Low Center of Gravity All-Terrain Power Chair

by

Vikram Shenoy, Niaz Khan, Selome Mandefro, Alex Mann

Annalee Hughes, NSF Projects

Tolland, CT; (860)-872-7000
Executive Summary

This project involves the design and creation of an all-terrain power chair for Annalee Hughes, a ten-year-old girl with cerebral palsy. The main purpose of this project is to allow Annalee to enjoy outdoor activities with fewer worries. For this reason, the all-terrain power chair will have the following safety and technical features: safety harness, seat belt, tilt sensor and a low center of gravity. In addition, this device will have adjustable parts such as the clearance, seat, safety harness and safety belt. The design of this device can be classified into three categories which are mechanical, electrical and software. The mechanical features of this device that play a main role in the structure, mobility and safety of the device are the seat, chassis, tires, drive train and suspension. The electrical components are the kill switch, steering, motor, battery and charger inverter. These parts can be used to power and operate the device. The software components include the joystick control and tilt sensor. The estimated cost for building this device is $4400.

1. Introduction

1.1 Background

This project is aimed at designing and building an all-terrain power chair for Annalee Hughes, a ten year-old girl with cerebral palsy. Cerebral palsy is a neurological disease that is diagnosed in children, usually at birth, and permanently affects muscular movement. Annalee cannot walk nor stand on her own power as a result of the disease, and she also has very poor upper body strength. She loves exploring the large, three-acre property on which her house is set, which includes a barn, small pond, and brush from which blueberries can be picked. However, the property is also very hilly and rocky, making it very difficult for her to travel around the yard in her current power chair. She has tipped over in her power chair while trying to access the yard, which shows the need for a new means of transport. She cannot get up on her own power if the current chair tips over. The all-terrain power chair with a low center of gravity will erase the danger associated with the traversing of the rugged backyard.
1.2 Purpose

The ultimate purpose of this project is to design an all-terrain power chair with a low center of gravity that allows Annalee to travel on her property without her or her family having to be concerned with her safety. Her current power chair has proved to be unreliable as she tried getting to various parts of the large yard, and thus a new chair is necessary for her to enjoy the outdoors around her house. As a very adventurous girl, she loves visiting the various parts of the yard, but she needs a safe means of getting there. Safety is the primary concern, and the chief difference between the power chair being built in this project versus the current power chair she uses is stability. The low center of gravity will prevent the chair from toppling over as she meanders around the uneven, rocky terrain of her yard. Furthermore, the chair will exercise other safety features, such as a kill switch, with which she can shut off the chair in case of emergency, and a tilt-meter, which will warn Annalee when she approaches a slope too steep for her to drive. Other typical safety constraints will also be in the chair’s design, such as a seatbelt and harness to prevent her from slipping out of the chair and to help her maintain proper posture.

1.3 Previous Work Done by Others

1.3.1 Products

Previous designs and products have been prepared in an attempt to achieve goals similar to that of this project, which is to create a power chair capable of providing the operator safety when traveling on any terrain. One of these products is the X4-Extreme 4x4 All-Terrain Power Wheelchair from Vestil. This product is intended to take the operator on any terrain, whether it is wet ground, dirt, or sand, reliably. The main difference between this product and a typical power chair is the size of the wheels, which are much larger than those of a normal power chair. It also features items such as a programmable joystick, different seating options, such as a recliner, adjustable footplates, various headrests, a power seat elevator, and other items. The base retail price of the chair is $16995, with some of the add-on items costing an additional fee.

Another product which aims to serve the same goal as the project for Annalee Hughes is the Tracabout IRV 2000. This product is another joystick-controlled mobility device with various features such as power leg rests, a vertical seat elevator, and a recliner. However, instead
of the large wheels that the X4-Extreme uses, it uses treads on its wheels. The retail price is $18498.

A third product designed with the same purpose as that of this project is the X8 Extreme 4WD electric wheelchair from Magic Mobility. The device features a multi-positioning seat, charger, and a standard positioning belt. The base retail price is $14995.

1.3.2 Patent Search Results

The Mountain Wheelchair by HANDI TRAK was patented by Adolf Hammer in 2000 in the category of a small self-propelled vehicle for use by the disabled for all terrain transport. The system was designed for self-assisted access, and had rear motor driven treads that spanned the whole distance of the chair. The vehicle was powered by an internal combustion engine which drove hydraulic or electric motors to control movement. The Mountain Wheelchair was controlled by two armrest mounted joysticks as well as a steering wheel.

