MECHANICALLY ASSISTED WALKER

A thesis submitted to the
Faculty of the Mechanical Engineering Technology Program
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology
at the College of Engineering & Applied Science

by

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Bachelor of Science University of Cincinnati

May 2011

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ACKNOWLEDGEMENTS

I’d like to dedicate this project to my mother-in-law, Alejandro Mendoza, who suffered a life threatening stroke in June, 2010. Her determination and love of life could serve as an inspiration to all. Without her support, this idea could not come into fruition.

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ABSTRACT

On June 12, 2010, my Mother-in-law was admitted into University Hospital due to what was eventually classified as a stroke. After spending several weeks recovering from surgery, she was released and permitted to start physical therapy at home. I was visiting her one day and realized that she had lost motion in her right arm and wasn’t able to use a walker independently. Someone had to support her right arm and assist her in lifting up the walker while helping her maintain her balance in order to proceed forward. There are many existing products out there that can aid people with handicaps, such as walkers, wheel chairs, and scooters. However, because she lives inside a small home, none of these are practical. They are either too big to navigate around tight corners or can’t address her problem with picking up the walker. My senior project tries to tackle this problem with a solution that is practical. The end result is a walker that will allow someone with partial paralysis to navigate around inside a small home by allowing the user to move the walker without having to pick it up.

There are existing patents that have been filed to try and address this problem, but there are serious flaws. Mr. Perkins filed a patent back in 1981 (1), but the product does not exist in the market today. His idea had several flaws, which included the need to have both of the user’s arms operational in order to control the walker. There was no easy way to control the speed and there were some pinch points that could present a dangerous situation for the user. The components were held together by metal straps that weren’t secured properly and could come apart rather easily. My research didn’t just end with existing patents. Ten users were surveyed to try and gather important information that helped me consider what is really important to the user. Based on their answers, I had a list of design criteria that needed to be met. The top three items on the list were safety, durability, and ease of operation.

This project can be broken down into three different categories. The design included looking at loading conditions on the different parts and motor sizing. The wiring needed to be completed in a manner that allowed for the walker components to work. The programming of the microcontroller needed to have the walker respond to the user interface, which included the potentiometer and the joystick.

The end product was a walker that could assist a person with partial paralysis to navigate inside the home. I designed and built a leg attachment with stepper motors mounted on the inside that didn’t have any pinch points. The holding torque offered by the stepper motors provided a braking effect that was a much desired safety concern. It also maintained its adjustability and portability. The potentiometer was the perfect solution for a speed limiting device and the joystick enabled the user to control the complete motion of the walker with only one hand. The wiring was ran in a manner as to not hinder the user’s motion and the battery life was more than sufficient for a normal days use, which would allow the user to walk over one mile before needing to recharge. After having a couple of users try it out, the response was very good and they feel that there is a market that exists for this project.
INTRODUCTION

BACKGROUND

There are many available products on the market today that help elderly and handicapped people move around within their homes. They range from a simple cane to a Segway that uses gyros and a mini-computer to help maintain their balance. Canes are limited in the amount of assistance that it can provide a person. Segways are nice, but the average person doesn’t live in a house big enough to warrant one. Walkers are the next best thing due to its usability and cost effectiveness. However, limitations also exist for a walker.

There is a sequential order of operations that must be followed in order to properly use a walker. Users place the walker in front of them and step towards it while holding on for support. After the user takes a couple of steps to get himself or herself parallel with the walker, the process is repeated again. Although the previously described actions appear to be really simple, it is a big challenge for users with disabilities. The hardest part for people with partial paralysis to complete is the act of picking up the walker and placing it in front of them. This demands a lot of arm strength and an ability to maintain his or her balance while the walker is off the ground.

PROPOSED SOLUTION

The focus of this design project is to engineer and modify an existing walker that will mechanically assist the user by eliminating the need to pick up the walker in order to advance forward. This will allow people with partial paralysis in their arms the ability to walk independently without assistance from another person. This invention can also benefit an average elderly user because it will help conserve energy and make it easier for them to use their walker. A successful invention will encourage a healthier lifestyle because people will be more likely to get up and walk around, which will strengthen their overall physical and mental health.
RESEARCH

EXISTING WALKERS

There are many commercially available walkers on the market today. They range from the simplest design in the form of a cane to the more sophisticated rollators that offer many features such as a seat and mechanical brakes. Each one offers unique advantages and disadvantages over the others. However, none of them address the problem that has been presented. Users with handicaps, especially paralysis in the arms, are unable to use them effectively. For a complete list of research items, please reference Appendix A.

The Drive Medical Cane (Figure 1) is a simple design, but serves the purpose as a support device for the user. It easily folds and unfolds without the use of any special tools. Despite its lightweight aluminum frame, it can support a person that weighs up to 300 lbs (1). Because it is essentially a rod with a handle, it takes up very little space and can fold small enough to fit into a holster. However, its basic design is also the reason why it’s not very effective for someone that has a hard time maintaining his or her balance.

The Bariatric Small Base Quad Cane (Figure 2) is similar to the Drive Medical cane. However, it has some advantages, which include four legs that provide more stability for the user. Its steel frame offers a maximum weight capacity of 700 lbs (2). There is also a locking ring that provides additional security after the user adjusts the height. The disadvantages of this cane include a total weight of 5 lbs. Although this doesn’t sound like much, 5 lbs of weight on one arm can get tiring after a while. This cane is limited in its portability because it does not fold.
The next step up in walker design includes the Invacare Value Line Walker as shown in Figure 3. This walker offers much more stability with four legs and a wide and deep frame that helps support the user’s weight. The aluminum frame is light weight and weighs a total of 5 lbs 7 oz (3). Even though it weighs almost the same amount as the quad walker, the user doesn’t expend as much energy because it is meant to be handled by two arms.

Figure 3 – Invacare Value Line Walker

The Lumex UpRise Onyx Folding Walker (Figure 4) is unique because it has a second set of handles on the frame that provides the user with assistance from the seated position. Another advantage this walker has is the single release folding mechanism, which makes it easier for people with manual dexterity to fold. The durable aluminum frame tubing provides strength and a maximum weight capacity of 400 lbs (4).

The walkers that have been discussed so far require that the users have an ability to maintain their balance and the strength to pick up the walker in order to advance forward. The next set of walkers has wheels at the base that allow the user to push or scoot the walker, eliminating the need to pick it up.

The Drive Walker with Trigger, as shown in Figure 5 on page 4, is a common walker that is priced under $40. It is almost identical to the Invacare Value Line Walker (Figure 3) with the exception of a couple of things. The 5” wheels are interchangeable and the trigger release allows people with manual dexterity to collapse the walker more easily (5).
A popular group of walkers, also known as rollators, provide the user with more ability to move forward without having to pick up the walker itself. Rollators have wheels on all legs and require the user to have an ability to either stop the advancement forward on their own power or at least have the hand strength to squeeze the manual brakes.

The Drive Medical Go Lite 3 Wheel Rollator, as shown in Figure 6, is one of the lightest rollators on the market. It weighs 9 lbs and has a detachable carry pouch that provides users with much needed storage. Its three wheel design allow for easier maneuverability without giving up sturdiness. The 7.5” wheels helps to overcome friction and allows the walker to be used on many different surfaces (6). Despite the many benefits of this rollator, there are disadvantages. The hand brakes are a nice feature that will allow the user to stop the rollator from moving forward, but provides a challenge for people without much strength in their hands.

The Medline Freedom Rollator (Figure 7) is considered by many users to be the Cadillac of rollators. It offers many of the benefits of the previously mentioned Drive Medical Go Lite 3 Wheel Rollator and a few more. The first thing that is noticeable is the cushioned seat.
As the user gets tired, he or she can pull to the side, lock the brakes and get some rest. The other feature this rollator has is a comfortable curved back rest (7). Tools are not needed to adjust the brakes or the height of the rollator.

![Tool free adjustable brakes and height adjustment](image)

Figure 7 - Medline Freedom Rollator  
Figure 8 – Invacare Adult Blue Rollator

The Invacare Adult Blue Rollite 8” Wheeled Rollator (Figure 8) is unlike any other in the industry. The Rollite offers all the standard features such as flip-up seat with a built in handle, flexible backrest, ergonomic dual paddle folding mechanism and hand brakes (8). The 8” wheels set this product apart from other rollators because it allows for the user to travel on tough terrain. However, these features come with a bigger price tag of roughly $200. This item weighs a total of 16.5 lbs, which is at least 5 lbs heavier than the other products.

