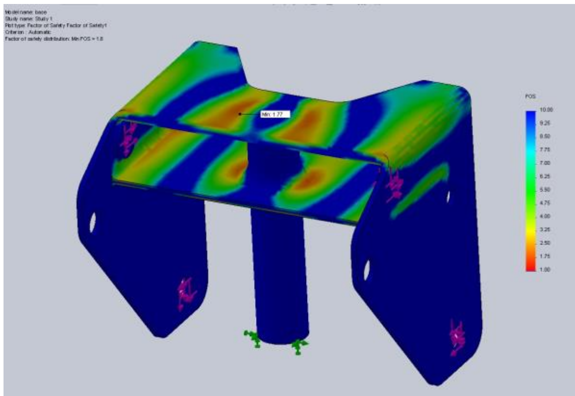

Fig. 20.11. FEA factor of safety plot for seat base.

Using a House of Quality, the four wheel design was found to offer the most stability of the three designs while also being the safest, and thus was determined to be the best design. The two front wheels are contained within the frame of the cart and do not interfere with the swinging motion of the golfer or travel of the golf ball. However, the four wheel setup will result in an increase in the turning radius of the cart, resulting in decreased maneuverability. A schematic of this design is shown in Figure 20.12.

Installing a wider front tire, while maintaining as much of the three wheeled design of the cart has several advantages including a tight turning radius, ease of implementation, and the ease at which the handlebars could be steered. It was also the most cost effective option. However, the main disadvantage of this design is that it did not provide a great amount of stability for the cart. The four wheel design provides an increased stability and ground contact areas. Incorporating dolly wheels into the cart's original three wheel design provides more stability than just the three wheels, and is less costly than modifying the front axle to accommodate two front

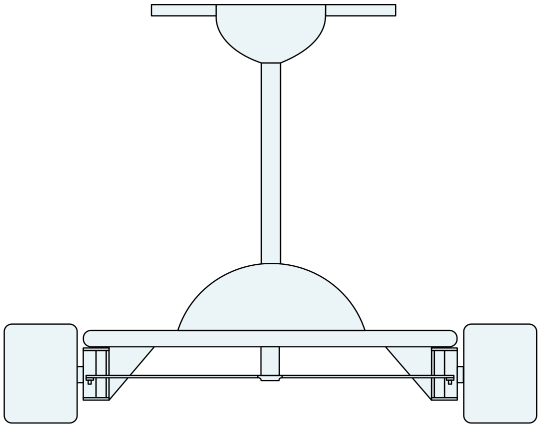

Fig. 20.12.Schematic of four wheel design.

wheels. The drawbacks to the dolly wheel design were that it would require the cart to tip a little before the wheels would come into contact with the ground. Also, the dolly wheels could possibly stick out into the swinging radius of the golfer. The four wheel design provides a superior stability and ease of use.

The tires needed to be small in diameter in order to retain as much of the cart's driving force as possible. They also needed to be fairly wide to increase ground contact area and include a tread for enhanced off road traction. The tires ultimately selected were Carlisle Turf Saver® 9x3.5-4 tires rated at 260 lbs. per tire. A contact area comparison was calculated to compare their ground contact areas with that of the original cart tires. The cart originally used three Cheng Shin brand tires that were 8 inches in diameter and 2 inches wide. Contact area was increased by 40% for the entire cart by using the Turf Saver® tires.

To determine spindle loads, it was first recognized that there are two main forces that act on them; one of these is a vertical force generated by the weight of the cart and rider and distributed among the four wheels and the other is a force axial to the spindle caused by friction at the tires' contact patch when turning. To determine the vertical force acting on the spindle, the weight of the cart and rider together was assumed to be 350 pounds. Then, to account for uneven weight distribution that could be encountered on hilly terrain, it was assumed that 75% of this weight acted through one tire as a worst case scenario. This resulted in a normal force from the ground of 262.5 pounds. The calculation of the turning force was slightly more involved. Since the actual turning force is dependent on the coefficient of friction between the tires and the ground, it would be very difficult to calculate because of the wide variance of friction coefficients that could be encountered in off road terrain. Therefore, the force was derived by calculating the maximum centrifugal force experienced by the cart when turning at maximum speed at the tightest possible turning radius. The centrifugal force calculated using this method was 137 pounds. Then, once again due to possibilities of uneven weight distribution, it was assumed that 75% of this force acted through one tire. By doing this, a turning force of 103 pounds was determined.

