CHAPTER 20
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The Art Class Assistor: A Drawing Armrest for Students Who Suffer from Muscle Weaknesses

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INTRODUCTION

A supportive device has been developed to enable handicapped students who suffer from various forms of muscle weaknesses to perform normal artistic activities in art class. These students often have trouble drawing because they are not able to move their arms freely over the paper. This device supports the student's arm and enables the student to move any portion of the paper to accomplish the necessary drawing activities.

Many handicapped people who suffer from muscle weakness have trouble drawing because they are unable to support their arm with their own strength. As a result they are unable to perform routine, artistic activities effectively because they drag both their arm and their drawing utensil over the drawing paper. This dragging motion causes drawing smudges, paper movement, and inaccurate drawings. For the students associated with this project, the two most common diseases which result in muscle weaknesses are cerebral palsy and muscular dystrophy. Depending on how seriously the student is affected, some students have only a little trouble drawing, while others are not able to draw at all. It is both psychologically and socially beneficial to most students that they be involved in as many activities as possible. Thus, there is a need for a supportive device that would permit handicapped students to perform the functions of drawing as would any other students. The "Art Class Assistor" has been designed and built to fulfill this need of the students at a resident rehabilitation facility.

SUMMARY OF IMPACT

The Drawing Armrest, which was originally designed to meet the needs of a particular student, has aided a wide range of students with varying capabilities. The device provides ease of movement in all directions assisting the student in performing the task at hand with greater control. Thus, the student experiences a greater sense of satisfaction and less frustration.

TECHNICAL DESCRIPTION

The following is a list of the task specifications that needed to be accomplished in order for the drawing armrest to successfully meet the needs of the students. The device is designed such that it:

a. Is low in friction so the students will be able to move freely over the drawing paper.

b. Accommodates both the left and right handed students.

c. Will not smudge or interfere with the student's drawings.

d. Is lightweight and portable so it can be easily moved from one work station to another.

e. Is stable in all positions.

f. Is low in cost, so this device can be available to as many students as possible.

g. Is comfortable, safe, and aesthetically pleasing for the students.

h. Maintains a fixed distance between the paper and the student's arm. This distance should be about 1.5 inches.

i. Is manually operated, in order to provide simplicity and satisfaction for the students.

j. Accommodates a drawing paper with dimensions of 8.5 by 11 inches. The outer bounds of the device should take into consideration the free movement of both the user's arm and the support, and also the size of wheelchair trays. This leads to dimensions of 18 by 12 inches for the device.

The design is a three degree of freedom device with two axes of translation and one axis of rotation. This device consists of a base, a forearm support, and two translational sub-assemblies. Three types of bearings were used in the overall design: four roller bearings, one thrust bearing, and two pillow bearings. The bearings allow for two types of linear translational motion, by means of the roller and pillow bearings, and one type of rotational motion, by means of the thrust bearing. The final prototype is shown in Fig. 20.1.

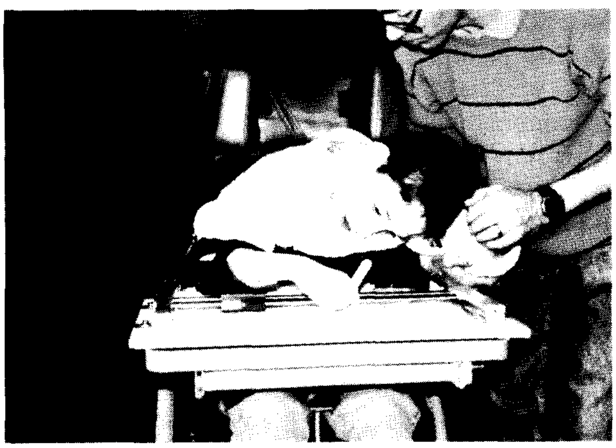

Figure 20.1. Client using the "Art Class Assistor."

Two pairs of roller bearings in aluminum tracks allow the arm support to move up and down the drawing paper. The tracks are fastened to the paper tray. The paper tray has two belts that wrap around the student's wheelchair tray to keep the device from moving while the student is drawing.

The sets of two roller bearings are connected to each other by two hardened steel rods. On each steel rod there is one pillow bearing. The dimensions of the hardened steel rods were designed to support an assumed leaning force of 15 lbs., from the user, and account for the corresponding deflection while maintaining a distance away from the paper tray.

