CHAPTER 6
MISSISSIPPI STATE UNIVERSITY

College of Engineering
Department of Agricultural and Biological Engineering
Box 9632
Mississippi State, Mississippi 39762-9632

Principal Investigators:

Jerome A. Gilbert (601) 325-3280
Jonathan W. Pote (601) 325-3282

An Ultrasonic Ranging System for the Blind

Designer: David T. Batarseh
Client Coordinator: Ms. Debbie Baker-Upton, MSU Student Support Services
Supervising Professors: Drs. Timothy N. Burcham, Filip S. To, Gary M. McFadyen, Jerome A. Gilbert
Department of Agricultural and Biological Engineering
Mississippi State University
Mississippi State, MS 39762

INTRODUCTION

The purpose of this senior design project is to develop a mobile ultrasonic ranging system for the blind. Currently, the most common method of range detecting used by blind people is the walking stick. The walking stick is economical, durable, and serves its limited purpose well. The limitation of the walking stick is that a blind person must come into close proximity with their surroundings to determine where an obstacle may be (i.e., bumping into walls and trees). This project uses the Sona Switch™ 1700 ultrasonic sensor to solve this problem. This sensor has 1) a DC voltage output that is a linear analog of the distance measured and 2) an internal solid state switch. Properly designed circuitry converts the DC voltage from the Sona Switch into an AC frequency that drives (oscillates) two small headphone speakers. The result is a system that produces a varying frequency of chirps that is a linear analog of the distance measured. By becoming acquainted with the different frequency of chirps emitted by the speakers, the user can estimate the proximity of an object. The user can also use the Sona Switch's internal switch mechanism. As described more thoroughly later, this mechanism allows for the production of a constant frequency of chirps on objects detected within a certain range. The sensor is mounted on a helmet allowing for mobility and control.

SUMMARY OF IMPACT

The ultrasonic ranging system developed allows a blind individual to "see" pathway obstacles that are outside the walking stick range and determine the distance to the obstacles. The device works in both outdoor and indoor conditions. For example, a blind individual can walk within a parking lot and determine the relative distances to the parked cars. The individual can use the apparatus inside a building to determine if he or she is in a hallway, where the doorway is to a room, and to estimate the perimeter of the room. However, this system requires practice in order to be useful. For example, when a blind individual is walking down a hall, he or she will hear a frequency of chirps while glancing left or right. While looking forward, the user hears nothing until the end of the hallway is reached (a wall). Over time, the user will recognize this pattern of chirps and correlate them with a hallway environment. With further practice, the user can form a mental picture of the environment based on the different patterns and frequency of chirps elicited. The user easily hears the frequency of chirps and can adjust the volume for different noise level environments.

TECHNICAL DESCRIPTION

The Sona Switch™ 1700 ultrasonic sensor is the main component of the ultrasonic ranging system. This sensor uses a pulse of ultrasonic waves to determine the distance to oncoming obstacles. The Sona Switch™ 1700 sensor has two essential features: 1) a DC voltage output that is a linear analog of the distance measured and 2) an internal solid state switch. These two features are used to produce a system that functions in an analog or digital mode of detection.

The analog mode of detection is accomplished by using the DC voltage output of the Sona Switch. Using computer calibration software, the Sona Switch is calibrated via an RS-232 serial port to produce a DC voltage output ranging linearly from five Volts on objects detected at 1.5 feet or less to zero Volts on objects detected at twelve feet or more. The analog voltage produced by the Sona Switch feeds into the AD654 monolithic voltage-to-frequency (V/F) converter. The AD654 converts the DC voltage from the Sona Switch into an AC square wave frequency that oscillates two small headphone speakers.