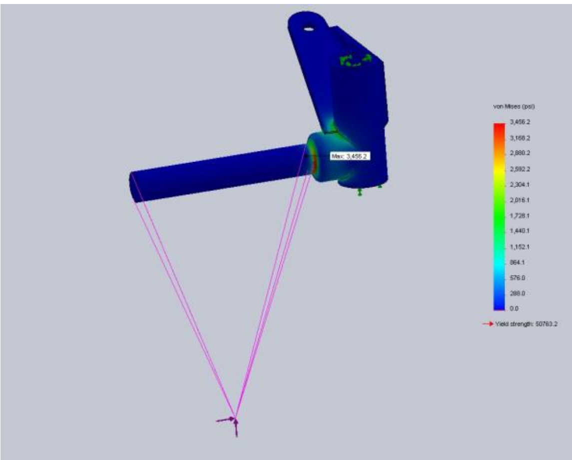

Fig. 20.13. FEA stress plot of spindle under turning loads.

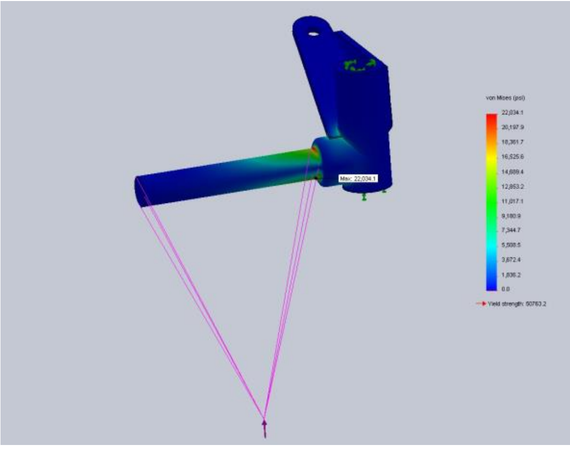

Fig. 20.14. FEA stress plot of spindle without turning loads.

Three dimensional spindle models were then created, and FEA analysis was performed on the spindles. Two cases were studied to simulate the non-turning (only the maximum normal force applied) and the turning (both the maximum normal force and turning force applied) conditions. Because of the opposing direction of the bending moments generated by each force, it was determined that the most stressed case for the spindles was when the cart was not turning. The material for the spindles was assumed to be AISI 1020 cold drawn steel. In each analysis, the inside of the pivot tube of the spindle was constrained as fixed geometry and the loads were remotely applied to the face against which the wheel mounts from the location of the tire's contact patch. Figures 20.13 and 20.14 show the FEA spindle models under turning loads and without turning loads, respectively. From the FEA results, a maximum stress of 3,456 psi and factor of safety of 14.7 was calculated for the turning simulation and for the non-turning simulation the maximum stress was 22,000 psi, resulting in a factor of safety of 2.3. Hand calculations were also performed for each case by finding the Von Mises stress at the point where the spindle bolt is welded to its pivot tube. This stress was computed based on the calculated axial, bending, and shear stresses acting at this point. The results showed a maximum stress of 3,238 psi and a factor of safety of 15.44 for the turning case and a maximum stress of 19,800 psi with a factor of safety of 2.525 for the non-turning case. Percent differences between hand calculations and FEA analysis were 6.3% for the turning scenario and 10% for the non-turning scenario.

A three-dimensional model of the frame of the existing cart was then created using SolidWorks. The models of the tires, wheels and spindles were then placed into an assembly with the frame based on desired track width, wheelbase, ride height, and clearance requirements. Once placed, the various components were moved through their range of motion within the model to check for any possible clearance issues. Figure 20.15 shows the frame of the cart and the final placement of the two front wheels.

The steering system was then added to the model. The steering system includes a simple triangular shaped bracket on the steering column to which the tie rods attach. The tie rods connect this piece to the spindles and allow the cart to steer. The tie rod attachment bracket was designed to provide a motion ratio such that the wheels could sweep their entire range of motion without having to turn the handlebars too far. The attachment bracket was positioned such that it would not cause binding in the tie rod ends at any point in its range of motion. The length of ach tie rod was determined from the 3D model. Figure 20.16 shows the finalized assembly of the front end of the cart with the steering system in place.

Parts, which were purchased to implement the redesigned front axle, include the tires, inner tubes, wheels, wheel bearings, tie rod ends, and spindle kits. Spindle kits included spindles, spindle attachment brackets, and all necessary mounting hardware. Fabricated parts included the new square tubing frame additions, the bumper, the tie rods, and the tie rod attachment plate. The new frame components and bumper were cut to length from 1 inch A500 structural square tubing and welded into their correct positions. The tie rods were made from 3/8" hot rolled steel rod, cut to length and threaded. The tie rod attachment plate was then fabricated and welded in place to the extended steering column.