The pillow bearings allow for side to side movement of the arm support. A piece of Acrylic Butadiene Styrene (ABS) plastic was used to connect the two pillow bearings and maintain the distance between the steel rods. Two aluminum stops, one at each end of the rods, also keep the rods separated and are used to keep the rods from moving out of the roller bearings.

The arm support is also made of ABS plastic and padded with foam for comfort. This arm support was heated and molded to the general shape of the student's arm. ABS plastic was chosen because it is inexpensive, available, and heat formable.

The arm support is attached to the ABS bearing plate with a pin that passes through the arm support, a thrust bearing, two washers, a spring washer, and a locking collar. The thrust bearing supports the weight of the forearm and allows rotation of the arm support through a full 360". This rotation along with the general design of the arm support permits both left and right handed students to use this device.

The paper is held stationary while drawing, by placing a piece of masking tape at each of the four corners of the paper, a common technique often used by draftsmen. For a right handed user, the paper is placed in the upper left hand corner of the paper tray. Likewise, if a left handed user is using the device then the paper is placed in the upper right hand corner of the paper tray. This movement of the paper, for both left and right handed students, allows the device to be compact.

The total price to manufacture this product is under $200.

Slide-Away Laptray Design

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INTRODUCTION

A student at the Massachusetts Hospital School requires a working and writing surface that will be permanently mounted to her wheelchair. This tray must have the ability to swing out of the way and store so as not to interfere with the normal function of the wheelchair or the client's transfer out of the chair. The client has the use of only her right arm, however commercially available trays that mount on the right side of her wheelchair interfere with the joystick that is mounted on the right armrest of her chair. Thus, a custom slide-away laptray was constructed. The design provides a large working area that is stored on the left-hand side of the wheelchair. The laptray is secure in the raised position as well as in the stowed position and slides to allow for changes in waist size.

STATEMENT OF IMPACT

A flat rigid laptray is a common accessory to a wheelchair and functions to provide the user with an accessible work surface for such activities as eating, academic tasks, and vocational endeavors. Typically, a laptray is independent of the wheelchair and require- either an attendant or a user with full upper body function to place it into position and to remove it. The custom swingaway laptray project was developed to address a unique set of circumstances. The end user is a woman with severe physical disabilities, who despite her limitations, actively attends school and is capable of participation in many social and vocational activities independently. However, due to the limited use of her upper extremities, she has had to rely on others to manage a conventional tray when engaging in these activities. The swingaway laptray was designed to provide the user with a tray surface while allowing her to independently swing it away and store it alongside her wheelchair. As a result, the new device has significantly reduced her dependence on others and has dramatically increased her ability to independently engage in a wide range of activities. She is now able to attend a full day of school while meeting her own personal needs (i.e., transferring in and out of her wheelchair for toileting, eating, taking classroom notes) all without requiring any assistance from others to manage her tray. The tray has not only made a major impact on the quality of this individual's life, but it also presents a unique prototype for the fabrication of alternative devices that can address the needs of others in similar circumstances.

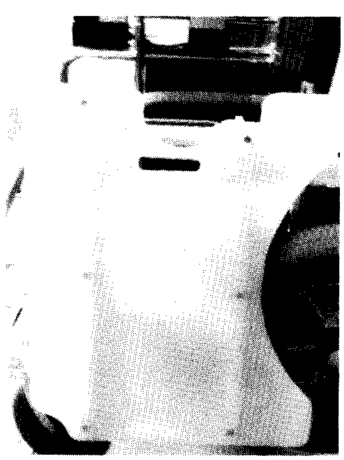

Figure 20.2. Slide-Away Laptray in Stowed Position.

TECHNICAL DESCRIPTION

The laptray is a left-side mounted slide-away laptray (Fig. 20.2).

The tray operation from the storage position to the working position is as follows:

1. Slide the tray as far forward as possible.

2. Pull the tray up and towards the right side of the chair until the tray reaches the end of its travel.

3. Slide the tray back towards the user until it is in desired position.

The operation is reversed when the tray is moved from the working position to the storage position. The mechanism provides fore/aft translation and couples translation across the body with rotation from vertical to horizontal.