The frequency output of the AD654 varies proportionally to the output voltage from the Sona Switch according to the following equation:

$$Frequency_{out(AD654)} = \frac{4 \times V_{out}}{\Omega F}$$

Therefore, the frequency of chirps emitted by the speakers ranges linearly from zero Hz at distances greater than or equal to twelve feet (0 V_{out}) to 20 Hz at distances less than or equal to 1.5 feet (5 V_{out}). By becoming familiar with the different frequency of chirps emitted, the user can determine the proximity of an object

The digital mode of detection is accomplished by using the internal solid state switch of the Sona Switch and an installed external circuitry switch. The external switch disconnects the analog DC voltage output line leading from the Sona Switch into the AD654 and reconnects the AD654 voltage input to a five-Volt source. This source is a Radio Shack model 7805 five-Volt regulator. The internal switch of the Sona Switch relays the AD654 to ground. Upon object detection, the internal switch closes allowing current to drain from the five-Volt regulator through the AD 654 and into ground. The AD 654 then produces the corresponding frequency output of 20 Hz. The internal switch is computer calibrated to close at object detection depths less than or equal to five feet. This gives the user an "alarm" when they are within five feet of an oncoming obstacle.

The Sona Switch™ 1700 is mounted on a lightweight biker's helmet with the sensor face lying horizontally (See Figure 6.1). Mounting the sensor on the user's head allows for accurate depth perception in whichever direction the user may be facing. It also allows for excellent echo pulse response and less wave disturbance due to the conical wave output angle of the sensor. The speakers are the stereo "walkman" type without a headband. Power is supplied to the Sona Switch™ 1700, AD654, and speakers by a 15-volt 650 mAmp-hr. power source. The AD654, power source, and other circuitry components are soldered to a breadboard. The breadboard is encased in a plastic experimenter box, and attached to the user's belt. The power source which is constructed of twelve 1.25 V batteries is also enclosed in a separate experimenter box and attached to the user's belt. Volume control, headphone and power jacks, and the input interface jack of the Sona Switch are also incorporated into the circuitry and experimenter boxes.

The final cost of the ultrasonic ranging system was approximately $510. Further details may be obtained from the designer.

Figure 6.1 Ultrasonic Ranging Device.

Backpack Transfer Device

Designers: Thomas Cabell, Brian Deuter
Client Coordinator: Ms. Debbie Baker-Upton, MSU Student Support Services
Supervising Professors: Drs. G.M. McFadyen, J. Bumgardner
Department of Agricultural and Biological Engineering
Mississippi State University
Mississippi State, Mississippi 39762

INTRODUCTION

A backpack support, storage and transfer device has been designed to facilitate independence for a student with cerebral palsy. The device (Figure 6.2) consists of three components: the track, the carriage and the mounts. The track is aluminum and has a 90^0 curve in the middle of it. The carriage consists of six ball bearings and a rectangular piece of aluminum. One bearing supports the load while four others keep the rectangle tangent to the track. The mounts are also made of aluminum. The front mount clamps to one of the two main frame supports of the chair. The two rear mounts clamp to a bar that is mounted behind the seat of the chair. At present, many students in wheelchairs carry their books and belongings by wrapping the straps of their backpack around the two handles on their wheelchair. This is the best place for the books because it is out of the students' way and it does not interfere with the mobility and clearance of the chair. This results in a dependence on others for books and supplies in and out of class. The approach taken was to devise a system that would store the books behind the chair thereby maintaining the chair's profile and clearance while allowing the books to be moved to the side of the chair when needed.

SUMMARY OF IMPACT

This device was designed for a particular client but could be adapted to fit many styles of wheelchairs. Several of the client's friends in wheelchairs have expressed a great interest in the device as well. The client could not be more pleased. She is now able to retrieve her books and supplies whenever she wants and no longer has to rely on someone else for her books. This has increased her level of independence and freedom dramatically.

TECHNICAL DESCRIPTION

This device was designed for a particular client but could be adapted to fit many styles of wheelchairs. The main design requirements of the device were: 1) the device, when not being used, had to be within the plane of the chair, i.e., no part of the device could extend past the rear wheels; 2) it had to be easily removed and remounted in case of emergency, or when the wheelchair was being transported by vehicle; 3) it had to be as light as possible so as not to affect the handling of the chair or to excessively drain the battery due to the increased weight; 4) it had to be motorized due to the limited strength and mobility of the client; 5) it had to guide the backpack far enough around to the side and at an accessible height to allow access by our client; 6) the device had to be mounted so that in no way does it damage or cause a permanent alteration to the chair.