Most of the walkers and rollators mentioned previously do not offer travelers much flexibility in terms of portability. This is due to the fact that the outside legs fold in towards each other, but the front part of the walker doesn’t fold at all. This limits the walkers to be reduced to a width of 21” to 26”. The Stander Metro Walker, as illustrated in Figure 9 on page 6, is one of the most compact walkers on the market today. It folds into dimensions of 6”x4”x32” and weighs 6.5 lbs, which is about four times smaller than the average walker (9). Despite its compact design, the weight capacity is quite sufficient at 250 lbs.

As illustrated by the nine previously mentioned walkers and rollators, there are many different options for the users to choose from. Each one has its own unique feature, which can be conceived as an advantage or disadvantage, depending on the user. The goal of this project is to design and build an attachment for one of these walkers that will advance the walker forward without the handicap user having to pick up the walker. The design will also incorporate other beneficial features from the different walkers.
There have been several patents that have been filed with the United States Patent Office for a mechanically assisted or motorized walker. In 1981, Jack E. Perkins filed patent for a motorized walker that utilizes two drills as its main drive motor (10). As shown below in Figure 10, Mr. Perkins used two drills that are independent of each other to drive the front wheels. Castor wheels were added on the two back legs to help the walker along. Bicycle handles were used as the engaging mechanism to activate the motors.

There are advantages and disadvantages for this design. The advantages include the fact that the components are commercially available, such as the handles, drills, and wheels. The parts are designed to be add-ons for existing walkers. The total weight of this product is quoted to be roughly 10 lbs, which is great for portability. The disadvantages include the durability of the product itself. The drills are held in place by thin metal straps. Excessive use of the walker and the motor combined create a lot of vibration that could cause the components to separate from each other. In order to drive and steer the walker, both hands are necessary. The controller could be simplified to help users with finger dexterity. Safety is a big concern with this design because there are a lot of uncovered pinch points.
The survey was distributed to 30 people throughout Cincinnati. They included neighbors, friends, co-workers, friends and families, and people at random nursing homes. Of the 30 surveys that were handed out, 10 were completed and returned. Refer to Appendix B for full results. Although it was a small sample size, it included a wide variety of people. The age group ranged from 50 to 85, and included both male and female. A large majority of the sample size included elderly folks that need walkers to help them get around due to weakened muscles. One user was placed on a walker due to a stroke earlier this year, which caused her to lose the functions in her right arm. Pastor Richard Fisher has a blood and muscular disorder called acute intermittent porphyria (11).

The survey asked the users to rank 10 different product features on a scale from 1-5 with 5 being the most important. The first set of questions gave the designer insight into what features the users felt were important in the design of the mechanically assisted walker. The second set, included the same 10 questions but were aimed at finding out how satisfied they were with their existing walkers. Of the 10 features listed, the customers replied that safety, durability, and ease of operation were the three most important items to them. The survey also asked the participants what kind of walker they were currently using. Six of the participants are using the standard Invacare or Drive walker with the four legs and a yolk in between them. There was also a question on how much customers would be willing to pay for a mechanically assisted walker. Of the 10 people who responded, three said that they would be willing to pay over $500.

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Customer Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>5.00</td>
</tr>
<tr>
<td>Durability</td>
<td>5.00</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>4.80</td>
</tr>
<tr>
<td>Portability</td>
<td>4.50</td>
</tr>
<tr>
<td>Height Adjustability</td>
<td>4.50</td>
</tr>
<tr>
<td>Long Battery Life</td>
<td>4.33</td>
</tr>
<tr>
<td>Low Cost</td>
<td>3.80</td>
</tr>
<tr>
<td>Low Noise</td>
<td>3.70</td>
</tr>
<tr>
<td>Appearance</td>
<td>3.10</td>
</tr>
<tr>
<td>Accessories</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Table 1 is a ranking of the product features by customer importance, which is an average of what the survey participants chose. The higher the value, the more important it is to the customer. As shown, safety was their biggest concern and accessories were the least important. These results will be taken into consideration in the design of the mechanically assisted walker.
The survey results were placed into a quality analysis spreadsheet to determine the true design weight of all the surveyed items. For a complete result of the quality analysis (or QFD), please refer to Appendix C. Table 2 below is an abbreviated version of the QFD as it relates to the product features. The Customer Importance, as mentioned in Table 1 on page 7, is the value (on a scale of 1 to 5) that the customer places on each of the 10 product features. The Improvement Ratio is a combination of how satisfied the customers are with their current product and the designers planned satisfaction. The designer hopes to improve safety and ease of operation by 120% when comparing the mechanically assisted walker to the customers’ current walkers. Durability will be improved by 110% by way of design specs and material selection. Portability, height adjustability, and accessories will not be improved upon, because the designer will be using a commercially available walker frame. The aforementioned features are all standard on the walker.

Not all the product features will be an improvement over the customers’ existing walkers. Low noise will be reduced by 30% because the mechanically assisted walker will actually sound louder than their existing walkers due to the addition of a motor. The appearance will not improve because the additional components and their housing will be more obtrusive to the viewer. The cost of the mechanically assisted walker will be higher than their current walker because of all the hardware and fabrication that will be added to automate the movement of the walker. The Relative Weight percentage, as illustrated in Table 2 below help to illustrate the importance of each customer feature when compared to the other features as a whole. This value is a combination of the Customer Importance, Designer Multiplier, and the Improvement Ratio. Of the 10 product features, the designer plans to improve upon three of the features, which are safety, durability, and ease of operation. The designer did not want to affect the portability, height adjustability, or the ability to accessorize the walker. This included the ability to place a carrier basket in front of the walker.

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Customer Importance</th>
<th>Improvement Ratio</th>
<th>Relative Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>5.00</td>
<td>1.20</td>
<td>15%</td>
</tr>
<tr>
<td>Durability</td>
<td>5.00</td>
<td>1.10</td>
<td>15%</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>4.80</td>
<td>1.20</td>
<td>15%</td>
</tr>
<tr>
<td>Portability</td>
<td>4.50</td>
<td>1.00</td>
<td>10%</td>
</tr>
<tr>
<td>Height Adjustability</td>
<td>4.50</td>
<td>1.00</td>
<td>10%</td>
</tr>
<tr>
<td>Long Battery Life</td>
<td>4.33</td>
<td>1.00</td>
<td>10%</td>
</tr>
<tr>
<td>Accessories</td>
<td>3.00</td>
<td>1.00</td>
<td>7%</td>
</tr>
<tr>
<td>Low Noise</td>
<td>3.70</td>
<td>0.70</td>
<td>6%</td>
</tr>
<tr>
<td>Appearance</td>
<td>3.10</td>
<td>0.90</td>
<td>6%</td>
</tr>
<tr>
<td>Low Cost</td>
<td>3.80</td>
<td>0.60</td>
<td>5%</td>
</tr>
</tbody>
</table>

The Relative Weight will also be used to rank the product features and illustrate where the designer’s best effort will be placed in the design of the mechanically assisted walker. Please see page 9 for a full list of product features and objectives and how the designer plans on meeting the objectives.
PRODUCT FEATURES AND OBJECTIVES

Mechanically Assisted Walker

The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met. The product objectives will focus on a mechanically assisted walker that will help customers with partial paralysis. The walker is intended to be used on finished surfaces.

Safety (15%):
1) Safety guards will cover pinch points and moving parts.
2) Power switch will disconnect power to the motor when the walker is not needed.
3) Drive will disengage when operator lets go of the joystick or lever.
4) All electrical connections will be soldered and covered to ensure that there are no loose connections or bare wires.
5) The speed of the walker will be determined by using several customers in an experiment to determine a maximum speed that will be safe to the operator.

Durability (15%):
1) Durability of the attachment measured by component life and proper design criteria specified in the following spec sheets: Motor Spec Sheet, Controller Spec Sheet, and Battery Spec Sheet
2) Lock washers or fasteners will be used to hold components together to prevent failure from vibration.
3) A factor of safety (Mott, Mechanics of Material) will be provided by Cosmos to show that structural components will not fail due to repeated load.

Ease of Operation (15%):
1) Operator will engage drive by either pushing a lever or joystick.
2) There will be a zero degree turn radius that will allow the walker to turn around sharp corners and eliminate the need for a reverse function.

Portability (10%):
1) Walker will fold and fit within the trunk of a four door sedan. For a Toyota Corolla, it is roughly 12 cubic feet.
2) Walker will fit through normal interior door opening when it is in fully open position, which is 30 inches wide.
3) Total weight will be less than 30 lbs.

Height Adjustability (10%):
1) Walker height will be adjustable to fit people with heights that range from 5’-4” to 6’-2”.