The prototype design consists of the tray top, the transverse sliding mechanism and the fore-aft sliding mechanism. To provide the client with the maximum tray area and elbow support, the polypropylene tray top was designed to extend slightly outboard of the armrests while the tray is in working position. The overall dimensions of the tray are 26” x 19” x $\frac{3}{8}$". The portion closest to the user includes a body cutout and elbow support. The right side contains cutouts to allow joystick movement and waist adjustability. The transverse sliding mechanism consists of three parts: the tracks, the Teflon sliding blocks, and the slider mounting brackets. Two pieces of extruded aluminum z-bar are arranged to create the two tracks. Both Teflon slider blocks operate in between the two pieces of z-bar such that only one side of each block contacts one of the two pieces of z-bar. The tracks are fastened to the tray at each end with flat head bolts countersunk through the traytop. The middle sections of each track are fastened to the traytop with sheet metal screws. The tracks were located on the tray so that when the tray is in the working position the tracks would not contact the armrest. The dimension of the rectangular region in between the z-bar was established by the size of the Teflon sliding blocks. A bearing length of five inches limits the fore-aft play at the right edge of the tray to one inch for track tolerances of ±0.050 inches. The Teflon material provides a low friction surface for the tray to slide over. This design will limit binding and does not use rotating parts. The Teflon blocks must extend past the width of the mounting brackets to provide a low friction bearing surface and sufficient clearance between the mounting brackets and the tracks. The slider blocks are fastened to the slider mounting brackets with countersunk flat head bolts. The slider mounting brackets are welded to the aluminum sleeve on the fore-aft sliding mechanism, discussed below.

The fore-aft sliding mechanism consists of four components: the outer sleeve, the Teflon bushing, the mounting rod and the support brackets. The outer sleeve is an aluminum tube that provides not only fore-aft translation, but also rotation. The final size of the aluminum sleeve was dependent on the sizes available for the Teflon bushing. The OD of the Teflon chosen was 1.25 inches. Therefore, the sleeve has a 1.25” ID and 1.50” OD. The length of the sleeve was limited to the length of the tray. This prevents the sleeve from protruding and becoming a safety hazard. The length was held at a maximum in order to maximize the bearing surface in all positions. This also prevents binding, limits stress concentrations, and decreases the amount of play in the mechanism. The motion of the sleeve, and therefore the attached tray, is limited to a single path by a keyway cut into the aluminum sleeve. The keyway was designed to provide 10 inches of forward-backward motion in the storage position to aid in stowing the tray aft of the seat. Four inches of waist adjustability was accounted for in the working position. The two parallel slots forming the keyway are connected with a perpendicular slot when the tray is fully forward allowing the 90” of rotation necessary to move the tray from the working to the stowed positions. The Teflon bushing provides the aluminum sleeve with a low friction bearing surface. The length of the bushing provides the maximum amount of bearing surface at any one time, and prevents deflection in the aluminum tube. The stainless steel mounting rod is 0.855 inches in diameter. Threads were tapped in the end to fasten the rod to the support brackets. The support brackets support the entire mechanism. One end of each bracket is bolted to the mounting rod and the other end clamps to the wheelchair armrest tubing. The clamping portion of the brackets were made separately and then welded to the rest of the bracket. The brackets also serve as keys for the keyways in the sleeve. In order to prevent weakening of the sleeve the keys were made as narrow as possible.

In summary, the laptray functions very well. The client has a permanently mounted writing and working surface that has the ability to slide out of the way and store beside the wheelchair when not in use. The tray does not prohibit the normal functionality of the wheelchair in any position. Over three square feet of working area was provided at a weight of approximately 4.25 pounds. The total cost of the laptray was approximately $150.

The Design and Development of a Reacher/Gripper

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INTRODUCTION

The purpose of this project was to design and develop an easy-to-use, unobtrusive device that would provide a young girl with Arthrogryposis the ability to grip and transport objects from ground level to within reach when seated in her electric wheelchair. Arthrogryposis is characterized by deformities in the upper and lower extremities, and severe contracture and stiffness of the joints. The client has very gross movement capabilities as the fine motor control in her arms, hands, and legs is adversely affected. As a consequence of these symptoms, she is confined to a wheelchair.

As would be likely, one of the most challenging and frustrating situations occurs when she drops an object from her grasp; she cannot reach it on the floor below because of her very elevated position in an electric wheelchair, and poor grasping capabilities resulting from her physical condition. Consequently, she must depend on others to retrieve dropped objects.