2. Product Description

2.1 Objective

The main objective of this project is to design an all-terrain power chair for Annalee Hughes with a low center of gravity. The all-terrain power chair will be designed in such a way she can operate it in hilly and rocky parts of the yard so that she does not tip over and harm her body. In order to achieve a safe device, the design team considered the following safety and technical design features: a seat belt, a center of weight at a different angle, the relationship between her body and the device, communication systems (alarm and driving controller), and the adjustment of the device to accommodate Annalee when she grows up with the device.

In order to do this the all-terrain power chair should have a safety harness, not just only a safety belt, that helps to stabilize her upper body since she has a weak upper body strength that makes her grapple with gravity. As a result, the seat should keep Annalee's posture at angle of 90° at the time of operating the device. Since Annalee is not in complete control of her body, the all-terrain power chair also needs to have a waistband on the side of the seat at an angle of 45° to
prevent her from slipping out of the chair and to hold her firmly. The waistband should secure her pelvis to eradicate any drift of her body. If her pelvis is not secured enough it causes the rest of her body to fall into uncontrolled movement.

This device will be controlled by a joystick interface, which will allow Annalee to control the direction of the device. It will also be used as a brake when in the neutral position. There will be a kill switch to turn the all-terrain power chair on and off. The kill switch is also a vital safety component that will allow Annalee to turn off the device immediately in case she loses control of the device. It is also necessary to have the device be adjustable to a certain limit for instance the seat belt, the waistband and the clearance, in view of the fact that Annalee is a 10 years old child who is still growing. This feature of the device will allow Annalee to use the all-terrain power chair even after she grows up.

Since the main purpose of designing this device is for the safe operation in a yard with rough terrain and in the unevenly paved area, safety and security are the main concern. For this purpose, the all-terrain will be equipped with an alarm system that will notify the operator as they approach exceedingly steep slopes and high speeds. Also, the battery life of the chair need not be as long as the current power chair because it will predominantly used outdoors for short periods of time. For the rest of the time (i.e. indoors), Annalee will mostly use her current power chair, which can be seen below.

Finally, the chair must be able to be kept indoors, so it must be small enough to fit through a standard doorway. Also, in the event of the family going on vacation, the chair preferably would be able to fit in the trunk of a Chevrolet Trailblazer sport utility vehicle.
2.2 Methods

The all-terrain power chair will predominantly be built from scratch, with the exception of the safety harness and seat, which will have to be purchased separately. The design of the device can be separated into three distinct categories, which are mechanical, electrical, and software. These three categories will be interconnected to allow the successful building of the power chair. By specifying these categories, we will be able to logically account for all of the various parts of the device, as well as divide the work efficiently.

2.2.1 Mechanical

The mechanical components of the power chair encompass all of the parts that have a role in the structure and mobility of the device. These parts include the seat, chassis, tires, drive train, and suspension. The way in which each of these parts plays a role in the mechanics of the power chair is described below.

Seat

The seat of the power chair plays a vital role in keeping the proper positioning of the operator. Since the client is unable to maintain herself in the upright position, it is both an issue of safety and health for the seat to be manufactured to precise specifications. Thus, this part will be purchased pre-made from a supplier and modified to mount onto the power chair. The seat also plays an important role in securing the operator via a harness and seat belt. These parts must work in unison to support the client without restricting or harming her as she drives the chair around her rugged yard.

Chassis

The chassis will be built from scratch out of a metal frame, and will contain the axles, battery, drive shaft, motor, and suspension system. It will also be the framework on which the seat is mounted. The seat will be mounted modularly, so that as Annalee grows, it can be interchanged and replaced with a larger seat without having to dismantle or redesign the entire chair. It is very important for the chassis to be able to support the weight of the client, as well as
withstand any external forces generated during operation, such as by rocks or uneven ground. It must be large enough to house all necessary sub-components, but small enough to maintain portability of the device.

**Tires**

The tires will be one of the key differences between the client’s current power chair and the all-terrain power chair. There are two main options that can be used for the mobility of the power chair. One option is to use four large wheels, and the other is to use tread system similar to that of a tank. If four wheels were used, two large tires in the rear would be powered by two electric motors, and their size would account for increased stability and traction. Two smaller, yet still durable and stable, tires in the front would be used as well. The tread system would provide even greater stability, and each could be individually powered to improve maneuverability over obstacles. Wheels are much easier to acquire, but a tread system would provide a unique aspect and increased safety for the client.

**Drive Train**

The drive train is dependent upon the type of wheels chosen for device mobility. If the four wheels are used, then a two-wheel drive system will be used, and thus power will be divided from the motor to the front two wheels. If the tread system is used, then a motor for each side will be utilized for powering the device.

**Suspension**

The suspension of the device is essential for preventing imbalance and tipping during operation, which has happened with the client’s current power chair. Furthermore, since the device will be operated on rough, hilly, and rocky land, the suspension will play an important role in keeping the operator's body stabilized. Annalee's upper body strength is already very weak, and she will not be able to compensate for any extra forces from the terrain.