Long Battery Life (10%):
1) Battery capacity will allow the walker to travel at least 1 mile before it is required to be charged again.

Low Noise (6%):
1) Components will be carefully selected to ensure that the noise level does not exceed 50 dB. It will be comparable to an electric motorized wheel chair.

Appearance (6%):
1) Walker will look similar to existing walkers that are presently on the market.

Low Cost (5%):
1) The prototype will not exceed $1,000.00.
ENGINEERING CHARACTERISTICS

Using the items surveyed, the physical aspects of the system were determined and analyzed. A list of engineering characteristics was compiled by the designer to satisfy the product features. Each characteristic is a measurable performance of the walker.

Table 3 - Engineering Characteristics

<table>
<thead>
<tr>
<th>Engineering Characteristics</th>
<th>Relative Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guarding</td>
<td>19%</td>
</tr>
<tr>
<td>Size</td>
<td>17%</td>
</tr>
<tr>
<td>Speed</td>
<td>13%</td>
</tr>
<tr>
<td>Weight</td>
<td>12%</td>
</tr>
<tr>
<td>Material Selection</td>
<td>9%</td>
</tr>
<tr>
<td>Battery Capacity</td>
<td>8%</td>
</tr>
<tr>
<td>Number of Components</td>
<td>7%</td>
</tr>
<tr>
<td>Motor Selection</td>
<td>5%</td>
</tr>
<tr>
<td>Manufacturability</td>
<td>4%</td>
</tr>
<tr>
<td>Setup Time</td>
<td>4%</td>
</tr>
<tr>
<td>Noise Level</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 3 is a summary of relative importance for each engineering characteristic that will be taken into consideration. As shown, the top three characteristics all relate to safety in one fashion or another, which is what the customer stated as their biggest concern. Guarding strongly impacts both safety and durability. The proposed housing will prevent items from getting tangled in the moving parts and it will also protect the components from natural elements, such as weather. It will also help reduce the noise level that the walker will create. Speed directly reflects safety because customers who will use the product can’t walk at a fast pace, so it must be controlled. Size and weight affect many aspects of the product features, such as safety, portability, ease of operation, and battery life.

The least important engineering characteristics were determined to be manufacturability, setup time, and noise level. Manufacturability only affected two of the 10 product features, which were product cost and appearance. The survey results showed that appearance was not high on the list of customer importance. Setup time only affects portability and ease of operation. The user will only have to set up the walker once, unless they transport it in a car. Noise level only affects low noise feature, thus it has a relative importance of 3%. Please reference Appendix C for full results of the engineering characteristics and how it affects the relative importance.
CONCEPT GENERATION AND SELECTION

As previously mentioned, the main objective of this Senior Design project is to engineer an add-on for existing walkers. Therefore it was determined that the main area of focus will be on the drive system or the front drive wheels. Three different concepts were explored. All three concepts will allow the walker to maintain its height adjustability. However, the decision will be based on the advantages and disadvantages that one concept has over the other. A weighted decision matrix will be used to determine the best design.

WORM GEAR DESIGN

The first concept as shown in Figure 11 below will be referred to as the Worm Gear Design. The main idea behind this concept is to use a DC motor connected to a shaft, which will rotate a worm gear and turn the front wheels of the walker. It was calculated that a rotational speed of 37 RPM would be required to turn the 5” diameter wheel at a linear speed of 0.8 ft/sec. This is the top speed that my mother-in-law can travel with a walker. If the worm gear was attached to a stepper motor, the necessary rotational speed could be met without any problems. Please see Appendix F for a complete list of calculations.

This seemed like a viable option at first, but there are some downsides to this design. Safety is the number one customer feature and there are pinch points involved with this design. A cover could be fabricated, but at the expense of increased weight and number of components. Worm Gears are also very expensive when compared to other options.

Figure 11 - Worm Gear Design
**SPUR GEAR DESIGN**

The second concept as shown Figure 12 and will be referred to as the Spur Gear Design. This design utilizes a DC motor and spur gears to achieve the mechanical assistance necessary to move the walker. Transmitting rotation from a DC motor to the wheel via a gearbox is one of the most popular methods out there. The output shaft from the gear box is designed to withstand higher amounts of stress and the gearing can provide the reduced RPM and high torque necessary for this application.

DC motors are designed to run at very high speeds. However, with increased speeds, torque is reduced. In order to reduce speed and increase torque, gearing is necessary. This concept would increase the total cost. Similar to the Worm Gear Design previously mentioned, there are pinch points in this design as well. Any time gearing is involved, noise level increases. After researching the cost associated with DC motor, it was determined that the cost would be upwards of $200 for the motor and gears alone.

![Figure 12 - Spur Gear Design](image)

**DIRECT TRANSMISSION DESIGN**

The third and final concept explored was the Direct Transmission Design in Figure 13. The main idea behind this design is to use a stepper motor and directly mount it on to the leg of the walker. The shaft of the motor would then be set inside a shaft and held in place with a set-screw. The wheel would be keyed and mounted in the center of the shaft. This design was favorable because bending moments and load was distributed evenly. The number of components involved to make this all work would be minimal and there are absolutely no pinch points. To further justify the selection of this concept, a weighted decision matrix was constructed. Please see Table 4 for the weighted decision matrix.
The three concepts were evaluated using a weighted decision matrix and a five-point scale. The scores ranged from zero to four. A score of zero meant that the design was inadequate and four meant that the design was excellent. Seven design criteria were used to determine which concept would be best suited for the walker application. The relative weights were taken directly from the QFD. Please see Appendix C for a complete QFD. The weights were adjusted a little by the designer in order to get a total weight of 1. This is due to the fact there were only 7 criterion compared to 10 project features. The scores for each criterion were multiplied by the weight factors and added together to determine the total rating for each concept. Please see Table 4 on the next page for the complete Weighted Decision Matrix.

Evaluating the weighted decision matrix can be a little confusing. The lower the value for each design criterion meant a higher score. For instance, the Direct Transmission Design received a score of four based on the number of components involved with the design because it had the least number of actual components associated with it. The only exception to this rule was torque. The higher the torque value, the higher the score. Based on the decision matrix, the justifiable solution to the presented problem is the Direct Transmission Concept. This concept scored higher than the other two on almost all categories.

Price doesn’t only include the cost of the motor and the gears, but also other parts of the walker. For instance, the stepper motor used in the Direct Transmission Design offers a holding torque. This holding torque characteristic would eliminate the need to design and purchase a braking system for the walker. As a result, the score of three was assigned to this design. As mentioned earlier, anytime gearing is involved, you get increased noise. Because
there is no gearing involved with the Direct Transmission Design, it received a score of three. Based on the QFD, noise was on the bottom of the list for most important product features; therefore it was assigned a weight of 0.10. One of biggest benefits of this design is that there are no pinch points. Safety had the highest relative weight on the QFD with a value of 15%.

Table 4 - Weighted Decision Matrix

<table>
<thead>
<tr>
<th>Alternative Design Selection</th>
<th>Weight</th>
<th>Worm Gear</th>
<th>Spur Gear</th>
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MECHANICALLY ASSISTED WALKER DESIGN

This project exposed the designer to many different aspects of engineering. The drive system components had to be carefully chosen to get the walker to respond as desired while meeting the product features and objectives. Once the design criteria and loading conditions were met, the designer needed to figure out how the controller components will work. This involved both wiring and programming. Figure 14 below is a SolidWorks model of the proposed mechanically assisted walker.

![Mechanically Assisted Walker in Fully Open Position](image)

**Figure 14 – Mechanically Assisted Walker in Fully Open Position**

**DRIVE SYSTEM COMPONENTS**

The first value that was calculated was the speed at which my Mother-in-law could walk while using a walker. She was able to travel 20 feet in 25 seconds, which turned out to be 0.8 ft/sec. Based on this linear speed, the designer was able to find the necessary rotational speed (RPM) of the motor when the diameter of the wheel is known. Because the drive wheel is five inches in diameter, the motor shaft would have to rotate at an angular speed of 37 RPM. Please see Appendix F for a complete list of calculations.

A stepper motor was chosen to drive the wheels for a number of reasons. Unlike other DC motors, stepper motors turn a fraction of a revolution based on the number of pulses it receives per second. Most stepper motors have a step angle of 1.8 degrees. It would take 200 steps in order for the shaft to make one complete revolution. A wide range of rotational speeds can be achieved because it is proportional to the frequency of the input pulses. What all this means is that stepper motors offer precise motion in an open non-feedback system. Stepper motors offer great response to starting and stopping signals. The user of the walker
will use a joystick to control the motion of the walker. They will have complete control over where it travels; therefore, no feedback is necessary.

