CHAPTER 17
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A Universal Arm Wheelchair Attachment

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INTRODUCTION

The purpose of this project was to develop a wheelchair attachment to hold small objects, such as a mirror, hair dryer, or camera, and position these objects for use. Our client has a form of cerebral palsy called Spastic Hemiplegia. The effect is limited fine motor control in the right side of her body. The client's physical capabilities were evaluated using a series of preliminary tests including range of motion, lifting abilities, and use of various knobs and levers. These tests assisted the project team in determining what types of interfaces could be incorporated into the design. A manual-powered device attached to the right side of the client's wheelchair was constructed.

SUMMARY OF IMPACT

Physically challenged individuals with limited use of one upper extremity are often unable to perform self-care, vocational and recreational activities without assistance. Devices are commercially available which act as a support arm to help in such cases, but they are often expensive and have been developed for the able-bodied population, typically requiring the use of two hands to manipulate them. The universal articulating arm mount project was developed to address this need for a seventeen-year-old with right hemiplegia secondary to cerebral palsy. The client uses a power wheelchair and is limited in the use of her right upper extremity. She has been unable to participate independently in many bilateral activities such as grooming and photography, often leaving her reliant on others for assistance. The universal arm was designed to reduce this dependence on others and enhance her independence in self-care and recreational activities. The universal arm conveniently mounts to her wheelchair. Once an object is attached to the end of the arm, she is able to move the item through space and lock it into any position. Thus she can now maneuver a camera into optimal picture-taking position, shoot the picture and change film all on her own. The device also has the potential to help her be more independent in her self-care given its flexibility to hold such items as a hair dryer, a mirror and the like. The ability to engage in these activities independently with minimal set-up has truly enhanced the quality of her life.

Figure 17.1, Client Enjoys a Photography Session with her Universal Arm.

TECHNICAL DESCRIPTION

The design for the prototype, based on a common floor lamp, was chosen for its range of motion, compactness and simplicity. It is composed of four subassemblies: the gear assembly; the vertical tubing assembly; the horizontal assembly; and the attachment interface. The device is positioned vertically by turning the handwheel on the gear set. Positioning within the horizontal plane is accomplished by moving the horizontal tubing around two rotational joints. The attachment interface holds the accessories to be used, and also allows two more degrees of freedom: tilting and swiveling.

The gear assembly consists of a handwheel, worm, worm gear, pinion, and rack, as well as two shafts, bearings, and the mounting bracket. The assembly converts single-hand crank rotation into vertical motion. The steel rack and pinion have a diametral pitch of 16 and a $14\frac{1}{2}°$ pressure angle. A worm and worm gear are included for self-locking. The worm gear, attached to the pinion shaft, has diametral pitch of 12 and a $14\frac{1}{2}°$ pressure angle. The worm has a 0.2618" lead, and a single thread for self-locking. The assembly has a mechanical advantage of 1:10, while being contained in a small package. Five glass filled Teflon flanged type bearings provide low friction surfaces for the shafts to rotate within and act as thrust bearings for the worm and worm gear. A four inch diameter handwheel is attached to the end of the worm shaft. The gear assembly is mounted to the vertical outer tube with a bracket constructed from $\frac{1}{8}$" aluminum plates. The bracket ensures that shafts of the worm and the worm gear are perpendicular to each other, and maintains the proper center distance between the rack and pinion. One revolution of the worm generates approximately $\frac{1}{2}$" of lift. With a forty pound tangential force applied to the pinion, the torque required for one revolution of the handle is approximately 6.5 in-lbs.

The vertical tubing assembly consists of six parts; the outer tube, the inner rod, two bearing sleeves and two linear bearings. The outer tube acts as the main framework of the device, protection for critical parts, and the point of attachment to the wheelchair. The solid aluminum inner rod has a turned down top serving as a rotational joint and attachment point for the horizontal assembly. The inner rod's function is to raise and lower the horizontal assembly. It is set in the outer tube and travels through a pair of linear bearings. The vertical motion is actuated by the rack and pinion. When the attached rack is driven by the gear assembly, the inner rod travels vertically through a pair of linear bearings. A flat surface was milled along the length of the rod to prevent contact between the rack and outer tube. This surface recesses the rack to prevent spatial conflicts, and facilitates attachment of the rack to the rod. A slot milled into the side of the outer tube allows the pinion to interface with the rack converting input torque to linear motion. Two bearing sleeves hold the linear bearings inside the top of the outer tube. The Thompson Open Type Super Ball Bushing bearings provide linear tracking, and the opening accommodates the rack.