Once all of the parts were fabricated, the front end was assembled and tested. The cart was then test driven to be sure there were no unforeseen problems with the design. With everything finalized and working properly, the frame was disassembled, painted, and reassembled for the finished product.

The total cost of all required materials is $1000. Generous donations to the project were made by several sponsors. The Ability of Center of Greater Toledo donated the Lynx cart, a value of $350, to the project. Rich Evans, a member of the American Society of Mechanical Engineers, donated $100, which was used to cover the cost of the linear actuator. The Andersons, Inc. donated $225 towards the purchase of the rims, bearings, and tires. The machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering at the University of Toledo donated several parts costing about $130. The actual charges made to purchase parts totaled about $200. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-03/Website/

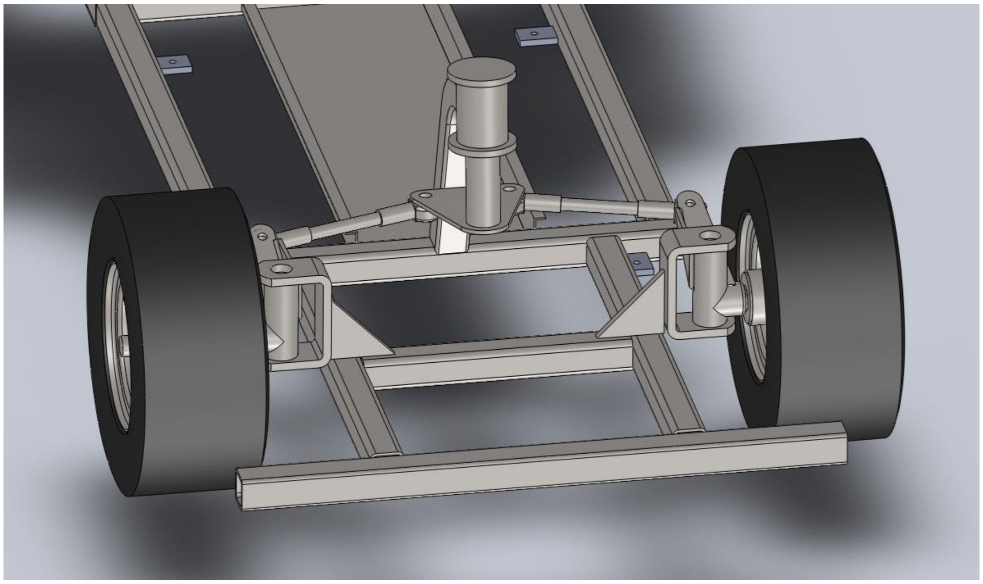

Fig. 20.15. Model of frame showing final wheel placement.

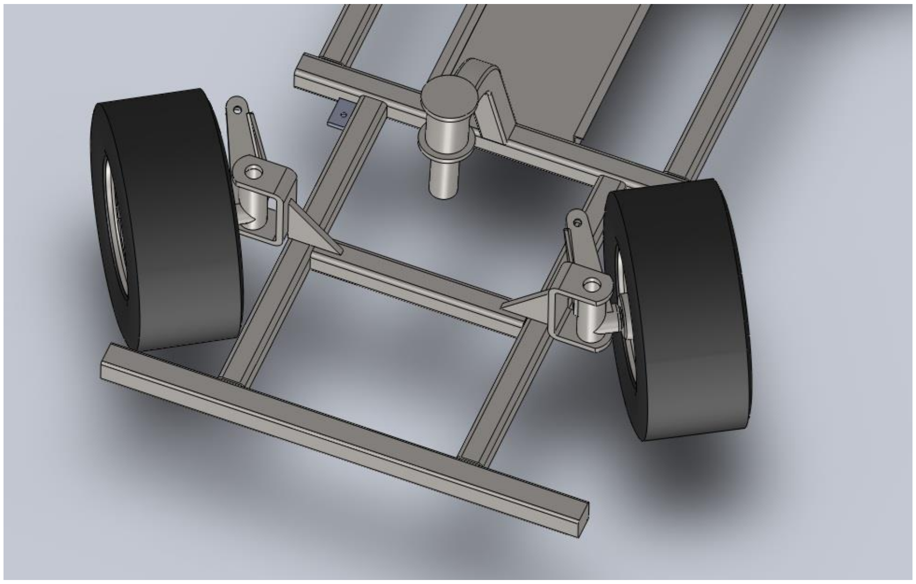

Fig. 20.16. Finalized Assembly of Front End.