The second reason for using a stepper motor is the fact that they offer good amount of torque at very low speeds. It was determined that 180 oz-in of torque would be required per motor to move a walker with a total weight of 18 lbs. This included the weight of the walker and all its components, such as the batteries, microcontroller, etc. A coefficient of friction value of 0.5 was used in the calculations. This is the value for rubber on a tile floor as recommended by OSHA. Figure 15 below is a screen print of an Excel spreadsheet that was used to help calculate the total torque required. Please refer to Appendix F for a thorough calculation of torque and the formulas that were used in the spreadsheet.

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</tr>
<tr>
<td>Torque per Motor (oz*in)</td>
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Figure 15 - Excel Spreadsheet for Calculating Torque

Now that the rotational speed and the required torque are known, it is possible to choose a sufficient stepper motor for the walker driver wheels. Based on a required torque of 180 oz-in and rotational speed of 37 RPM, it was determined that the CTP22NLF31 by Danaher Motion would be sufficient. Please see Figure 16 on the next page for a speed-torque curve for this motor. After hours of research on the internet for a factor of safety value for electric motors, it was determined that a 1.25 factor of safety was sufficient. The selected motor would exceed this value at 1.78 times the required torque. This will help with the durability product feature because the motor will not need to be run at its full current rating of 3.1 amps in order to supply the required torque of 180 oz-in. This also means that it will use less battery power and reduce the amount of heat that the wiring and coils will emit.
The third major reason for using a stepper motor is its ability to provide a holding torque when the windings are energized. What this does is eliminate the need for a separate braking system. The walker has a limited amount of surface area to mount different components on. By eliminating a braking system all together, we save money, weight, and conserve mounting space. Overall, this will allow for better portability and reduce the amount of components necessary for the user to assemble.
**Drive System Loading Conditions**

Now that the stepper motor has been chosen, the next step is to determine the material and evaluate the important loading conditions for the Direct Transmission Design. Although appearance only had a relative weight of 6% on the QFD, the designer felt that it was important to try and maintain aesthetic consistency. Therefore, the first material taken into consideration was aluminum, which is the same material that the walker is made from. As it turns out aluminum is the best material for this application for multiple reasons. Aluminum has a material density of 2630-2820 kg/m^3. This is 1/3rd the density of steel. For the same amount of volume, aluminum weighs 1/3rd that of steel. In order to help maintain portability (4th most important in the QFD), weight is an important factor to consider. Although aluminum T-6 is a little more expensive than steel, the benefit that would be gained in weight savings out-weighed the minimal increase in cost. The cost is very minimal because a 6’ x 2.5” x 0.25” bar stock can be bought for $31.37 from McMaster Carr will provide more than enough material for both drive wheel frames.

The other reason that aluminum is an ideal material for manufacturing the drive wheel frames is its manufacturing characteristics, such as weldability and machinability. It is well known that aluminum has good to excellent rating for machinability. In other words, it is one of the easier metals to cut, mill, and manipulate on a lathe. The downside to using aluminum would be its weldability. Even though it isn’t as easy as steel to weld, it’s definitely possible with a rating of fair in the *Applied Strength of Materials* book (12). Aluminum has a yield strength of about 40,000 psi, which is more than enough to withstand the maximum load that will be applied to the walker.

Because a commercially walker will be used, there is specified weight limit of 300 lbs (per the manufacturer). This value will be used for all loading calculations for the design. The free-body diagram is illustrated below in Figure 18.

**Figure 18 - Free Body Diagram of Drive Wheel**

There will two driver wheels, therefore the distributed weight is cut in half and given a value of 150 lbs. The 75 lbs on each side of the shaft represents the normal force that the side plates will place on the shaft itself. Cosmos in Solid Works was used to evaluate the location at which failure is likely to occur due to continuous static load. Figure 19 is a screen print of the applied load on the top plate of the driver wheel frame. As illustrated, the maximum
stress, identified by the red color, is located around the perimeter of the 1 inch bore for the tube alignment piece. The maximum stress has a value of 2,870 psi. Keep in mind that aluminum has a yield strength of 40,000 psi. The maximum stress applied to the weakest link is less than 8 % of the available yield strength. It is safe to say that the top plate will exceed any applicable factors of safety involving static load.

![Figure 19 - Cosmos of Top Plate](image)

The static load on the side plates was also evaluated. Figure 20 below is a screen print of the load that the side plate will experience.

![Figure 20 - Cosmos of Side Plate](image)

The maximum stress experienced by the side plate is 658 psi. The last static load considered
Mechanically Assisted Walker

Vanna Un

takes place on the shaft that is mounted onto the motor and keyed to the 5 inch diameter wheels. Figure 21 displays the Cosmos completed on the shaft.

![Figure 21 - Cosmos of Shaft](image)

The shaft will be made of 1018 cold drawn steel and has a yield strength of 50,763 psi. The maximum stress experienced by the shaft is 5,113 psi and is located at the edge of the drive wheels. The calculated stress on the shaft is only about 10% of the maximum yield strength of its material. Again, we are well under any applicable factor of safety that could be considered.

**CONTROLLER COMPONENTS**

The third most important product feature is ease of operation. This is what will separate this walker from the ones that are available on the market today. One of the main objectives to address this product feature is to engineer a control system that will be easy to use and respond well to the user. After spending several weeks thinking about all sorts of possibilities, the designer decided to use a mini-joystick as the component that will control the walker. The mini joystick in Figure 22 is the joystick that was chosen. This is very similar to the size and feel of the joysticks that are used in the Playstation 3 controllers. The joystick has two potentiometers, one for the x-axis and y-axis. This will allow the user to motion the walker forwards, backwards (which will not be used), left and right. It has been determined that backwards motion will not be necessary due to the sharp turn radius that the driver wheels will provide for the walker. Also, most people with disabilities aren’t able to walk backwards effectively. The joystick sends analog signals to the microcontroller or Arduino Uno.
One of the biggest flaws with the patented design by Mr. Perkins discussed earlier is that there isn’t a good way to limit the speed of the walker (10). The designer decided to use a rotary sensor, pictured in Figure 23 to accomplish this task. Users have different speeds at which they can walk. The rotary sensor will be a limiting component that will allow the user to set the maximum speed at which the walker can travel. It ranges from 0 to 300 degree turn, this will allow for a wide range of speed variations. However, the max speed will also be determined by the stepper motor and its driver limitations as well. Both the joystick and the rotary sensor will be placed on the handle bar of the walker inside a fabricated housing for accessibility. In order to allow for easy connections to the micro controller, an electronic brick shield will be purchased, which is shown in Figure 24. Three pin male connectors will be used to make the connections.

The electronic brick shield sits directly on top of the Arduino Uno, which is shown in Figure 25. This will eliminate the need to solder directly onto the Arduino board. The Arduino Uno is the brains behind the walker. It contains the microcontroller and uses its own programming language to interpret the analog signal. After receiving the signal from the joystick and rotary sensor, it will send a digital signal to the driver, which will ultimately drive the stepper motor and turn the front wheels.

The bipolar stepper motor driver supplies the voltage necessary to drive the stepper motor. Please refer to Figure 26 for the stepper motor driver. It takes the 5V digital input from the Arduino Uno and utilizes the 28.8 volts that the batteries can offer to operate the
stepper motor at its peak torque as necessary. The selected motor offers a full torque of about 320 oz-in if a minimum of 24 volts is provided. The motor driver chosen will work anywhere in between the range of 7 to 30 volts.

![Figure 26 - Bipolar Stepper Motor Driver](image)

**BATTERY SELECTION**

In order to power the multiple components, two lithium ion batteries will be used. The voltages required to operate them range from 7 V up to 24 V. In order to satisfy the different voltage and current requirements, voltage regulators will be used as necessary to step up or step down the voltage. The two 14.8 V batteries will be wired in series in order to supply the maximum voltage required by the stepper motor. The capacity of the selected battery is 4400mAH a piece. Based on the designer’s calculations, it should provide enough power for one hour and 22 minutes of continuous run time. Please refer to Appendix F for complete calculations. The battery is illustrated in Figure 27 below.

![Figure 27 - 14.8V Li-Ion Battery](image)
PLANNED FABRICATION AND ASSEMBLY

Figure 28 is a Solid Works model for the assembled walker in the fully open position. The green aqua colored box on the handle is the joystick that the user will use to control the walker. The white box hanging from the side rail will house the electrical components. The two batteries, which are pink and blue in color, will be inside a plastic housing as well. All four wheels will be purchased components. The front driver wheel frame will be fabricated in the school’s machine shop.

