Collapsible, Lightweight Power Chair

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Executive Summary

Annalee is a 10 year girl with Cerebral Palsy. Cerebral palsy is a disorder that affects the body’s balance, movement and posture. The lightweight power wheel chair will provide her with a chair which can both offer her support and mobility so she can explore other indoor environments other than her home. The power chair will also accommodate Annalee for her growth over the next few years as seat and strap adjustments will be constructed. The power chair will contain several components such as the joystick, seat apparatus, and wheels with gears system controlled by a motor which will be run by a battery. The main criterion required for the chair is lightweight, portability and adequate support for Annalee.

The wheelchair with its safety and support mechanisms will allow Annalee to be supported within the chair and it will allow for her to explore environments other than her home in a safe manner. The lightweight and portability will allow her guardian to place it within a vehicle and be used in other indoor environments. The chair will be expensive to build due to the nature of the project; it must be lightweight but at the same time durable and still support her adequately. This chair will provide her with the freedom of movement through her environments in a lightweight, independent, portable fashion which none of her chairs to date can provide.

1 Introduction

1.1 Background

Annalee Hughes is a 10 year old girl with Cerebral Palsy. Cerebral Palsy is a non-curable disease caused by abnormal development or damage to the motor control center of the brain during brain development. This part of the brain is responsible for the control of muscle tone and motor activities. Generally, Cerebral Palsy affects the body’s balance, movement, and posture. A major symptom caused by this disorder is spasticity or muscular hypertonicity. Spasticity causes certain muscle to continually receive messages from the central nervous system to tighten and contract. The continuous and permanent “over-fire” of the central nervous system causes the muscles to be unable to regulate themselves, which results in uncontrollable stiffness or tightness that
interferes with movement. To reduce this continuous over-firing and symptoms a baclofen pump can be placed in the abdomen that will continuously release medicine into the spine.

In Annalee’s case this disorder has enabled her to walk or stand unassisted. Her legs and feet tend to remain twisted together. She doesn’t have the strength to push her legs apart and keep them in that position. Due to the baclofen pump placed in her abdomen, Annalee has very poor trunk strength. Her abdominal and back muscles are not strong enough to keep her in the upright position and she leans forward consistently. Supportive safety straps are needed to maintain her balance and posture when seated. Annalee’s has slight more muscle control on the right side of her body this allows her to control her own power wheelchair with a joystick, giving her a little independence.

Annalee is permanently confined to a wheelchair but just like any other child of her age she can read, learn and respond appropriately to her surroundings. She is very active and enjoys interacting in public settings other than her home. Annalee has various wheelchairs, but out grows them quickly and only one provides the ability for her to move around independently. The chair that she currently uses is not feasible for travel because it is very big, heavy, and bulky. Her parents can’t easily put the chair into their van and when in houses other than her own home she has difficulty moving around. Since her home was design specifically to accommodate her wheelchair. Annalee does have two portable wheelchairs but out grew both chairs within a year. The two chairs aren’t ideal for her because she likes to be independent and someone needs to assist her at all times since neither of the chairs are powered.

1.2 Purpose of the Project

The purpose of this project is to design an inexpensive lightweight, portable, compactable powered wheelchair for Annalee that will support her health needs, while giving her more independence and allowing short social gatherings to be a little easier. The powered wheelchair will be light weight and compactable enough so that any adult individual can pick it up easily and transport it in any type of vehicle. Since, Annalee is actively growing the chair will have adjustment so that her growth will be accommodated and her chair will last longer than one year. The chair will be powered giving Annalee more independence in social settings but also have handles to ensure she can be helped when needed. The chair will be designed to so that it can fit through
standardized doors so movement within other people households will be possible. The most important aspect of the chair is that it will ensure Annalee’s safety and health needs. There will be a tilt option on the chair that will help reduce the amount of stress on Annalee as she has a tendency to lean forward and fatigues easily. Also, adjustable straps and support braces will be designed into the chair to ensure Annalee is anchored into the chair appropriately. Since, the main purpose of this chair is to make it lightweight and portable the battery and motor will be limited on their dimensions and weight. The wheelchair will only be used for short outings so the battery and motor won’t need as much power. This will result in the chair being slower the maximum speed is only expected to be 5 mph. The battery life is only expected last 2-3 hours but also be durable so that it will not be replaced repeatedly. The wheelchair is also expected to be maintainable so all part that are needed for it can easily be replaced.