The two horizontal members are each constructed from three aluminum pieces and purchased fastening knobs. A two member horizontal section was selected to allow maximum motion with a minimum number of parts. The main component of each horizontal section is a piece of hollow aluminum tubing. The top and bottom segments are nine and eleven inches long, respectively. One inch diameter, $\frac{1}{8}$" thick tubing was selected for strength and durability. These pieces form 360" rotational joints at the vertical member and between the two horizontal tubes. The solid cylinder at the end of the upper tube is used for mounting different arm accessories. After fishmouthing the horizontal tubes, solid cylinders were welded to each end. Lastly, the fasteners between the vertical member and the horizontal sections are oversized plastic knobs with threaded steel shafts. Both knobs have large finger recesses so that the client can operate them with either hand. The attachment interface is where accessories are connected to the universal arm. Without the attachment interface, the universal arm has 3 degrees of freedom for positioning the end point of the arm. This is acceptable if the accessory being used requires only translational positioning. Both a camera and hair dryer would necessitate rotation to ensure appropriate and adequate usage. A Slik Mini-Tripod mount, attached to the upper horizontal arm, supplies rotation around two axes. The knob and handle used to move and lock the mount in place were replaced with a larger knob and handle. This modification made it easier for the client to grasp them and operate the mount. The simplicity of using these knobs was verified through testing. Clamps were designed to allow quick attachment of the universal arm to the wheelchair, without requiring tools. The cost of the universal arm is about $300.

Typical operation is as follows: (1) with the arm in its storage position, the client loosens the fastening knobs, (2) using one or both hands, the client moves the horizontal members out in front of her, (3) she then turns the hand crank until the horizontal members are at the desired height, (4) horizontal members are readjusted, (5) the fasteners are tightened to secure the arm's position. This is usually done with the unaffected hand, but if the arm is in an awkward position the simple knob geometry allows use of the affected hand as well, (6) the arm accessories (camera, mirror, hair dryer) can then be used. This procedure is reversed to store the arm after use.

A Rehabilitative Mobility Device for a Child with Arthrogryposis

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INTRODUCTION

Arthrogryposis is a disorder that affects the growing joints of a fetus. Upon birth, children with arthrogryposis frequently suffer from severely limited joint flexion. Most frequently, the hands, feet, and knees are affected. The inability for children with arthrogryposis to bend their joints, combined with a resulting lack of muscle mass makes it nearly impossible for them to use existing bicycles and tricycles. As a result, they are frequently omitted from participating in activities with their peers. A scooter device was designed and manufactured specifically for one child that granted him mobility while simultaneously providing a therapeutic activity. The device is propelled by pushing either one or both feet along the ground. Folding foot plates allow the therapist or parents to determine which foot will be used for propulsion, thus allowing the device to be used for therapeutic purposes as well as for recreation.

SUMMARY OF IMPACT

The subject of this project was a three year old boy suffering form arthrogryposis cogenita of the amyoplasia type. He has severely limited knee flexion in his right knee, clubbed feet, and dislocated hips. He is currently receiving therapy to increase his flexibility and to teach him how to cope with everyday problems encountered as a result of his condition. Due to his age, however, he frequently becomes frustrated and tired during the therapy sessions. The child's disabilities have resulted in a slowed incurment of "normal" childhood developments. Only recently has he learned to walk. Many difficulties exist in his attempts to perform such basic functions. In walking, he tends to lift his right leg by tilting his body to the left, and then turns his entire body, 'throwing' his right leg in front of him. The child's parents wanted the device to allow him to play as an equal with his friends in his neighborhood. His therapists wanted the device to provide a therapeutic action that they could incorporate into the child's therapy sessions. Each of these requirements were integrated into the final design. This resulted in a therapeutic device that the child wanted to use. The final design allows the child to play with his friends while performing a therapeutic activity geared towards increasing his ability to walk normally. The device was manufactured with 'fun in mind to keep the child's motivation high. This device should continue to be used by the subject for some period of time. This is expected because the scooter is durable, adjusts for growth, and the child wants to use it. Initially, it was feared that the solution of this project would require a device that looked foreign to the child and his friends. This may have resulted in fear or teasing on the part of the child and his friends respectively. Because the scooter looks like a normal tricycle, these concerns are not a factor. Based on interviews with the parents and therapists, and observing the child on the scooter, the vehicle will be able to provide a therapeutic activity for several years to come. Over tune, this therapy may teach the child to walk with a normal motion. The correction of the previously used motion through the scooter's use will be beneficial to the child in several ways; first, the child will be capable of living a more normal life, second, the child should stay more motivated during therapy sessions at the DuPont Institute, and most importantly, the child will have fun when he 'rides bikes' with his neighborhood friends.