The device consists of three main components: the track, the carriage and the mounts. The track is a 40 by 4 by ¼-inch rectangle of T6-6061 aluminum. It is curved 90 degrees roughly in the middle with the 4-

Figure 6.2. Device Mounted on a Motorized Wheelchair.

inch-wide face mounted flush to the side of the wheelchair. At the front of the curved track is a piece of aluminum box tubing, 1 by 1 by 18 inches. The tubing is mounted to the track with two 5/16 by 2-inch steel screws that insert into the front mount, which is clamped to the wheelchair frame under the left side of the chair. The track is supported in the rear by two rectangular shaped mounts, 2¼ by 2½ by 3 inches, which clamp around a bar mounted to the seat posts of the chair. These rear mounts are each secured by four ¼-inch allen bolts. The rear mounts are mounted four inches apart. The track is attached to these mounts by way of a block-in-channel mechanism. At the top of each rear mount is a smaller rectangle with a ¼-inch hole in it. Mounted to the track are two channels with each channel matching the length, width, and depth of the rectangle on the mounts clamped to the chair. The channels on the track slide down over these rectangles and a bolt is placed through the channel and the rectangle securing both together. The channels are attached to the track by aluminum spacers, 1 by 1½ by 2½ inches. These spacers are then attached to aluminum plates, 2 ½ by 3 ½ by ¼ inches, which are mounted to the track via four ¼-inch countersunk allen bolts.

The carriage uses six 7/8 by ¼-inch ball bearings to support and guide the weight of the books. One bearing is located at the top of the carriage and supports the load. It runs along the ¼-inch-wide top of the aluminum track. The bearing is attached to carriage by a 5/16-inch steel bolt. The backbone of the carriage is a rectangular piece of aluminum, 1 by 3/8 by 6 inches. Mounted to the other side of the top bearing is a rectangular piece of aluminum, ½ by 2 by ¾ inches, in which is mounted two more bearings that are mounted horizontal and tangent to the inside of the track. These bearings react against the weight of the books to pull the top bearing off the track. On the other side of the track in between the carriage backbone and the track is another set of bearings mounted 1½ inches from the bottom of the track. These bearings are mounted horizontally, i.e., perpendicular to the track, and also react against the weight of the books pushing the carriage into the track. These bearings also keep the carriage tangent to the plane of the track as it moves around the curve. A sixth bearing is mounted underneath the track to promote rotational stability and to stabilize the carriage when encountering bumps and other jars. Attached to the backbone of the carriage is an L- shaded piece of aluminum made of two pieces welded together. The vertical piece is 10 by 5 by ¼ inches. The horizontal piece is 9 by 6 by ¼ inches. This L-shaped has 5 5/16-inch holes in it through which the backpack is attached via grommets inserted in the backpack in the corresponding areas.

Backpack transportation is provided by a 24V DC reversible gear motor attached directly to the rear of the track. This motor is powered by the 24V system of the wheelchair and is powered by plugging an ASM three-prong plug into the recharge jack. The backpack is then moved by a cable that is wrapped in opposite directions on a partitioned drum that is mounted to the shaft of the motor. The cable is wrapped around a nylon bushing that is located on the front of the track. The carriage is attached to the cable by a screw and washer that is tightened down over the cable. The cable runs between the track and carriage.

Two lever-type limit switches are mounted to the track to prevent motor overload and burnout. Both switches are wired in the normally closed position. One switch is mounted at the front of the track just before the aluminum box track support. This switch is wired to cut the power in one direction only so that contacting the switch opens the circuit that moves the pack forward but the backwards circuit is still closed. The second limit switch is mounted to the rear of the track and prevents the backpack from running into the motor in the same manor as the first switch. The system is controlled by a DPDT on-off-on switch mounted to the front of the track.