Commercially available, manually operated gripper units have proven insufficient. These designs require not only a considerable amount of hand-eye coordination to position the "hand" around the object, but also that the user must maintain a constant application of force (to keep the object in its grasp) while pulling the object to within reach. Considering the physical limitations of our client, these are very difficult tasks to accomplish. The final design reflects the complex challenges presented by the variety of objects required for transport on a daily basis, as well as those inherent in designing an adaptive device that will ultimately function as an extension of a physically challenged individual's self.

SUMMARY OF IMPACT

Many of the everyday fine motor control functions that the average able-bodied person takes for granted can prove to be virtual impossibilities for the physically challenged individual who is confined to a wheelchair. Consequently, the need for useful adaptive devices is great. Not only do such mechanisms provide such individuals the ability to interact more easily with their environment, but they also create a greater sense of independence, self-esteem and hence, a more positive self image.

The reacher/gripper has been a popular item at the Massachusetts Hospital School. The device has enabled the student to have the capability of retrieving items that were previously out of reach. The reacher/gripper enables the client to pickup a wide range of items from a tube of toothpaste to a piece of clothing. The benefit of this device is the client's increased independence. The devices' success is evident in the number of requests from other MHS students with similar difficulties in retrieving items.

TECHNICAL DESCRIPTION

The specifications that were developed for and met by the final design of the reacher/gripper are as follows:

1. The device can be operated without the assistance of a staff member of the rehabilitation facility.

2. The unit will attach to the frame of the client's electric wheelchair.

3. The design will be able to retrieve the following items efficiently and without damaging them:

- school supplies (pencils, pens, paper)
- items in the home (toothpaste, eyeglasses, hairbrush, clothes, cups, silverware)

4. The grip used will be of a locking type. That is, it will require no bodily force on the part of the user to maintain a hold on the object.

5. The device will be motorized and switch operated so as to provide ease of use.

6. The device will be aesthetically pleasing to the user.

7. The design must be durable enough to withstand constant, heavy, day-to-day operation.

8. The design must post no safety threats to the operator or her environment.

9. When not in use, the device must not interfere with the normal functions of the wheelchair; it must be compact and not protrude excessively from the frame.

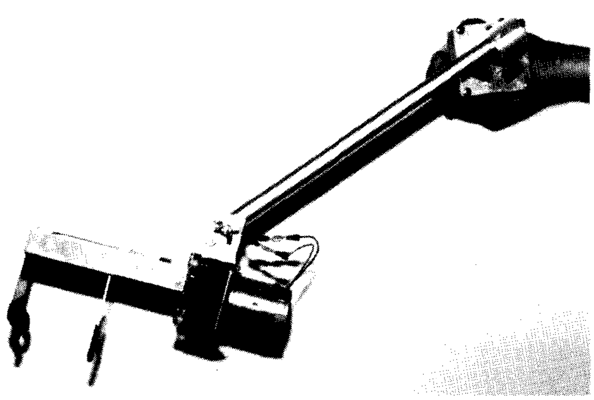

Figure 20.3. Reacher/Gripper Device.

The final design (see Fig. 20.3) consists of two basic parts: the arm and the gripper. Both portions of the design act independently of each other and are powered by reversible, permanent magnet, direct current (PMDC) motors, which are controlled via momentary, center-off toggle switches. Momentary switches were chosen so that power to the motor ceases immediately upon release of the switch. Both motors have been fused to protect them from potentially damaging surges of current. The switch controlling the gripper's motor has been wired to two light emitting diodes (LEDs) to indicate operation of the unit in the forward and reverse directions. (See Fig. 20.4 for wiring schematic.)

The arm of the gripper was manufactured from $\frac{5}{8}$" outer diameter, $\frac{3}{32}$" wall thickness aluminum tube stock. At the chair, the arm is attached to the shaft of a PMDC motor and gearbox transmitting 90 in-lb of torque and rotating at 5 rpm. The opposite end is mounted to the gripper with a custom-made clevis attachment that allows for adjustment of the angle the arm makes with the gripper and ground plane.

Microswitches are mounted on the face plate of the motor to limit the travel of the arm between two extreme positions. Just as important, however, they protect the motor from burning out should the client fail to release the switch controlling the arm's motion.