TECHNICAL DESCRIPTION

In developing a solution to this project, many potential designs were theorized for use by the child. In developing any device for the child to use, three primary factors pertaining to his condition needed to be considered. These are: 1) Only 45” of forced knee flexion was possible in the right leg, 2) Both feet were clubbed at birth and have subsequently lost virtually all flexibility, 3) Both hips are dislocated and have formed pseudo joints from scar tissue and cartilage. The lack of flexion in his right knee and his ankles and feet limit the potential to use a bicycle-like device. The condition of his hips is such that pain is encountered when the subject tries to bring both feet together while sitting on a bicycle seat. Prototypes were made of several designs which were found most likely to be successful. Testing of these prototypes proved that locomotion would be impossible by the subject if a pedaling motion were required. The prototypes were intended not only to test feasible designs, but also to determine which motions were easily performed by the child. The testing sessions of these prototypes indicated that the easiest and most therapeutic motion for the child was that found when testing a prototype scooter. The child performed extremely well on the scooter. Two factors suggested that the design would succeed in fulfilling the objective of the project. First and foremost, the subject used a proper walking motion in propelling the device. Secondly, the child enjoyed using the scooter. Together, these facts are suggestive of a potentially frequent, unsolicited, initiation of therapeutic activity. The child was previously using a tricycle with an improper scooting leg motion. To accomplish this, he would curl his left leg under the tricycle and push on the ground with the top outside section of his left foot. This problem was eliminated through the scooter design shown below.

To eliminate the problem observed on the tricycle/scooter the child was using, adjustable foot rests were added to an existing tricycle frame. The aluminum foot plates are hinged to a horizontal steel cross member added to the tricycle close to the ground. The plates fold up and down about the centerline of the scooter. When a footplate is in the ‘down’ position, it forces the use of the leg on the other side of the scooter. In the ‘up’ position, it makes it impossible for the child to curl his legs under the scooter. Locking mechanisms are provided for both up and down positions, to prevent the child from altering the scooter configuration as well as for safety considerations. The scooter also features adjustable seat and handlebars. The seat height has a range of three inches, and can be adjusted along the frame over a range of $3\frac{1}{2}$". The handlebars can be adjusted $2\frac{1}{2}$" vertically, and can also rotate around the center shaft to provide proper hand grip position. The basic construction of the device provides excellent durability (even from a three year old), safety, and adjustability. The approximate cost of constructing the scooter is $130, including the purchase of a standard child’s tricycle and complimentary accessories such as horn, bell and handlebar bag.

Figure 17.2. Child’s Therapeutic Scooter with Folding Foot Plates.

The motion used in propelling the scooter requires that the child move his legs in a manner similar to a proper walking motion. This motion was forced due to the child’s inability to throw his hips when sitting on the seat, and by adjusting the seat to a position where his torso is near the position it would be in if he were walking properly. Through frequent use, this proper motion should become second nature to the child and may replace the current motion he uses to walk.

A Quick-Release Pushcart

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INTRODUCTION

This project involved the complete development of a quick-release push cart, enabling a wheelchair-bound student to assist with setting and clearing tables for meals in his residence facility. The particular student that our group worked with is a sixteen year old boy. He is afflicted with a moderate form of spina bifida that has caused physical limitations in his legs. He has extremely good motor function in his upper body, and therefore uses a manual wheelchair. For ease of mobility, he prefers a lightweight, sports' wheelchair that rides very low to the ground. The main objective of this project was to design a cart that could attach to his wheelchair, enabling him to independently complete the assigned tasks without requiring multiple trips. Other considerations included maneuverability, task organization, aesthetic qualities and universal adaptability. The cart is fabricated from tubular stainless steel frame with a polyethylene work surface and features retractable legs and an adjustable clamping mechanism.