DEVELOPMENT OF A DRINKING SYSTEM FOR QUADRIPLEGICS

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INTRODUCTION

The goal of this project was to develop a safe, adaptable, easily accessible, and leak proof drinking system to be used by individuals with spinal cord injuries (SCI) who have independent control of only head movement. The system was designed to be activated by the users with their mouth using a bite switch. The system includes two fluid containers, two solenoid valves, a micro-controller and the bite switch. The micro-controller is set for two different predetermined times corresponding to a short bite less than 1 second and a long bite over 2 seconds. On a long bite, the micro-controller switches between the two solenoid valves. On a short bite, the selected solenoid valve will be opened and a predetermined amount of the contents of the corresponding container is delivered to the user. The developed circuit board was contained within a control box. Steel brackets and pole mounts were used to support the two fluid containers and the electronic box. Tygon tubing was used to connect all system components. The tubing was run through a goose neck while the wiring was wrapped around it. Figure 20.17 shows the completed prototype and Figure 20.18 shows the circuit board and its circuitry.

SUMMARY OF IMPACT

During the acute care management of individuals with limited mobility below the neck, a significant amount of time is spent by the nursing staff assisting the patient to drink 3 liters of water each day to maintain body hydration. The developed drinking system would reduce the demands on the nursing staff allowing them to have more time to focus on other aspects of SCI care. The developed system would also give the patient the ability to control their own water consumption allowing greater independence and comfort. The adaptability of this product from a post mount to a wall mount will be beneficial to many different individuals in different situations. Hospital patients can benefit by attaching the system to most IV stands and individuals that are

Fig. 20.17. Completed prototype.

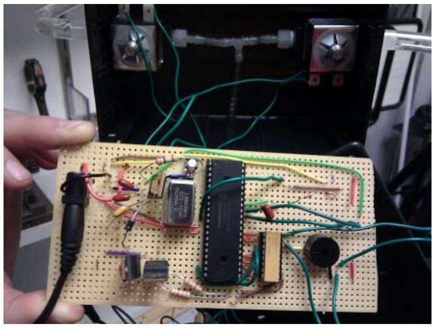

Fig. 20.18. Close up view of the circuit board.

unable to leave their bed at home can use a post mount or a more permanent wall mount.

TECHNICAL DESCRIPTION

Several factors were considered in the design. Adaptability to individuals in different living situations was taken into consideration, either in a hospital or living at home. Weight was also a concern for the caretaker; therefore a lightweight, portable design was necessary. Safety was another important factor that was considered in the design. Since there are electrical components in the system, it must not leak to prevent the user from getting wet or causing a short in its electrical circuitry. Two fluid containers were included in the system. The user could thus have their favorite two drink choices. A programmed micro-controller was used to control the system which includes a three way valve, a bite switch, and two solenoid valves. The switch bite is used by the user to control the delivery of the liquid. The microcontroller was set for two predetermined times of 1 second and 2 seconds. On the long bite, the micro-controller will switch between the two solenoid valves. This will allow the user to independently switch fluids by biting down on the switch bite. On the short bite, the selected solenoid valve will be opened to provide a specific volume of liquid to the user. The fluid will flow for a preset amount of time of 1 second. This time was determined using fluid flow analysis and will allow delivering one dose of liquid of 30 ml. The micro-controller is the key design aspect of the system. The micro-controller will wait for an input from the patient's switch. The micro-controller will switch to the opposite mode if it receives a long input from the patient's switch. Each mode corresponds to which solenoid would be activated by a short input from the patient's switch. The solenoid valves only remain open for a programmed amount of time which will be unaffected by the length of time the patient activates the switch. This will prevent possible lockjaw leading to large amounts of water harming the patient. In order to get these features, logic was programmed into the micro-controller. A speaker and LED system was also hardwired into the system, helping the patient understand what command the system is performing. The selected micro-controller chip operates at 5 volts and would be damaged by higher voltages. On the other hand, the solenoids require 12 volts to operate correctly. To overcome this problem, transistors and voltage regulators were installed to provide a barrier between the systems while allowing interaction between the components. An electrical design of the micro-controller has been developed and its wiring diagram is shown in Figure 20.19. Included in the circuitry is an override toggle switch. This switch can be activated to hold either valve open continuously. With this switch, the contents of the containers can be quickly removed for refilling and/or cleaning. Two steel brackets made of 1/8″ thick and ¾″ wide 1015 cold rolled steel and bolted to two 1/8″ thick steel pole mounts were used to support the two containers and the electronic box. The fixture can be attached to either a wall fixture for household use or a mobile IV stand. Finite element analysis was also performed using SolidWorks to ensure that the unit can safely handle the normal loading and foreseeable unwanted loads from personnel. The bite switch and mouth piece are mounted via a flexible gooseneck tube that can readily be positioned in front of the user. The tubing was run through the gooseneck while the wiring was wrapped around the outside. Short lengths of 3/8 inch tubing were used to connect the containers and solenoid valves, and 1/8 inch tubing was used to carry the liquid the remaining distance from the solenoid valves to the mouth piece. Barbed tube fittings were used to easy connect-disconnect. The tubing, barbed fittings, and liquid containers were sealed properly. The prototype was completely assembled and tested for full functionality. The project has a total cost of $342.89, with the majority of the cost consisting of electronic components. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: http://www.eng.utoledo.edu/mime/design/clinics/2010/Fall/2010-03-01/