![Figure 28 - Walker in Fully Opened Position](image)

Figure 29 is a Solid Works model for the assembled walker in the fully closed position. The walker, as purchased from the supplier, folds to a minimum width of about four inches. After the modifications, the new dimension will increase to approximately 8 inches. This is primarily due to the length of the stepper motors and where it is located on the walker. Portability is has a relative weight of 10 % and is the fourth most important feature. One of the objectives for the design project is to be able to pack the walker inside a 12 cubic feet trunk. This is an average capacity for a Toyota Corolla. At less than 4 cubic feet total, the closed walker will not have any problem fitting inside the smallest sedan’s trunk. The walker will have a total weight of approximately 18 lbs and easily fit through a 30 inch wide interior door.
A 3-D printer will be used to fabricate the housing for the batteries, electrical components, and the joystick. The only part of the walker that needs to be fabricated in the machine shop is the driver wheel frame (Figure 30).

The driver wheel frame will be constructed out of ¼ inch bar stock. The different plates that make up the driver wheel frame all have a 2.5 inch dimension in common. McMaster
Carr offers a 2.5 inch wide bar stock in 6 feet lengths. By purchasing the bar stock in the exact width that the shop drawings call for, it will eliminate a lot of machine time. Each plate will be cut to size with a band saw. All holes will be made using a milling machine and tapped to receive 10-32\textsuperscript{nd} bolts, which will hold the plates and motors together. The lathe machine will be used to take remove material from the half inch steel shaft, so that it can fit into the bronze bushings. Please refer to Appendix G for full detailed assembly and shop drawings.
ACTUAL FABRICATION AND ASSEMBLY

It took approximately six weeks to complete all fabrication of parts and full assembly of the walker. The machining was done at the lab on campus (see Figure 31 and 32). The designer spent roughly 30 hours in the shop making the driver wheel frames and roughly two days to assemble the parts. There were countless hours spent on figuring out the wiring and the programming of the electrical components. There were several stumbling blocks along the way, but the walker was completed on time.

Figure 31 - Designer on Mill Machine

Figure 32 - Designer on Lathe Machine
**Driver Wheel Frame**

The driver wheel frame turned out just like the designer had planned. By purchasing aluminum bar stock that was 2.5 inches wide and 0.25 inch thick, the designer was able to cut the pieces to length with a band saw. An additional 0.125 length was added to the drawing dimensions in order to leave room for machining and cleaning up the edges. An end mill was used to clean up the finished parts on the mill machine in order to achieve its true dimensions. The holes were either drilled on a small drill press (if slower speeds were desired) or drilled on the Bridgeport milling machine for more accuracy. Tapping for the screws and bolts were made using hand taps. See Figure 33 for the finished parts.

![Figure 33 - Parts for the Driver Wheel Frame](image)

Figure 34 illustrates the assembled driver wheel frame. There were a couple of things that the designer had to change on the final product as opposed to what was in the original planned. The original drawings called for the bolts that held the top plate to the side plates to be 10-32s, however there wasn’t enough material to grab on to due to the plates being a quarter inch thick. The bolts were reduced to 6-32s that were 0.5 inches long. With three bolts on each side, it was more than enough to handle the maximum capacity of 300 lbs pushing down on the walker.

The second change involved reducing the diameters of the bushings and side plates that were opposite the motor. This prevented the shaft from slipping out of the opposite side of the motor without the need for any additional parts. Instead of making the shaft the same diameter from one end to the other, it was reduced on one end to fit inside the
aforementioned change in diameter. Because the shaft was attached to the motor using set screws and the motors were mounted to the plates with four bolts, the designer didn’t have to worry about any components coming loose on the inside part of the leg. Please refer to Appendix G for final shop drawings.

Figure 34 - Assembled Driver Wheel Frame

**WIRING**

Once the designer determined all the necessary components to control the motion of the walker, he had to figure out how to wire it all up. Due to inexperience, preliminary wiring was performed on a breadboard. This allowed for easy temporary connections between different electrical components. Twenty-two gauge aluminum wire was used for all connections due to its ampacity rating of 7 amps. This rating was more than twice the demand of the maximum ampacity draw of 3.1 from the stepper motors. The other components’ ampacity draw was much less than that of the stepper motor. Therefore, the designer knew that the twenty-two gauge wire would work for them as well. See Figure 35 for the breadboard that was used for testing.

There are a couple of key points that the designer had to consider. Up to this point, it was unknown how much voltage was going to be necessary to supply the necessary current to turn the stepper motors. For testing purposes, an 18 volt drill battery was used to supply the power to the breadboard. The second important thing to remember was to keep everything grounded and make sure all the grounds were connected to the breadboard.
During this testing period, the designer found out that the original stepper motor drivers weren’t going to supply enough ampacity to the motors in order to turn the wheel while it was sitting in the driver wheel frame. The decision was made to change to a more powerful stepper motor driver, known as the Rugged Motor Stepper Motor Driver. A picture of this stackable driver can be found in Figure 36.
After hours and hours of trial and error, the designer was able to determine how the components needed to be connected. A generic overall schematic of the wiring can be found in Figure 37 below. The joystick and potentiometer were connected to the electronic brick shield using buckled 3-pin connectors (Figure 38). The electronic brick and the two stepper motor drivers were stackable on top of the Arduino Uno, therefore eliminating the need to connect any wires between them. This was nice and convenient and reduced the number of total wires in the controller housing. Refer to Figure 36 on the previous page to see how they stack on top of each other.
Two different types of batteries were used to supply power to the walker. The stepper motors required the most voltage and current. In order to achieve the necessary torque of 180 oz-in to turn the wheels and move the walker, 24 volts was necessary. Two 14.4 volt lithium ion batteries were wired up in series to achieve this. Male and female connectors were used in order to allow easy connections between the batteries and the controller components. See Figure 39 for the Tamiya connectors that were used. Charging the batteries was easily accomplished with a Tenergy Universal Smart Charger, pictured in Figure 40.

In order to power the Arduino Uno microcontroller a separate power supply was used. Voltage over 15 volts will damage the Arduino Uno. In order to achieve this, a 9V battery was used. See Figure 41 for the 9V battery housing and its connection to the microcontroller. This second battery could have been avoided if the designer had chosen to use a voltage regulator. However, there wasn’t enough time to figure out how to accomplish this without wiring it through a breadboard.
The only thing left to wire up was the connection between the stepper motor driver and motor. This was easily accomplished using 22 gauge aluminum wire. Bipolar stepper motors have two coils in them. Each coil uses two separate wires to send current through its’ coils in order to create opposing magnetic fields to turn the rotor. What this means is that there are four wires total per motor. These four wires were connected to the stepper motor driver by means of set screws. See Figure 42 for the stepper motor driver wiring.
Once the designer figured out how to wire up all the components, he had to determine how to attach everything to the walker without getting in the way of the user and giving up the walker’s ability to fold. It was determined that three different housings would be necessary to achieve this.

The joystick and potentiometer fit inside a black rectangular box that was purchased from Radioshack. The holes were cut into the box using a drill press. In order to secure the housing to the walker, a bolt that was ½” longer than the original bolt was used. It mounted perfectly on top of the original bolt hole of the walker. See Figure 43 for completed assembly of the joystick housing. Figure 44 is an open view of the joystick housing.

The remaining controller components were placed inside an aluminum project enclosure. The box was lined with foam insulation tape in order to avoid any electrical faults that could damage any one of the components due to the aluminum box’s ability to conduct electricity. It was attached to the walker with two u-bolts. U-bolts were chosen because it allowed enough flexibility for the housing to spin about the cross bars of the walker. This was necessary in order for the walker to fold. See Figure 45 for a picture of the housing that contains the Arduino Uno, electronic brick shield, and the two stepper motor drivers. Figure 46 is an open view of the same housing.
The two lithium ion batteries were housed inside a 4"x4"x4" electrical junction box that was purchased from Lowes. This was also connected to the walker with u-bolts. A ¾” hole was drilled in the front of the box so that the male Tamiya connector could be exposed to attach to the electrical components inside the aluminum housing. Figure 47 illustrates the finished battery housing when it is attached to the walker. Figure 48 is an image of the box and how the batteries sit in there.
**Completed Walker Assembly**

The mechanically assisted walker was assembled flawlessly. The purchased components fit on the walker without any problems. This included the arm platform attachment and the 3” rear wheels with brakes. The driver wheel attachments were carefully mounted to the walker so that the two front wheels were parallel with each other and perpendicular to the walker’s front brace. This was very important so that the walker would travel in a straight line. Any misalignment would cause the wheels to turn towards each other and prevent the walker from moving. The wires were placed inside ¼” black corrugated wire tubing and attached to the walker with zip ties in order to minimize hanging wires that could be a hindrance to the user. Figure 49 is a picture of the walker in the fully open position.