1.3 Previous Work Done by Others

1.3.1 Products

The powered wheelchair in figure 1 was a NSF project designed by people at the University of Massachusetts at Lowell. It has some similar properties that should be included in this project. This powered wheelchair was constructed for a 40 year-old woman with multiple sclerosis. It is controlled by joystick with a maximum speed of 8 mph, the height of the chair can be adjusted, and it has the ability to be disassembled into four main pieces for easy portability. The wheel mounting points were weld in place with a 23” by 21” wheelbase which is suitable for standardized doors. Two 12 volt batteries where need to more a 24 volt source and a PWM controller was used. The total cost of this project was $1500.
There are lots of different products out there that are similar to this project except they are very expensive and don’t include all of the accessories needed for Annalee’s safety and comfort. The electric wheelchair in figure 2 is a product form SpinLife.com it cost $1299.00. The chair uses two 12 volt batteries that power 24 V 420W motor and has a battery life of about 15 mile. The maximum speed is 5 mph. The entire wheelchair folds up and weighs approximately 130 lbs making easily transportable, and it maximum weight capacity is 300 lbs. The rear wheel drive will only allow a turn radius of 30”. 
1.3.2 Patent Search Results

One patent was found for a portable powered wheelchair. A lightweight motorized wheelchair was patented on December 11, 2001 by Oong Choi and Fred E. Ingle. This patent is a general patent for any wheelchair that is foldable, portable, and motorized. It

2 Project Description

2.1 Objective

The client has asked for a battery-powered, yet lightweight and collapsible wheelchair so that it can be self operated and still easily lifted, stored, or transported. All other chairs that the client has are either too bulky or not battery powered. The bulky chairs cannot be lifted and do not allow Annalee the freedom of movement in all environments. The other wheelchairs are not battery powered requiring Annalee to have assistance in order to move around.

The wheelchair must be joystick controlled so that Annalee will have no difficulty in using it on her own. The joystick will be placed on the right arm rest since she has better muscle control over the right side of her body. The current chair's joystick and previous joystick designs will be taken into great consideration. The previous joystick was an Invacare, MIVA, this joystick was donated but is made completely out of metal and weighs about 15 lbs. The
weight of the wheelchair is one our main concerns; the use of a plastic joystick would be more efficient. The battery must last for two to three hours so that Annalee can use the chair for short visits such as to homes or to the mall. These visits also require that the chair be small enough to fit through a standard size doorway and also that Annalee’s mother has the ability to lift the chair, thus restricting a weight limit to about sixty pounds. In order to achieve a light weight the two largest concerns are the choice of motor and of battery. These ordinarily are by far the two heaviest parts of a power chair. Since the chair only needs to be operational for short periods of time, two to three hours rather than a whole day, this will significantly reduced the necessary battery capacity. Two 12V rechargeable batteries will probably be used.

The chair must have adjustable restraints to fit Annalee and help her stay anchored in her chair. These restraints include a few straps and multiple foam pads on the sides of her chair. There should be a lap strapped that is at a 45 angle with the seat of the chair. The chair must have footrest with heal support and a strap to ensure that her feet remain secure. There will be foam pads needed to maintain Annalee’s support in her chair, they include the following; two side supports to keep her from moving side to side, and a pad placed between her legs to hold her legs apart. The chair must also have a tilt option of 90 to 105°, in reference to the level ground, in order to accommodate Annalee’s tendency to lean forward. The client has also asked that the chair be adjustable. Annalee is a young girl who is still growing so in order to give the chair some longevity multiple parts will need to be adjustable. The foot platform for example will be allowed to extend or retract.

2.2 Methods

2.2.1 The Motor & Battery

Most low price electric wheelchairs have light-duty, two pole wheelchair motors. A two-pole motor is powered by electricity that enters at two points in the motor. This type of motor provides about 1.5 ft-lbs of torque per horsepower. This motor works well for indoor activities but will only withstand less than 250 pounds. The two-pole electric wheelchair motors will burn out easily during heavy driving condition. The more heavy-duty electric wheelchair uses a four-pole motors this type of motor is powered by electricity that enters the motor at four points instead of two. This type of motor provides about 3 ft-lbs of
torque per horsepower and obtains a speed that is half that of the two-pole motor. With this type of motor the electricity and heat are distributed evenly making the motor have a lower rate of burn out. Another type of motor that could be used is a brushless, gearless motor. This type of motor is a rather new innovation they have few mechanical parts that come into contact, making this type of motor a lot more durable then the two or four-pole motors. This type of motor provides opposing drive wheels so that the axles of the drive wheels are coupled directly to the rotor of drive motor. The brakes are housed within the motor and come in direct contract with the rotors. Permanent magnet rings within the motor are magnetized and create a trapezoidal wave function. The wave function generated by the motor in turn is used by the microprocessor to control the two opposing drive wheels. A belt driven wheelchair could be another possible option for the wheelchair. These type of wheelchairs are very quiet by require a lot more maintenance then those that are driven by gears.

There are various batteries and chargers that could be used for powering these motors. Most likely two motors will be used, and two rechargeable 12V batteries with an amperes*hour between 17 and 24 would be efficient. The charger that would be most efficient for this type of battery unit would be a 24V charger with a current between 3 and 5 amp. A light weight electric wheelchair with a speed of 4.35 mph would use a 24V/200W x 2 motor power with two 12V 24AH batteries.

2.2.2 The Joystick

There must be much consideration to the joystick chosen, as there are three basic types of joysticks that exist. These are paddle, digital and analog. Each of these styles has different features and different complexities. The more complex the joystick the more control delivered by the joystick. The joystick needs to allow Annalee movement in any situation.