2.2.2 Electrical

The electrical components of the all-terrain power chair include the motor, steering, and the kill switch. It is the electrical components of the device that will allow the chair to actually operate. From the power being delivered to the wheels to the steering system, the electrical components are very important to the overall successful operation of the chair.

Motor

An electric motor will be used to transmit power to the wheels of the device. It must be able to generate enough torque for the chair to overcome hills and rough terrain, but still be governed to a top speed set by the client. It will be powered by the battery and further specifications will be governed by the form of mobility (tires versus treads).

Steering

The steering will be operator-controlled by a right-handed joystick. It will have a front, back, right, and left control working off of a potentiometer to allow for speed adjustment. When the joystick is returned to its neutral position, the device will not run, due to the properties of the electric motor. If treads are used, a two-button control to operate the left or right tread exclusively will be implemented.

Kill Switch

A kill switch will be implemented for the increased safety of the all-terrain power chair. This will be in the form of a button that will cut off the power from the battery to the motor. This will also function as an on/off switch for the power chair. When set in the off position, the battery will not drain, and the motor cannot operate.

Battery

The two batteries will be used for the powering of the power chair by supplying current to the motor, joystick, and tilt sensor. It can be turned off by using the kill switch, which will stop any
current flowing from the battery. This will subsequently shut down the circuit and turn off the device. The battery will also be rechargeable so that it does not have to be replaced constantly.

**Charge Inverter**

The charge inverter will play a key role in the quick recharging of the batteries. It will allow the power chair to be plugged into a wall socket to charge the batteries. With an efficient inverter, the batteries should be recharged within two hours and last long enough for a day of use.

2.2.3 **Software**

The software components of the all-terrain power chair include the joystick controller and the slope sensor warning system. These are both extremely important components of the chair, as they deal with the control and the safety of the device.

**Joystick Control**

The joystick control will allow Annalee to operate and guide the chair by herself, as she does with her current power chair. It will be made as similar to her current chair as well. The software will be a microcontroller that will allow her to move forward, backward, left and right, and will keep the chair idle when assuming the neutral position.

**Tilt Sensor**

The tilt sensor will also use a microcontroller in its operation. As the device approaches slopes that are too steep, the tilt sensor will recognize the danger involved with the chair's orientation and in turn will set off a warning alarm. It will utilize an orientation sensor that can transmit the signal to the microcontroller, hence setting off the alarm.

3. **Budget**

The following is a list of preliminary parts that will be necessary for the building of the all-terrain power chair. Each part plays a vital role either in the structure, functioning, or safety of the device. Since some of the components are specially manufactured for Annalee, the price is
higher than that of a standard part. For example, the seat must be able to properly support her due to her lack of upper body strength. The total cost of these parts will be approximately $4400. This would be much less expensive than the products already on the market, which have retail prices ranging from $15000 to $18000 and above.

<table>
<thead>
<tr>
<th>Part</th>
<th>Estimated Cost</th>
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<tbody>
<tr>
<td>Chassis/Harness</td>
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<tr>
<td>Seat</td>
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<tr>
<td>Joystick</td>
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<td>Motors (2)</td>
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<tr>
<td>Batteries (2)</td>
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<tr>
<td>Charging Inverter</td>
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<tr>
<td>Tires/Wheels</td>
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<tr>
<td>Shocks</td>
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</tr>
<tr>
<td>Circuitry/Miscellaneous</td>
<td>$100</td>
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Total: $4400

4. Conclusion

Overall, the all-terrain power chair will provide Annalee Hughes with a device she can safely use in her rugged backyard. By creating a power chair that allows her to travel on any terrain, whether it be hills, rocks, or uneven pavement, she will be able to enjoy the outdoors and various features of her property. She needs a way to access the family's barn and pond, but the current power chair is too unstable for her to safely reach those places. She has already tipped over in the current chair, further expressing the need for the all-terrain power chair.

The new chair will implement standard safety features such as a safety harness and seat belt, as well as other items including a kill switch and a tilt sensor. The safety harness and seat belt will keep her stable and help maintain her posture in the seat. The kill switch will provide a means of stopping the device in the event it goes out of control, and the tilt sensor will provide a warning when the device approaches slopes that are too steep for safe operation.
Thus, an all-terrain power chair with all of these features must be built for Annalee in order to ensure her safety as she enjoys the outdoors. It would provide her with an opportunity to explore her large yard by herself, as her condition limits her from doing so already. Nobody should have to feel constrained, and the all-terrain power chair will allow Annalee to feel adventurous and independent.

5. References


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