The gripper is likewise powered by a PMDC motor and gearbox that generates approximately 17 in-oz of torque at 600 rpm. The shaft of the motor is connected to a t-20 threaded rod via a slip coupling. As the threaded rod rotates, it drives a set of "fingers," free to slide on roller type bearings made from delrin plastic in slots milled in the side pieces, towards a set of stationary fingers. Any object that is placed between the fingers will be held in place by the force resulting from the torque applied to the threaded rod. The fingers were manufactured from $\frac{1}{16}$ inch thick aluminum sheet. The compliance inherent in such thin pieces of material has proved to be an added precaution against crushing the objects. To increase the friction between fingers and object and provide increased cushioning, the ends of the fingers have been coated with a flexible, rubber compound.

Should the operator fail to release the switch when the fingers have closed fully around an object, the slip coupling will protect the gripper and object. This commercially available coupling consists of two friction plates that "slip" against each other when a certain torque is attained (adjusted for this application to deliver a maximum resultant grip force of approximately 7 lbf - comparable to that of a human grip). In this way, the threaded rod driving the fingers is halted while the motor shaft is allowed to continue rotating. Again, similar to the limit switches for the arm, the addition of this component serves to limit the gripping force generated by the gripper, and to protect the motor from burning out due to overload.

Sequence of operation

1. With the arm in the fully or partially upright position, and the gripper fingers completely open, the operator maneuvers her electric wheelchair to within reach of the dropped object.

2. The toggle switch controlling the raising and lowering of the arm is activated so that the gripper is directly over the object. At this point, wheelchair position is also readjusted accordingly.

3. The gripper is lowered the remainder of the distance to the ground so that the object is between the two sets of fingers.

4. The switch controlling the motion of the gripper fingers is activated until the object is securely grasped.

5. The arm is now raised to the completely upright position so that the gripper and object are well within the operator's reach.

The final prototype has proven to be very effective in gripping and transporting the objects specified above. Also, the simple, two-switch control box is very easy to understand and hence very user friendly.

The entire cost of parts and materials is approximately $350.

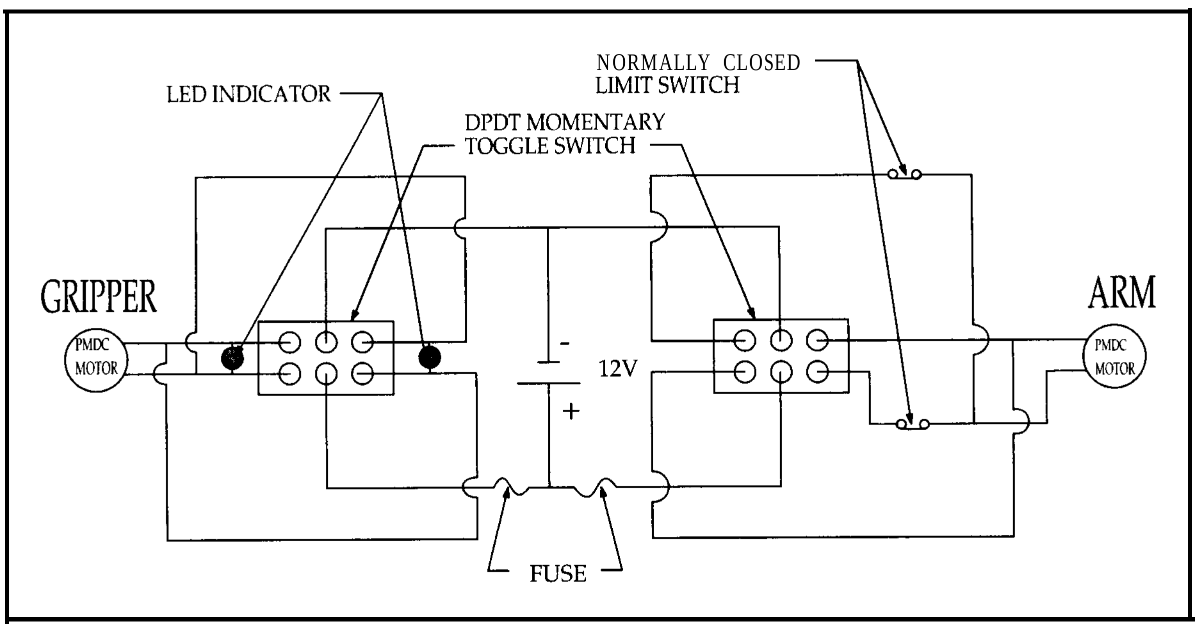

Figure 20.4. Wiring Schematic for Reacher/Gripper Device.