One of the biggest reasons that the designer chose this style of walker was its portability. It was important that the walker can still fold in order to be carried from one place to another inside the back seat of a small sedan or small trunk. Figure 50 demonstrates that the walker still maintained its ability to fold even after everything was attached.

![Figure 49 - Fully Opened Walker](image1)

![Figure 50 - Fully Closed Walker](image2)
PROGRAMMING THE MICROCONTROLLER

The most complicated portion of this project for the designer was programming the Arduino Uno microcontroller to move the walker. This was due to his inexperience in programming language. However, the Arduino Uno made programming more novice friendly. Mr. Banzi states that the “Arduino is an open source physical computing platform based on a simple input/output (I/O) board and a development environment that implements the Processing language” (13). Figure 51 is a screen print of the Arduino environment that was for programming. For the complete program, refer to Appendix J.

Figure 51 - Arduino Environment

The analog reads were taken from the joystick and potentiometer. Each component operated on 5 volts and sent an integer value read between 0 and 1023 to the Arduino. The joystick had an x-axis and y-axis. The 1023 range was split in half for both the x-axis and the y-axis. If the joystick was in the top half position of the y-axis, the walker would move forward. If the walker was in the bottom half position, the walker would move backwards. Likewise, if the joystick was in the top half value of the x-axis, the walker would start to turn right. If the walker was in the bottom half value, it would turn left. If the joystick was not pressed, the wheels locked and will not move.
TESTING AND PROOF OF DESIGN

USER INTERFACE

The user controls two aspects of the walker, which are speed and direction. When the program was written, the designer limited the rotational speed of the wheel to a maximum value of 40 RPM. This safety factor was built in so that the walker can’t move faster than what the average elderly person or the designer’s mother-in-law can travel at. As one can recall, the fastest that the designer’s mother-in-law could travel was 36.67 RPM. The potentiometer worked great as a speed limiting knob. With a range of 0 to 300 degrees, the maximum rotation of 40 RPM occurred at the 300 degree mark. If the knob was in the 0 degree position, the wheels did not turn. If the knob was anywhere in between 0 and 300, the rotational speed of the wheels responded proportionally.

The joystick controls the direction of the walker. The walker moves in a straight line forward when the joystick is pressed in the forward direction only. When the program was written, the y-axis was split up into six different sections. The top three sections controlled the forward direction and divided the speed set by the potentiometer to slow, medium, and fast. Likewise, the bottom three set the reverse function to slow, medium, and fast also. This worked flawlessly because the user could actually feel the speed change as the joystick was pressed. If the joystick is pressed forward and to the right, the walker starts to turn right. As the joystick is pressed forward and to the left, the walker starts to turn left. Reverse turning works the same way.

HANDLING THE LOAD

During the design stages, it was calculated that the walker would weigh about 18 lbs. Therefore, the motor torque required to move the walker was calculated at 180 oz-in of torque. However, the walker actually weighs about 23 lbs. The motors that were purchased have a maximum torque rating of about 320 oz-in of torque, therefore it was still able to move the walker despite its heavier weight.

The ¼” thick plates provided enough material for all the bolts to grab onto. As demonstrated in the Cosmos load analysis in Solidworks, the 1/4” aluminum plates at its weakest point (directly beneath the walker leg) experiences almost 3,000 psi of pressure. With a yield strength of almost 40,000 psi, the driver wheel frame should not fail. The maximum weight that the walker is meant to handle from the manufacturer is 300 lbs. Although the designer wasn’t able to find someone that weighed 300 lbs to apply their weight to the assembly, the designer was able to apply his entire 154 lb frame to the assembly without damaging it.

BATTERY LIFE

During the design stages, it was calculated that the battery life could provide the walker with approximately 1 hour and 22 minutes of continuous usage in between each charge. Due
to the lack of time that was afforded to the designer, he wasn’t able to take the walker out to a track to test it out on a real surface. However, the walker was suspended off the ground and the joystick pressed down all the way to see how long it would take to drain the battery. After seven continuous hours, the motor was still rotating at 40 RPM. This equates to over three miles of travel distance. There is no doubt that if the walker was placed on the ground, more current would be necessary to turn the motor shaft and overcome friction in order move the walker. Even if it only offered $\frac{1}{3}$rd of the travel distance, that is over one mile. Most elderly or handicapped people do not or can’t walk one mile in one day.

**SAFETY**

Safety was most important amongst the product features and objectives. The walker did not have any pinch points. All electrical connections were soldered and covered either inside a housing of some sort or $\frac{1}{4}$” corrugated wiring tubing. Zip ties were used to secure all the wires to the walker and keep them out of the way of the user. The stepper motor’s holding torque provided enough braking power to prevent the walker from moving as the user steps up to the walker. The walker responded immediately to the position of the joystick. The potentiometer limited the maximum speed of the walker so that users of different speed could use the same walker without having to worry about keeping up with the speed of the walker. Power to the motor and microcontroller can be cut off by disconnecting the Tamiya connectors and removing the 9V battery.

**DURABILITY**

The motors that were purchased are industrial grade motors. This means that they were designed to withstand continuous usage in a manufacturing environment all day long. The steppers motors chosen will provide many years of continuous usage in the walker application. The batteries chosen are lithium ion batteries of high quality. Lithium ion batteries are amongst the newest forms of battery technology out there today. There is no memory loss, which means that you get full capacity with each charge. The user does not have to worry about draining the batteries completely before each charge. They are 20 to 30% lighter than other batteries, which helps keep the total weight of the walker down. Every part of the mechanically assisted walker is held in place by either a screw or nuts and bolts. This will prevent the parts from coming apart due to vibration.

**EASE OF OPERATION**

The user only has to worry about two things. Limit the speed by turning the potentiometer knob and control the direction of the walker by manipulating the joystick. The real brains behind the mechanically assisted walker can be found in the program that the user doesn’t ever see. Sharp corners can be achieved by the walker, which will allow easy navigation inside a small house.
PORTABILITY

In the fully open position, the walker is approximately 29” wide. This will allow it to fit through interior door openings of 30” or more. The walker in the fully closed position is about 5.63 cubic feet. This allows it to be easily transported in the back seat of a small sedan. With a weight of 23 lbs, some users can carry it with one arm. Users with less strength can use both hands to complete the task.

HEIGHT ADJUSTABILITY

The mechanically assisted walker gave up a little bit in terms of height adjustability. The driver wheel frame added an additional 6” to the height of the walker. This means that the shortest person that can use the walker comfortably is about 5’-4” tall. If a user is shorter, the walker needs to be modified (or cut) a little bit in order to compensate for the additional height due to the driver wheel frame. The recommended height range for the user is 5’-4” to 6’-2”.

LOW NOISE

In the design stages, the designer stated that the walker noise level would be comparable to an electric motorized wheel chair. Of the many different product features and objectives, this was the only one that was not met. After hours of research, it was determined that this problem could be due to a few different reasons. The noise can be attributed to the stepper motor driver. One way to find out for sure is to use a different driver. However, this would require more money and perhaps a different program altogether. The second reason for the loud annoying sound could be attributed to the frequency at which the signal is sent to the stepper motors. This could be addressed through programming, but the designer would need more time to figure out the coding. The third and final reason is the fact that mounting the motors to thin hollow aluminum tubes amplifies sound.

APPEARANCE

The mechanically assisted walker looked similar to exiting walkers on the market today. The materials were carefully chosen to blend in with the purchased walker. The driver wheel frame and controller components were made out of aluminum and had the same color as the original walker. The black housing for the potentiometer and joystick blended in nicely with the black on the joystick and ¼” tubing that was used. The gray battery housing was unobtrusive to the eye.

LOW COST

The designer had a set a budget of $1,000 in the beginning of the project. After all the receipts were tallied up, the total cost of the mechanically assisted walker came in at $631.
KAY PUTS IT TO THE TEST

The designer was able to find one person to test the walker out. Her name is Kay (Figure 52) and she was a complete stranger who uses a rollator to assist her in walking around (14). She was able to provide some valuable feedback. The first comment that she made is how much fun she is having while using the walker. She said that the joystick “takes some getting used to.” The potentiometer and its ability to control the walker speed was a nice feature for her.