SUMMARY OF IMPACT

Vocational and independent living skills' training is a critical component of programming at the Massachusetts Hospital School designed to help transition physically challenged youth from life at the facility to a less structured community residence. Often adaptive devices are employed to optimize an individual's abilities to engage in these educational experiences. The dining room service cart project was developed to enable a sixteen-year-old young man in a manual wheelchair to participate in a daily work program which required him to set and clear the dining room tables in his residential cottage. Previously, the young man had used a standard push cart which he had to manipulate while also maneuvering his wheelchair. The awkwardness during mobility and the limited accessibility of this standard cart made this experience extremely frustrating and restrictive for the student. Alternatively, he carried the dishes on his lap, back and forth between the table and the counter. This has proven to be a time consuming chore since he can only carry a few dishes at a time. The newly-developed service cart, which attaches directly to his wheelchair and can be maneuvered simply by propelling the chair, provided the youth with a much more efficient and accessible means for conducting his work. He has responded enthusiastically to this device and is now fully engaged in the work program. He is learning critical skills of vocational responsibility and reliability which will transfer readily to a more productive life in society. As a further benefit, the cart design was flexible enough to adapt to many sizes and styles of wheelchair frames, allowing others to benefit from its use as well.

Figure 17.3. Client with his Quick-Release Pushcart.

TECHNICAL DESCRIPTION

Before beginning the design process, the client's reach in several directions was observed to determine maximum possible cart dimensions. In addition, physical dimensions such as those relating to the client's wheelchair (tubing size, chair height, chair width, etc.), work environment (door width, table height, etc.), and occupational tools (bowls, plates, etc.) were determined to aid in the future design. The client's method of setting and clearing the tables was observed.

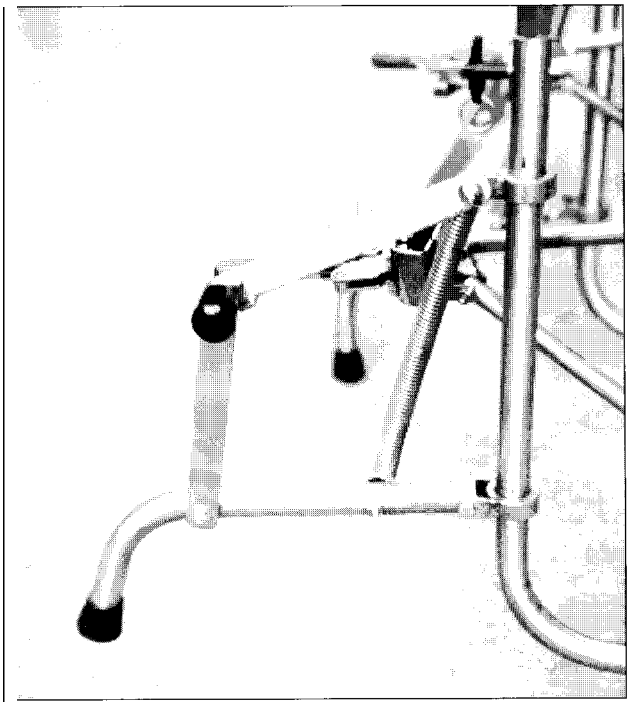

Figure 17.4. Toggle Mechanism for Retractable Legs.

The pushcart prototype is shown in Figure 17.3. It consists of a modular frame which will accommodate wheelchair widths up to 22" and lap heights up to 36", and features a variable-height top, setting and clearing inserts, retractable legs and adjustable clamping mechanisms. The majority of the frame members are made from 1" diameter 1018 steel tubing of 0.062" wall thickness. The top portion of the frame consists of a 24" square of tubing welded to four posts of 0.875" outside diameter tubing and 0.062" wall thickness. The four posts of the top have holes drilled 1" on center and slide into the vertical tubes of the frame bottom. They are held in place by quick-release T-handle pins which slide into the holes and prevent the height of the top from accidentally changing. These pins are easily removable and allow the height of the cart to be adjusted without the use of any special equipment. A pair of 2" diameter chrome-plated steel and plastic swivel castors attach to the front vertical members using a snap ring configuration.