The device was mounted and tested on our client's chair for one week. The device performed well under normal, everyday classroom situations and in travel across campus. The device moved the books from the rear of the chair to the side without problems and our client was able to have access to her books whenever she wanted. The device is easily removable with only the mounts remaining permanently on the chair. These can also be removed with no damage to the chair.

Final cost of the backpack transfer system is approximately $1,300 including parts and labor.

Motorized Wheelchair Table

Designers: Jason Keeley & Michael Roach
Client Coordinator: Ms. Debbie Baker-Upton, MSU Student Support Services
Supervising Professor: Drs. G. McFadyen, S. D. To, J. Gilbert and Ms. Kim Reed
Agricultural and Biological Engineering
Mississippi State, MS 39762-5465

INTRODUCTION

In many of the classrooms on campus at our university, tables are not readily available to students with disabilities for taking notes or doing class work.

These students have tried wheelchair tables in the past and have not been pleased with the disadvantages of such devices. There were a number of factors to consider in designing such a device for them. Some of the disabled students had an arm reach basically limited to the armrest of their wheelchair. This made it difficult to move tables that required reaching outside the armrest. Strength is also a limiting factor; some of the students can only lift relatively small weights, less than five pounds, repeatedly. In the past, because of these limiting factors, assistance was needed for these students to be able to move a wheelchair table in and out of position.

The purpose of this project was to deal with these limitations by designing a motorized wheelchair table that could be operated repeatedly and independently. The design mounts the device on the side of the wheelchair, with a switch in an easily accessible position for the student. The motor will rotate the table from the in use to the stored position shown in Figures 6.3 and 6.4.

SUMMARY OF IMPACT

Disabled students are sometimes reluctant to use facilities that do not accommodate them properly. This device will allow these students to enjoy the use of a table for doing in-class work, as well as work outside of the classroom. The device is controlled via a switch mounted in a convenient position on the wheelchair, and therefore will not require the assistance of others. Devices such as this one give such students more independence in their daily lives.

Figure 6.3. Table In Use Position.

TECHNICAL DESCRIPTION

The table is rotated in and out of position by a 12-VDC geared motor. The motor provides 43 in-lb of torque at 4.5 RPM. A circuit was constructed to control the device. It contains a double-pole double-throw momentary ON-OFF-ON switch that allows the motor to move the table between positions. When the switch is pressed in the forward direction, an electrical path is established between the battery and relay-2 as shown. This allows the motor to rotate the table until it makes contact with limit-2, which energizes relay-2 and establishes an alternate path to reverse the process when the switch is thrown in the reverse direction.