It took Kay a couple of minutes to get used to the walker, but after familiarizing herself with the joystick, she was off and walking. Kay is 84 years old and in a lot better shape than people her age. However, she commented that there is a market out there for the mechanically assisted walker. When asked if she feels safe using the product, she said “yes…it looks strong.”

There were a couple of things that she said could be improved upon. The first being larger wheels. Her concern was that she was going to get her hair done and her hair dresser has a long gravel drive that makes it hard for her rollator to travel on. She feels that bigger wheels would help overcome the rough terrain. The second negative comment that she had for the walker is the noise level. She said that after a while, it would start to get annoying.

Figure 52 – Kay Trying the Walker
PROJECT MANAGEMENT

SCHEDULE

The project schedule began the last week of September, 2010. The complete project timeline was spread out over 37 weeks and ended on the first week of June, 2011. Table 5 is an abbreviated schedule listing the general tasks that were completed. The first column lists the tasks to be completed. The numbers inside the yellow highlights indicate how many weeks will be involved for each task. For a detailed schedule, please refer to Appendix D.

Table 5 - Abbreviated Schedule

<table>
<thead>
<tr>
<th>Schedule</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dates</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Concept Sketches &amp; Selection</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Design (2D &amp; 3D Drawings)</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
<td>Parts &amp; Assembly Drawings</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Fabricate Parts &amp; Order Parts</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Assembly, Testing, &amp; Modification</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Demo to Advisor &amp; Faculty</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
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<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Although the designer wasn’t able to keep up with the schedule, all due dates were met with success. This was due largely to his unfamiliarity with programming, logic control and other stumbling blocks along the way. The research section of the project took place during autumn term. The designer used every and all forms of media made available to him to find useful information, which included the internet, books, interviews, and several other resources.

The design phase of the project took place during the winter term. The drawings were completed in SolidWorks. Modifications were made to a few of the drawings that included the exterior side plate, the top plate and the shaft. Through trial and error, the designer had to change out the original stepper motor driver in order to obtain enough current to turn the motor shaft that drives the walker.

The build process took place during the spring term. 30 to 40 hours were spent inside the school lab using the different machines to manufacture the driver wheel frame. This took place in the months of April and May. After 30 to 40 hours of programming time over a 3 week period, the walker responded exactly how the designer had intended it to.
**BUDGET**

Another important step in design is creating and limiting oneself to a budget. After careful evaluation of existing products and prices of different components that are available on the market today, a budget was created. This will help ensure that the design project at hand is affordable. The preliminary budget for the mechanically assisted walker came out to $680.00 as shown in Table 6.

<table>
<thead>
<tr>
<th>Purchased Parts</th>
<th>Preliminary Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walker (Frame)</td>
<td>$124</td>
</tr>
<tr>
<td>Motor(s)</td>
<td>$100</td>
</tr>
<tr>
<td>Battery</td>
<td>$80</td>
</tr>
<tr>
<td>Controller</td>
<td>$80</td>
</tr>
<tr>
<td>Brakes</td>
<td>$50</td>
</tr>
<tr>
<td>Cables, Belt(s), and Gears</td>
<td>$52</td>
</tr>
<tr>
<td>Raw Stock</td>
<td>$90</td>
</tr>
<tr>
<td>Nuts, Bolts, and Screws</td>
<td>$15</td>
</tr>
<tr>
<td>Miscellaneous Parts (15%)</td>
<td>$89</td>
</tr>
<tr>
<td><strong>Total Purchased Costs</strong></td>
<td><strong>$680</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fabrications</th>
<th>Preliminary Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Cutting, Welding, &amp; Machining</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Fabrication Costs</strong></td>
<td><strong>$0</strong></td>
</tr>
</tbody>
</table>

Table 7 is the actual budget based on the bill of materials. As shown, the designer came in under budget by $49.00. Most of the components were purchased from on-line vendors. Fabrication of additional parts was completed by the designer in order to reduce cost. Because stepper motors were chosen to drive the walker, the actual motor exceeded the original estimate by more than 200%. However, by eliminating the need for a braking system, he was able to save money and put that towards the cost of the two motors. The direct transmission design eliminated the need for belts and gears. The money that was budget for this was applied to the cost for the controller components. The driver wheels are the only parts of the walker that need to be fabricated out of aluminum and steel. Therefore the budgeted amount was able to be cut by almost a half.
CONCLUSION AND RECOMMENDATION

A man once told me that chaos creates opportunities for some people. It’s hard to imagine that on June 12th, 2010, my mother-in-law’s unfortunate accident would create an opportunity for me to build a mechanically assisted walker that could help people with partial paralysis get around their house better. However, that is exactly what happened. There were many bumps and bruises along the way, but overall, it was a success. Just when I thought the programming was complete, the stepper motor driver couldn’t provide enough current to drive the motors after the wheel was mounted inside the driver wheel frame. Upgrading the stepper motor driver meant a completely different list of programming functions and terminology altogether. This meant that all the time spent on trying to figure out the logic and wiring for the old drivers was wasted.

Nothing beats learning on the fly. I remember sitting on the couch talking to my mother-in-law and her husband about what the existing walker lacked. “What does the new walker need in order for you to be able to move around?” I asked her. The challenge of coming up with a solution to control the walker with just one hand was difficult. However, my exposure to videogames presented a perfect opportunity to utilize a joystick to accomplish this. After researching existing patents, more desirable features became apparent. Customer survey brought to light just how important safety is to the average user.

Mr. Banzi, co-founder of Arduino, mentions that his hero, James Dyson made 5127 prototypes of his vacuum cleaner before he was satisfied that he’d gotten it right (13). Throughout the learning process of building my first prototype of the mechanically assisted walker, several different ideas have crossed my mind that would improve the walker. Using the theory of Design for Assembly, the number of parts that make up the driver wheel frame could be reduced from six to only one part through methods of extrusion. Machining time would be reduced in the process. The number of hardware such as bolts to hold the parts together would be reduced also.

The total weight of the walker could be reduced a number of ways. The ¼” bar stock at its weakest point under maximum loading conditions was less than 10% of the available yield strength. This means that thinner material could be used. The stepper motors weigh about 2.5 lbs each. Perhaps the use of a different motor combined with gearing could reduce the weight without giving up torque.

In regards to motor torque, a few of the people that have been exposed to the walker feels that it would be beneficial to incorporate a motor that could supply enough torque to move the walker even if the user leans on the handles of the walker.
APPENDIX A: RESEARCH

Interview with customer, Sept. 26, 2010
Pastor Richard Fisher, uses a walker, 3722 Clifton Ave, Cincinnati, OH, 45220.
Has a rare hereditary blood and muscular disorder called acute intermittent porphyria.
It hinders him from walking independently.
The walker is easier and safer to use than a cane.
Pastor Fisher’s suggestions:
  • Bicycle brakes to be able to brake as needed for when a person is traveling up or
down an inclined plane or ramp.
  • Sturdy and more permanent basket on the front; existing one falls off.
  • Permanent skids on the back. He’s tried tennis balls and gliders, which have a
tendency to wear out quickly.
  • The gliders have a tendency to turn on people, which throws them off balance
and makes the walker harder to push forward.
  • Something that reminds people to “keep focus.”
  • Come with a set of rules or guidelines on how to operate the walker.
  • Reflectors or paint built into walker so that it is bright (red or white) and visible
to people driving vehicles.
  • Walker should fold into something more compact.
  • Locking system so that it doesn’t open up on people.
  • Simplify and identify the adjustable height; push pins are hard to press.

Safety is the biggest concern.
The ability to have a walker that helps people get around will allow them to live longer
because their cardiovascular system will improve.
Safety, longevity… there are more benefits to gain despite high costs.
Enhance a person’s lifestyle encourages them, helps them psychologically and
physically.
Standard size cane. Cane easily folds and unfolds without tools, making storage or travel convenient. Comes with a handy plastic carry holster which keeps the cane folded when not in use. Handle height adjusts in 1" increments from 33" to 37" allowing for personal sizing. Premium grade wood handle is contoured to increase hand comfort and provide safety. Cane folds into 4 convenient parts for easy storage. Handle height adjusts in 1" increments from 33" to 37".

Attractive wood handle with brass collar. Available in 14 great colors this cane provides style and quality all in one. Available in black floral, purple floral and white dot colors.