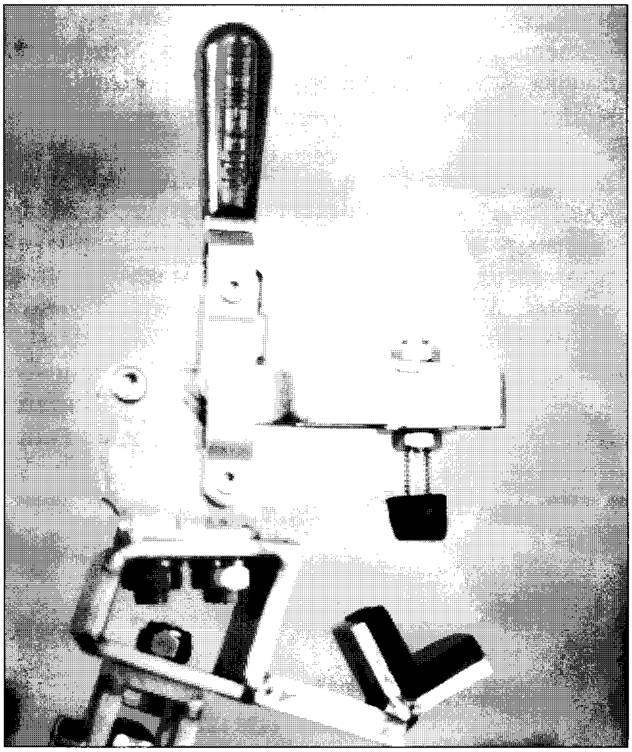

Figure 17.5. Clamping Mechanism.

The retractable legs, shown in Figure 17.4, are four-bar linkage mechanisms that rotate in the vertical plane and lock past a toggle position. This spring-loaded mechanism is constructed of $1" \times \frac{1}{4}"$ stainless steel. The mechanism is designed to raise a maximum of 2" when retracted. Welded to the upper link is a $\frac{1}{4}"$ square metal nub which serves to limit the motion of the two links with respect to one another. When the leg is in the down position, the two links swing past the toggle position. This small nub keeps them from swinging too far, yet allows them to swing far enough to lock. If any force is applied to either end of the linkage mechanism, it presses the bottom link against the nub and does not allow it to rotate any further. On the other extreme, when the mechanism is retracted, the nub restricts its motion in that direction as well. When the leg retracts a certain distance, the lower link presses against the nub and is stopped. This is to ensure the cart's stability in case the legs are inadvertently retracted when the cart is not directly attached to the wheelchair.

The clamping mechanism used to attach the cart to the wheelchair consists of two sets of a commercially purchased toggle clamps, telescoping tubing, and collars, as shown in Figure 17.5. The mechanism is located on the front vertical frame members, with the collars placed 12” apart. Each set of clamps and attachments possesses 5 possible degrees of freedom, allowing attachment to any vertical, horizontal, or angular member of the wheelchair frame.

The clearing insert is a flat top with a section removed, in which a single commercially purchased bin is recessed. High density polyethylene was chosen as the construction material because it is cost-effective, workable, available, easily cleanable, and possesses the durability to suit the client’s needs. The setting insert is a recessed bin-type configuration. The insert consists of various cavities depressed into the surface, arranged in a pattern similar to that of a table setting. Each dish and utensil is given its own section. This was done to help the user with organizational skills. Again, high density polyethylene was chosen as the material for the insert. All sections were constructed except for the silverware containers which were purchased commercially.

Analysis of the pushcart included structural/stress calculations for various loading conditions, roll-over/stability analysis, comparative weights and moments of inertia to assist in materials selection, and manueverability. Tha analyses maded extensive use of CAD and solid modeling software. The approximate weight of the empty cart is $18\frac{3}{4}$ lbs. The maximum load before roll-over is 200 lbs. The cost of the pushcart is approximately $200.