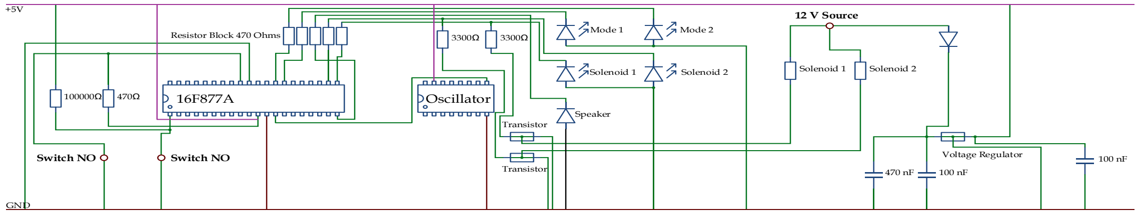

Fig. 20.19. Electrical wiring diagram of the microcontroller.

DEVICE TO LOAD AND UNLOAD A WHEELCHAIR IN AND FROM A CAR

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INTRODUCTION

Sunshine Foundation is a non-profit organization which cares for the needs and services of people with a wide range of developmental disabilities. One of the tedious tasks required of the staff at Sunshine is to load and unload wheelchairs from the trunk of vehicles. While performing this task, many staff members have injured themselves, either due to poor grip on the wheelchair, wrong posture and/or lifting positions. The objective of this project was to develop a portable device that allows someone to load and unload a wheelchair to and from the trunk of a car safely and easily. The unit that was developed is shown in Figure 20.20 and includes a wedge and a J-hook which are both placed inside the trunk of the vehicle. The J-hook is the only moving part while performing the task of loading or unloading the wheelchair. The wheelchair is placed on the J-hook which is lifted by the assisting personnel. A sliding motion is used to slide the J-hook into the trunk, and once inside the trunk, lays inside the wedge as shown in Figure 20.21. The unit was made out of aluminum making it lightweight.

SUMMARY OF IMPACT

There are few devices on the market that assist in lifting a wheelchair, but they are all electric, expensive, heavy, and difficult to move from vehicle to vehicle and they hang outside the trunk of the car. The developed unit was specifically made for Sunshine Foundation which is a non-profit organization where there are a large number of residents using wheelchairs. The unit will be used by staff members at Sunshine and family members assisting in the loading and unloading of wheelchairs. However, anyone assisting in the task of loading or unloading a wheelchair from the trunk of a car will also benefit from this design. The unit was tested by staff members and was found to meet all expectations. The final design is easy to use, lightweight, portable and ergonomic as it eliminates twists, bends and improper hand placements, making it safe and reliable.

Fig. 20.20. Picture of the device.

Fig. 20.21. Picture of the wheelchair on the unit inside the truck of a car.

TECHNICAL DESCRIPTION

The main objective of this project was to design and construct a system that assists in the loading and unloading of a wheelchair safely in and out of the trunk of a car. Design criterion included portability, ease of use, lightweight, size, safety, and cost. An ergonomic design was desired to eliminate twists and bends when lifting the wheelchair. Also, the system had to be portable and hence lightweight so it can be moved from vehicle to vehicle, and can be placed easily inside the trunk of the vehicle.