The first type of joystick is the paddle joystick. This is an old style invented and used in the beginning of television and videogames. It consists of only one potentiometer and has a very limited range of motions. The digital joystick has an increased range of motion, allowing for movement in any mechanically possible direction. These means it is limited two eight directions; forward, backward, left, right, forward-right, forward-left, backward-right and backward-left. This type of joystick took over, and was the most common until the invention of the analog joystick.
The analog joystick has been chosen to be used for Annalee’s wheelchair. This is because the analog joystick provides the widest range of motion. It works by use of either multiple potentiometers or by a magnetic flux detector, which determines the stick’s displacement from the neutral position. While a flux detector would be a better choice, seeing as it can sense any direction or angle, it may not be feasible due to the budget.

2.2.3 Wheels

Powered wheelchairs can have three, four, or six wheel mounting points. Typically wheelchairs are made with two sets of wheels, two larger ones in the front and two smaller ones in the front. This type of wheelchair is very stable but doesn’t have a very tight turn radius. There are some specialized sports wheelchairs that have only one small wheel in the front and a set of wheels in the back. Usually, the three wheeled chairs need bigger tires to make it stable, and the turn radius is a little better than the four wheeled chair. The other option which is usually used by high-end power wheelchairs is to have three sets of wheels (or six wheels all together). The wheelchairs that use six wheels usually have an excellent turn radius, some can even turn 360° without any motion. They are much more stable than either of the other types of chairs and have a high weight capacity.

Wheelchairs can be powered in three different ways, front wheel drive, rear wheel drive or mid wheel drive. Rear wheel is the standard and most common method for powering the chairs. This method allows for faster speeds though with a drawback with the turning capabilities. Front wheel drive provides tighter turn functions at a cost of speed. Front wheel drive also helps for uphill and uneven surfaces however the driving mechanics are difficult and much care needs to be undertaken when turning as the wheels are in front of the chair. Mid wheel drive will allow for even tighter turning but at a cost of stability when stopping and starting.

Due to the nature of the wheelchair it would seem that mid wheel or rear wheel would be the best choices. Given the fact that the chair needs a short turn radius, the difference in turn radius is not nearly lower enough with the front and mid wheel drive to be utilized. Outdoor use is not a huge concern though being usable on some flat outdoor surfaces such as asphalt is required to some
extent. This again favors rear and mid wheel as front wheel is not a necessity for the purpose of the chair.

2.2.4 Seat and frame

For the seat, the back/head rest can be developed using a wood cutout and placing cushioning around it. This might be a cheaper alternative to buying it separately from a vendor. Additionally if the seat is to have reclining abilities the appropriate mechanism must be constructed. The patient's back will be measured to determine the lower lordosis and upper kyphosis for the seat to gel to Annalee's back. Arm rests and a footrest will also be constructed with plastic to keep it lightweight. Straps will be tied to the seat and the arm/leg rests for safety.

The frame will consist of mainly plastic with possibly some steel supports. The steel needs to be minimized in order to keep it lightweight. Plastic will be the main option but durability will be a problem. The plastic needs to be adjustable and durability will be one of the major issues. With the chair needing to last several years (2-3 years) the plastic will need to last the cyclic loading of the adjustment and folding. Due to the use of the wheelchair, anticorrosive treatment will also need to be undertaken in order for the wheelchair to last for its lifetime. Another possibility would be to use a steel frame from a manual wheelchair. This option would be cheaper if the manual wheelchair was donated. It would also reduce the amount of time needed to design the frame of the chair.
3 Budget

The preliminary total cost of the wheelchair was estimated to be $1,980. The items that are included in this estimate are listed below; these prices were determined by investigation and ignoring donation and personally designed. Since, this is only a preliminary estimate many of the costs will change. Currently we do have a joystick but since the portability of the wheelchair is our main concern the joystick may be too heavy. There is a possibility that the joystick can be designed using computer software and circuitry. The cost of the wheelchair may also be reduced by the donation of a manual wheelchair to construct the frame. If the seats are developed out of wood cutouts and placed into cushioning then this will also affect the cost. Lastly the cost of the motor will be reconsidered when the dimension, weight, and horsepower are determined for the chair.

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<tr>
<th>Items</th>
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<tbody>
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<td>Motors (2)</td>
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<td>Frame</td>
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<td>Total Cost</td>
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4 Conclusion

In conclusion the project will provide the mobility and portability required by the client. It will do this while still providing support for Annalee. The safety mechanisms will keep her safe and the chair will allow for some growth room over a few years. This adjustability and mobility will ensure that Annalee will
enjoy the independence and freedom of the chair for years to come. The chair will be portable enough so it may be transported efficiently by a single person. The battery will last for several hours however will be rechargeable and this will be a perfect on the go power chair for Annalee. The main utilization will be in a mall or store, as well as friends houses where she can visit. This product will encourage Annalee to be more independent and allow her to experience the world in ways she might not have been able to before.

References