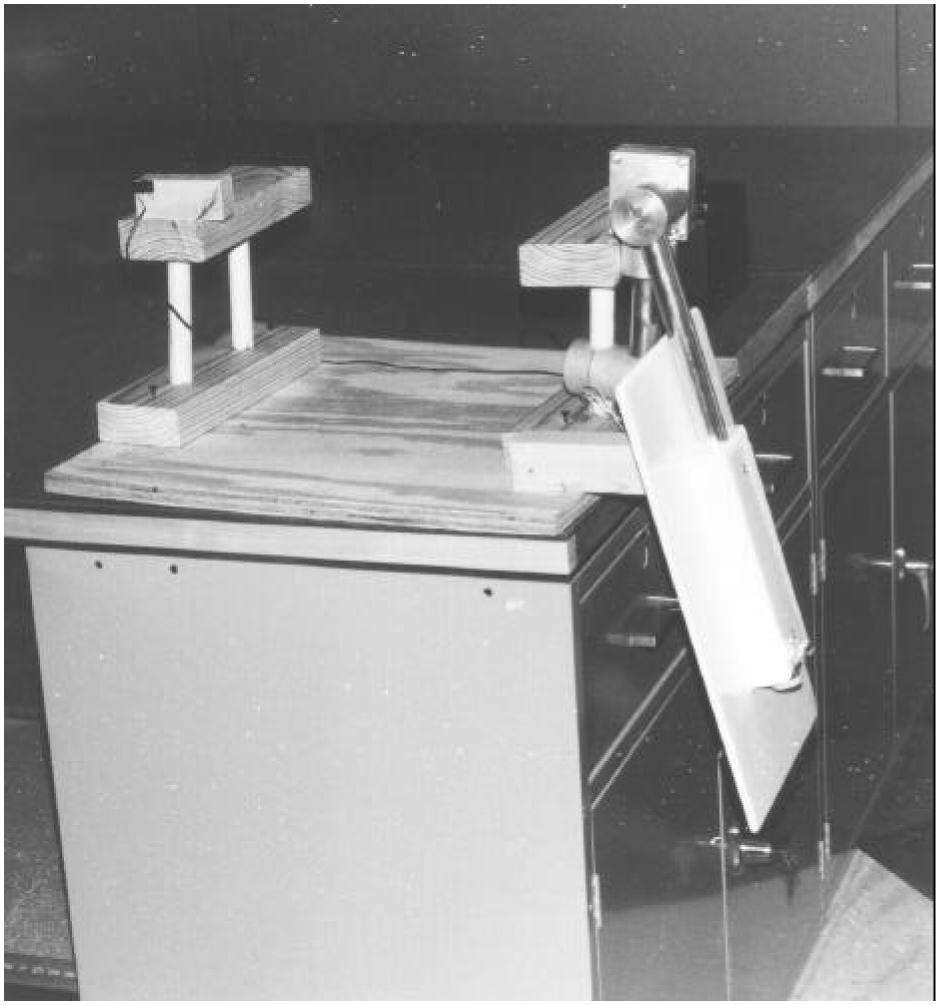

Figure 6.4. Table in Stored Position.

The Dog Walker

Designer: Kendra Ferrell
Client Coordinators: Mr. Mike White, Ms. Debbie Baker-Upton, MSU Student Support Services
Supervising Professors: Ms. Kim Read, Dr. G. McFadyen
Department of Biological Engineering
Mississippi State University
Mississippi State, MS 39762

INTRODUCTION

A device has been designed to aid a disabled client in walking his dog. The design consists of two components, a connector piece and a latching spring. The connector piece is a "u" shaped piece that fits snugly on the client's wheelchair. While not in use, the piece remains on the chair and can be disassembled if needed. The latching spring can be connected on two sides, one side to the dog's leash and one side to the connector piece on the chair. The latching spring can be removed along with the leash when not in use.

SUMMARY OF IMPACT

A paraplegic needs the use of his hands to control his movement in a wheelchair. If he wishes to walk his dog, he must hold the leash of the dog as well as propel himself along. This could cause injury if the dog lunges out of control or if the leash tangles in the wheel of the chair. It is important that the client has full control of the wheelchair in the event of such cases. The dog walker meets these needs of the client.

TECHNICAL DESCRIPTION

The dog walker was designed with a particular student-client in mind, but could be both beneficial and recreational to many student-clients. The main design requirements of the swing were: 1) it had to control the dog's lunges so as not to pull the client over; 2) it could not void the warranty the wheelchair; 3) it would be lightweight; 4) it would be easy to remove if the need arose; 5) it would not be in the way while in use; and 6) it would allow the client to propel himself along without the hassle of holding the dog's leash. Finally, it had to be safe to use.

The dog walker has two main components, the connector piece and the latching spring. The connector piece is an aluminum piece that was bent to fit a 1-inch diameter bar on the client's chair. Two ¼-inch holes were drilled in the connector piece, one being flush with the wheelchair bar and the other being an inch above to allow for connection of the latching spring.

The latching spring consisted simply of a spring with two clasps placed on either side, one to attach to the connector piece and one to attach to the leash of the dog.

In order to find the proper spring for the device, the force that the dog pulled was measured with the use of a scale similar to a fish scale. From this, a factor of safety of 2 was calculated and the proper spring was chosen. The proper bolts where found by calculating the shear force of the bolts on the device.

In order to find the proper placement of the device, testing of the device was conducted by having the client place the device on his chair in two different locations, the front and the back. The proper placement of the device was found to be on the back of the client's wheelchair where it would be easily accessed, would control the dog's lunges, and would be out of the way when not in use. One modification that came out of this test was the use of shorter leashes.