An electrical system that employs two linear actuators to tilt and slide a platform on a wedge on which the wheelchair would be placed was first considered. The user of this system does not have to do any lifting or bending since it is controlled by actuators. Although very convenient, this design required batteries to operate which are bulky and need to be replaced or recharged. Instead, a manual design was adopted which consists of a wedge and a J-hook. Figure 20.22 depicts a rendering of the system. The wheelchair is placed on the J-hook and then would be lifted and rolled into the trunk of the vehicle. The wheelchair is still attached to the J-hook when inside the vehicle. The advantages of this design are it is lightweight, ergonomic, reliable, and low cost. A disadvantage of this device is that human effort will be needed to load or unload the wheelchair.

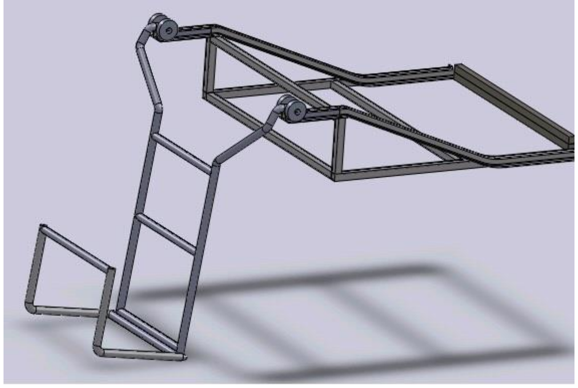

Fig. 20.22. Three dimensional model of the system.

The hook was made of T6 aluminum round tubes and aluminum square tubes were used to construct the wedge. The dimensions of the wedge and J-hook were determined using trunk dimensions of a mid-size car and the dimensions of a wheelchair. A locking hinge was placed at the bottom of the J-hook so that it lays flat on the ground to facilitate loading the wheelchair. Springs were used in the locking hinges along with round bars and steel casings. Tracks made of aluminum angle bars were placed on each side of the wedge for the wheels attached to the J-hook to roll on. The front of the J-hook consists of an aluminum bar that serves as a handle to lift the J-hook. To avoid any clearance issues, the wedge was made wider than the J-hook. Extendible arms were attached to extend out over the bumper to avoid any damage to the vehicle and its trunk. The length of the extendible arms was determined using the height of the trunk from the ground and the width of the bumper. These extendible arms are detachable so as to clear the trunk door when closed. It was determined that a moment would be created when the wheelchair is placed on the J-hook. Steel bars serving as counterweights were placed at the far end of the wedge to counteract this moment.

The final design was analyzed using hand calculations and FEA using SolidWorks software and found to be safe. FEA was also conducted on the locking hinge and the extendible arms to determine any major stresses or possible failure. Several parts were donated for this project. The actual total cost of all purchased parts was $375 after donations. The machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering at the University of Toledo helped cut the material to dimensioned sizes and Obars Machine and Tool Co. performed all the welding on the prototype.

The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: http://www.eng.utoledo.edu/mime/design/clinics/2010/Fall/2010-03-04/Main.html.

DEVICES TO ASSIST IN PAINTING AND SKETCHING

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INTRODUCTION

Amy and Luis love to paint, but cannot utilize a classical easel due to developmental disabilities that limit their mobility. They have much different levels of mobility. The purpose of this project was to develop two devices that would mount to their wheelchairs and provide adjustable surfaces for the media upon which they would be painting. An articulating arm mount was developed for Luis who has low mobility and hand dexterity. The arm allows the media surface to pivot up and down and from side to side, to move towards and from the user, and to adjust in height. Figures 20.23 and 20.24 show two different pictures of Luis using the arm mount. Also, a wheelchair tray media mount was developed for Amy who has relatively high mobility. The unit is mounted to the tray on Amy's wheelchair allowing her to be seated comfortably in her wheelchair while painting. The media mount include links that allow positioning the painting surface at 60°, 45°, and 30°. Figures 20.25 and 20.26 show two different pictures of Amy using the media mount.

SUMMARY OF IMPACT

The Sunshine Foundation serves individuals with developmental disabilities. They constantly strive to create a strong community in the activities they pursue and the interactions between the Aides and individuals spending their days there. The people being served are invited to take part in activities they greatly enjoy. Two individuals in particular, Amy and Luis, are active painters, but due to their disabilities, are unable to fully explore their hobby. The two painting aid devices that were developed through this project will allow them to further explore their interest in painting and fully exploit their creativity. The Aides, at the Sunshine Foundation who were at one time needed to hold the media for these painters, will now be able to further interact with other individuals, which will directly correlate to more happiness within the facility.