The final cost of the wheelchair spring was approximately $40.

Figure 6.5. The Attachment of the Connector and Latching Spring to the Wheelchair.

Wax Dispenser

Designer: Theresa Polk
Client Coordinators: Mr. Mike White, Ms. Debbie Baker-Upton, MSU Student Support Services
Advising Professors: Drs. G. M. McFadyen and S. D. To
Agricultural and Biological Engineering
Mississippi State University
Mississippi State, MS 39762

INTRODUCTION

Allied Enterprises is a company that evaluates and trains individuals with disabilities in a real-life-manufacturing environment. One of their training facilities produces candles. Currently, the employees use metal pitchers to fill the candle containers with wax. This method has proven difficult for the employees to master and creates too much variation in the amount of wax poured into each jar.

The approach taken to solve this problem was to automate the candle pouring process. Several requirements had to be considered in the design. The first was that it had to be simple to use. This is because the device will be used by employees with cognitive impairments. The second requirement was that the volume of wax dispensed had to be adjustable to account for the various sizes of candles poured. Other requirements were that it had to be easy to clean and have a capacity of at least two quarts to prevent frequent filling.

The selected design has a battery operated time delay relay and solenoids (Fig. 6.6). The solenoids are attached to a plug in a funnel. The relay is set to operate the solenoids that control the volume of wax dispensed from the funnel. The employees are required to fill the funnel with wax, set the relay for the size of the candle to be poured, roll the device over the jar and push the button. This is simple enough for them to use. The one and one quarter gallon funnel can be unscrewed from the container to be cleaned.

SUMMARY OF IMPACT

The recipients of the device can now work more efficiently. They operate the device by rolling it over the empty candle containers and pressing a switch. The device automatically fills the candle jars. There are fewer errors so employees spend less time repouring unacceptable candles.

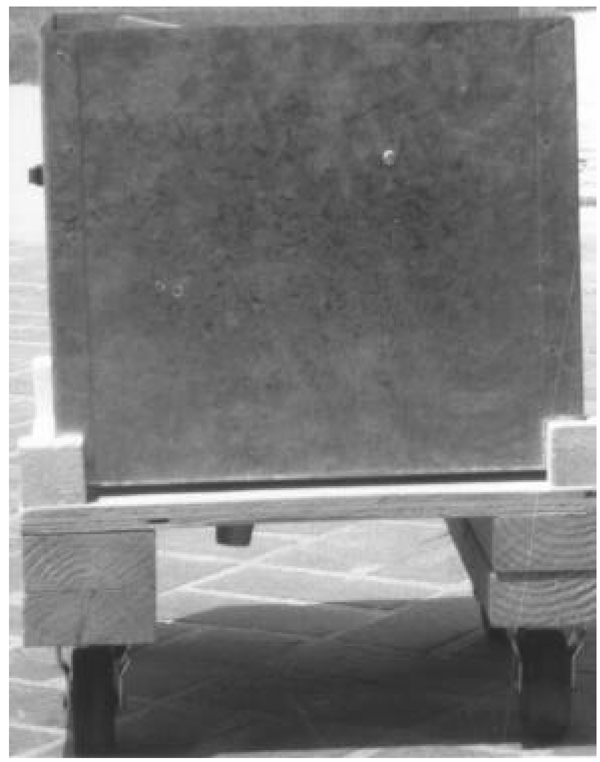

Figure 6.6. Outside View of Candle Wax Dispenser.

DESIGN ALTERNATIVES

The original design was for a valve in the spout of the funnel that would control the out flow of wax. This design was not implemented because of the cost of the necessary valve. The use of the solenoids and the other necessary changes were much more cost effective.

TECHNICAL DESCRIPTION

The funnel acts as a holding tank for the hot wax. The employees adjust the time delay relay for the size of the candle being poured. Then they push the switch. The solenoids pull on the lever that pulls the plug in the bottom of the funnel. The relay keeps the solenoids on for the allotted time and then releases, plugging the funnel. The employees then roll to the next candle and repeat the process.