Fig. 20.23. Luis using the articulating arm mount.

Fig. 20.24. Luis using the articulating arm mount.

TECHNICAL DESCRIPTION

The purpose of this project was to provide two individuals, who experience different low levels of mobility due to developmental disabilities, assistance in painting and/or sketching. The assistive devices

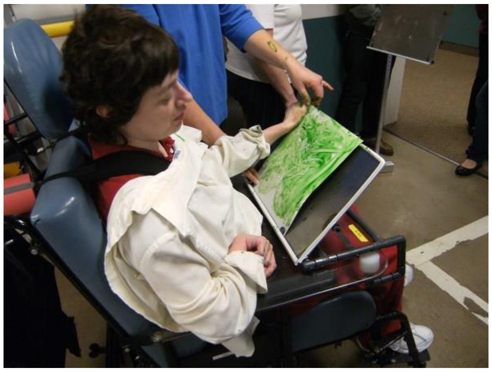

Fig. 20.25. Amy using the tray media mount.

Fig. 20.26. Amy using the tray media mount.

that were developed were designed to be lightweight, universal, and easy to use and to maintain. An articulating arm mount was developed for Luis who has low mobility, and a wheelchair media mount tray was developed for Amy who has relatively more mobility. Both designs were modeled using SolidWorks as illustrated in Figures 20.27 and 20.28, respectively. The articulating arm mount was developed to mount to the frame of Luis' wheelchair as shown in Figures 20.23 and 20.24. However, it can mount to any wheelchair whose frame tubes are up to 1.5 inches in diameter. The painting media surface of the construct has three means of adjustment such that it can pivot up and down and from side to side, it can move towards and from the individual; and its height can also be adjusted. The arms were made of 0.25″ thick 6061 Aluminum plate. The painting surface was made from stainless steel and magnets were used to hold the paper to the painting surface. The upright was made of square 6063-T52 square aluminum 0.35″ thick tubing. The frame of the media mount tray was made of PVC piping with a diameter of 0.5 inches. It was developed to fit the dimensions of Amy's wheelchair tray and to accommodate paintings up to 12 by 18 inches. The links were 3.2 inches long and were made of aluminum. The painting surface was also made from stainless steel and magnets were used to hold the paper to the painting surface. Pins were placed every 1.5 inches along the frame to connect with the link arms. The links allow positioning the painting surface at 60°, 45°, and 30°. The yield strength of the PVC was determined experimentally as 6540 psi.

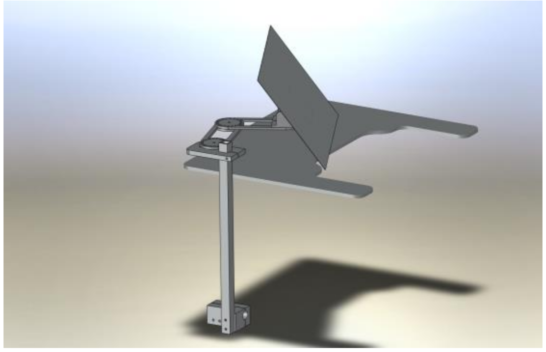

Fig. 20.27. Schematic of the articulating arm mount.

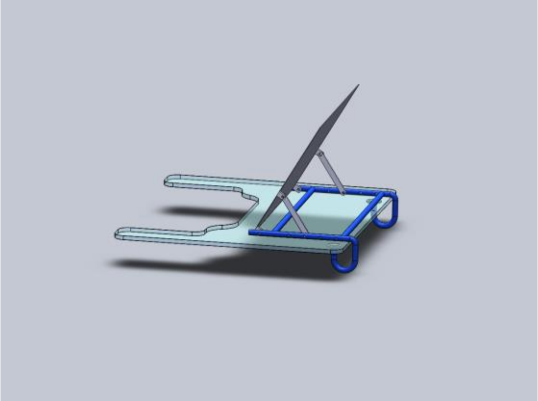

Fig. 20.28. Schematic of the wheelchair media mount.