The total cost of the project was $250.

Figure 6.7. Inside view of Candle Wax Dispenser

Quad-Friendly Lap Table

Designer: Kris Geroux
Client Coordinators: Mr. Mike White, Ms. Debbie Baker-Upton, MSU Student Support Services
Supervising Professors: Dr. Gary McFadyen, Ms. Kim Reed, and Dr. Jerome Gilbert
Department of Agricultural and Biological Engineering
Mississippi State University
Mississippi State, MS 39762

INTRODUCTION

A wheelchair lap table has been designed for a quadriplegic at Student Support Services at Mississippi State University in Starkville, MS. The client sustained a spinal injury in a gymnastics accident in 1986 and subsequently has limited control of his arms. The client was not happy with other laps boards that were available. He was excited about having a lap board design that was customized for him.

SUMMARY OF IMPACT

This wheelchair lap table is unique in that it has a hole cut out to allow the user to install and remove it at his own convenience. Most lap tables that are on the market today must be attached and removed from the chair by someone besides the user. The mechanism that holds the table in place was adapted from a gate lock. It requires no finger dexterity. It will lock into place by just sliding the table into place through the locking mechanism. To remove, the latch can be pushed with the wrist that frees the table from its locked position.

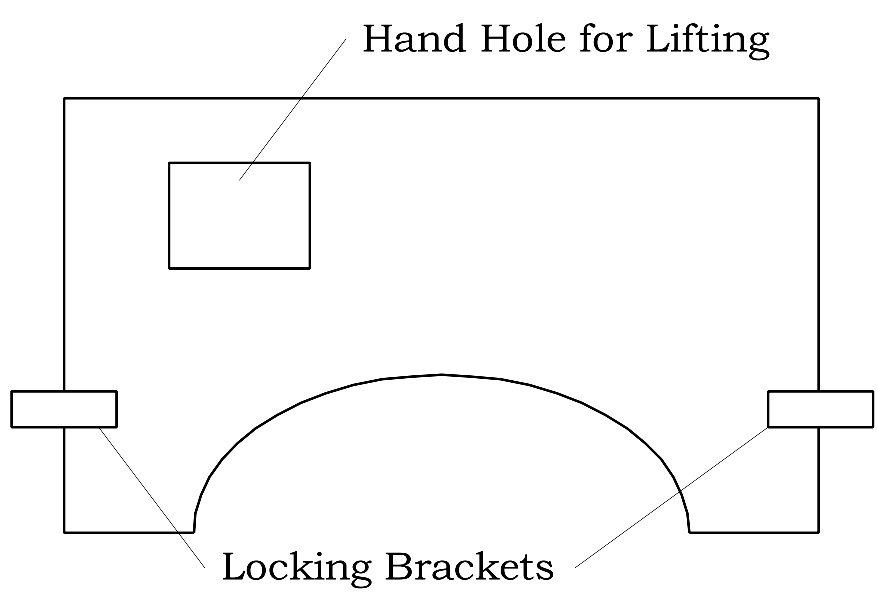

Figure 6.8. Line Drawing of Lap Table Layout.

TECHNICAL DESCRIPTION

After consideration of a number of factors such as weight, cost, strength, and impairment of front vision when in place, Plexiglas was chosen as the material for the construction of the lap table. The table is constructed of ¾ inch Plexiglas and a locking bracket. The layout of the board is shown in Figure 6.8.

The table is rectangular in shape with an arc cut out in the middle to allow the table to fit around the abdomen of the client. The locking brackets have been installed on the ends to allow the table to lock into place on the top of the armrests of the client's wheelchair. There is a square hand hole that has been cut out in the upper left corner of the table to allow the client to insert his hand and use leverage to lift the table independently. Figure 6.9 shows the actual board, as it would fit on the wheelchair.

The total cost of the board was approximately $75.

Figure 6.9. The Quad-Friendly Lap Table as it Fits on a Wheelchair.