FEA was conducted on both constructs which were found to be safe for a load of 25 lbs. placed normal to the painting surface. The total cost of the material for both constructs was about $210. All machining and welding was conducted at the machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering free of charge. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-01/main.html

DEVELOPMENT OF A DEVICE TO ASSIST IN PACKING AND UNPACKING BAGS: HANGING BAG ASSISTANT

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INTRODUCTION

The purpose of this project was to develop a device to assist an individual who lost control of most of the left side of her body with packing and unpacking various sized bags. With the use of only her right hand, the "client" struggles to keep a bag open in order to pack items into it. The developed device hangs from a door and holds various sized bags suspended off the ground, providing the client a simple way of holding the bags open while they are packed and unpacked. The device is lightweight and its frame was made of aluminum with one free standing upright and one adjustable upright. Two hooks attached to individual uprights were used to support the handles of the bag. The adjustable upright is controlled by a motorized aluminum wheel lined with a rubber O-ring that drives a threaded rod. The motor runs off a rechargeable battery pack. Two proximity sensors attached to the frame of the device were used to prevent the motor from expanding or contracting the uprights past its limits. This setup allows the client to vary the width of the uprights in order to accommodate small and large bags. A three-way toggle switch was used to operate the motor. The device is set-up and operated with one hand as illustrated in Figures 20.29 and 20.30.

SUMMARY OF IMPACT

Tami Williams has lost much use of the left side of her body because of a stroke. Packing and unpacking a bag was difficult for her, since most bags required one hand to hold it open and one hand to load it. The developed "Hanging Bag Assistant" allows Tami to independently pack and unpack various sized bags with one hand. Tami was able to easily lift the

Fig. 20.29. Client setting up the Hanging Bag Assistant.

Fig. 20.30. Client using Hanging Bag Assistant.

prototype off a table and hang it on the back of a door as shown in Figure 20.29. Once hung, she could suspend multiple sized bags from the two hooks and operate the motor using the three-way toggle switch as shown in Figure 20.30. Once packed, Tami was able to remove the bag from the hooks and also remove the prototype from the door. Overall, she was very pleased with the prototype.

TECHNICAL DESCRIPTION

The objective of the project was to develop a device to assist an individual who lost much use of the left side of her body in packing and unpacking various sized bags. Several factors were considered in the design including safety, ease of use and setup, weight, portability, cost and adjustability. Several design concepts were developed including using a tripod bag opener and a table top bag opener, both having multiple telescoping arms and legs and both controlled by linear actuators. However these designs were disregarded mostly because of cost and heavy weight.

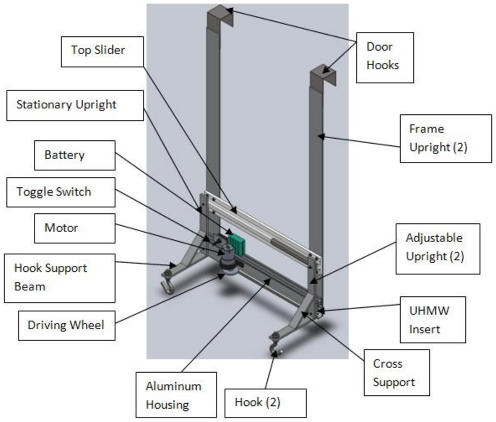

Fig. 20.31. 3-D model of the device.

Fig. 20.32. Close-up view of the unit.

The adopted design concept was modeled after a towel rack that hangs on the back of a door. The unit includes two steel hooks that hook over a door and attach to two vertical frame uprights. A plastic slider acquired from Spiratex Company and two small vertical uprights: one stationary and one adjustable were mounted on the vertical frame uprights. Hanging rods are attached to the two small vertical uprights for a bag to hang on for loading. The distance between the two small vertical uprights is controlled by a driving apparatus. The driving apparatus consists of square aluminum tubing (aluminum housing) with a hollowed out piece of UHMW plastic inserted inside the tubing. A threaded rod was placed inside the hollowed-out plastic insert and was attached to the adjustable upright. Mounted on the aluminum housing is a dc motor (rated at 15 rpm and produced 26.8 N-cm of torque at max efficiency) with an aluminum wheel attached. The aluminum wheel was outlined by a rubber O-ring and drives the threaded rod. Powering the motor was a rechargeable battery pack rated at 800 mAh and a toggle switch. The toggle switch allows for the polarity of the motor to be reversed in order to operate the motor in reverse. In order to limit the minimum and maximum distance of the adjustable upright, proximity sensors were installed. The sensors cut power to the motor when the maximum or minimum limits are met in order to prevent from over extension. Figure 20.31 shows a 3-D model of the device and Figure 20.32 depicts a close up view of the finished unit.

A structural analysis was conducted using SolidWorks and the unit was found to be safe. Several parts were obtained through donations. Machining was done free of charge. The incurred cost totaled $140.00. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:

http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-02/main.html