- 300 lbs Weight Capacity
- Material: Aluminum
- 0.75” Tubing Width
- Cane Height (Lowest): 33”
- Cane Height (Highest): 37”


Standard size Folds for easy storage Adjustable from 33” to 37” height Lightweight Aluminum Many different styles Not powered $ 17.16
The Bariatric Small-Base Canes are built with durable steel construction that provides maximum stability for individuals weighing up to 700lbs. All of the canes are height adjustable for a proper fit to the consumer and are designed with a twist locking ring providing additional security during height adjustment.

- 700 lbs Weight Capacity
- Material: Steel
- Grip Type: PVC contoured hand grip
- Patient Height Range (Min-Max): 4’-11” to 6’-5”
- Cane Height (Lowest): 29.5”
- Cane Height (Highest): 38.5”
- Footprint: 8” x 6”
- Product Weight: 5 lbs

Additional stability and walking assistance vs. the standard cane
Large client height adjustability range
Adjustable from 29.5” to 38.5” height
Heavier steel construction
Not powered
Doesn’t fold
$ 69.00

http://medmartonline.com/products/walking-aids
9/25/10 Bariatric Small Base Quad Cane
700 lbs Weight Capacity
medmartonline.com
New Invacare Value Line Walker. Providers, clinicians, and consumers gain the stability they need at an economical price with the New Blue Release Walker.

The New Value-Line Blue Release Walker offers a wide, deep frame with a large number of height adjustments.

Invacare’s Value-line Blue Release Walker is stable, lightweight and easy to lift and maneuver. Dual Blue-Release mechanisms provide both visual and audible “locked” cues. Anti-rattle “silencers” offer quiet operation. Compatible with most Invacare Walker Accessories.

Rigid dual sided brace design.
Wide and deep frame.

- 300 lbs Weight Capacity
- Material: Aluminum
- Patient Height Range (Min-Max): 5’-4” to 6’-6”
- Walker Height (Lowest): 32”
- Walker Height (Highest): 39”
- Product Weight: 5 lbs 7oz
- Depth Folded: 4”
- Overall Depth: 16”
- Width Inside Base Legs: 21”
- Width Inside Hand Grips: 17”

Additional stability and walking assistance vs. the canes
Large client height adjustability range
Adjustable from 32” to 39” height
Minimum patient height is 5’-4”
Quiet operation
Not powered
When folded, the depth is 4” and the width of legs is 21”
Not as compact as canes
$ 38.95

http://medmartonline.com/products/walking-aids
9/25/10 Dual Blue-Release Adult Walker
300 lbs Weight Capacity
medmartonline.com
Trigger release features is ideal for individuals with limited finger dexterity.
Durable, composite trigger release resists cracking and breaking.
Sturdy, 1” diameter anodized, extruded aluminum tubing construction ensures maximum strength while remaining lightweight.

- 350 lbs Weight Capacity
- Material: Aluminum
- Walker Height (Lowest): 32.5”
- Walker Height (Highest): 39.5”
- Product Weight: 5 lbs 7oz
- Depth Folded: 4”
- Overall Depth: 16”
- Width Inside Base Legs: 21.5”
- Width Inside Hand Grips: 18”

Additional stability and walking assistance vs. the canes
Large client height adjustability range
Adjustable from 32.5” to 39.5” height
Quiet operation
Trigger release helps people with finger dexterity
Not powered
Wheels to assist patient
Not as compact as canes
$ 35.89

9/25/10 Walker-Adult Trigger with 5” Wheels
350 lbs Weight Capacity
walmart.com
Combination of folding walker and rising aid all in one. Secondary handles provide stable assistance from a seated to a standing position. Attractive, upscale Onyx finish. Can be used as a portable toilet safety frame. Single release folding mechanism is designed to aid users with limited hand dexterity. Durable aluminum tubing provides strength while remaining lightweight. 400 lb weight capacity. Contoured, plastic grips for enhanced comfort and a secure hold.

- 400 lbs Weight Capacity
- Material: Aluminum
- Walker Height (Lowest): 32”
- Walker Height (Highest): 39”
- Product Weight: 6 lbs
- Overall Depth: 20”
- Width Inside Base Legs: 26”

Lumex UpRise Onyx Folding Walker
400 lbs Weight Capacity
csnstores.com

Combination walker and rising aid
Can be used as portable toilet safety frame
Single release folding mechanism for people with hand dexterity
400 lbs weight capacity
$ 45.99
The Drive Medical Winnie Go-Lite 3 Wheel Rollator is one of the lightest rollators available weighing in at only 9 lbs, yet it is sturdy and very easy to maneuver. The walker folds for easy transport and storage. The lightweight 7.5" wheels are ideal for both indoor and outdoor use. Comes with a detachable carry pouch. Your choice of 2 unique colors, flame blue or flame red.

- 300 lbs Weight Capacity
- Material: Aluminum
- Walker Height (Lowest): 32"
- Walker Height (Highest): 39"
- Product Weight: 9 lbs
- Overall Depth: 20"
- Width Inside Base Legs: 26.5"
- Unit Length: 24"

Loop lock brakes
Adjustable handle height
Easy, one hand folding
Standard carry pouch
Brake cable
300 lbs weight capacity
$ 77.00

http://www.alltimemedical.com/products/Rollators_Rolling_Walkers_Winnie_GoLite_SupremeGo_Lite_3_Wheel_Rollator.html

9/26/10 Drive Medical Winnie Go-Lite Supreme/Go Lite 3 Wheel Rollator
400 lbs Weight Capacity

Appendix A7
Removable, zippered, water resistant bag under the seat, with comfortable shoulder strap for portability, and mesh pockets on the side for easy access to your items. Adjusts to fit anyone from 4’10” to 6’2” tall. Folds easily for transport or storage.

Comfortable curved back rest. Roomy 13.25” x 13.25” seat has more padding than other rollators.

Locking brakes for your safety. Seat height and brakes adjust easily, with no tools required.

Attractive burgundy color. 250 pound weight capacity. Backed by a lifetime warranty on the frame.

- 250 lbs Weight Capacity
- Material: Aluminum
- Walker Height (Lowest): 27.5”
- Walker Height (Highest): 32”
- Product Weight: 11 lbs
- Overall Depth: 28”
- Width Inside Base Legs: 26.5”
- Unit Width: 24”
- Seat height adjusts from 17.5” to 22”
- Seat is 13.25” wide by 13.25” deep
- Distance between handles is 17”

Water resistant removable bag
Fits wide variety of people ranging from 4’-10” to 6’-2”

Seat with curved back rest
More comfortable seat
Locking brakes for safety
Tool-free adjustable brakes
Triple coat painting for better durability

250 lbs weight capacity
$ 82.00
This portable walker is about four times smaller than your average walker! Plus, the walker quickly and easily folds, so you can store it in small spaces and take it with you when you travel. Easy to use design opens and folds effortlessly—simply raise the easy-release lever with one hand to fold, and slide the handles apart to open.

- 250 lbs Weight Capacity
- Material: Aluminum and Urethane
- Walker Height (Lowest): 32”
- Walker Height (Highest): 36”
- User Height of 4’-10” to 6’-8”
- Product Weight: 6.5 lbs

Portable walker that folds to 6”x4”x32”
Perfect for taking along in airplane bins
Pricey
Easily collapsible
250 lbs weight capacity
$ 149.00

Stander Metro Walker
250 lbs Weight Capacity
footsmart.com

The Invacare Adult Blue Rollite 8" Wheeled Rollator is unlike any other in the industry. The Rollite offers all the standard features such as flip-up seat with a built-in handle, flexible backrest, ergonomic dual paddle folding mechanism and hand brakes. What set this apart are the 8" wheels that improve mobility on tough terrain. Ergonomic handbrakes lock the rear wheels for security. Flexible backrest for comfort. Flip-up seat with built-in handle. Folds into compact unit for storage and transport.

- 300 lbs Weight Capacity
- Material: Aluminum
- Walker Height (Lowest): 32”
- Walker Height (Highest): 36”
- Overall Width: 27”
- Overall Depth: 24”
- Depth Folded: 7”
- Seat Depth: 9.5”
- Seat Width: 17”
- Product Weight: 16.5 lbs

300 lbs Weight Capacity
activelivingnow.com

Flip up seat offers place for patient to rest
Bigger wheels allow for travel on tougher terrain
Flexible backrest for more comfort
Seat gets in the way of walking
Heavier than other units
More expensive
300 lbs weight capacity
$ 187.95
There is an existing patent that has been filed by Jack E. Perkins on Feb. 21, 1979 for a Motorized Walker for the Disabled. It utilizes bicycle handle bars to engage two independent variable speed drills that drive the front wheels.
APPENDIX B: CUSTOMER SURVEY WITH RESULTS

MECHANICAL ASSISTED WALKER
CUSTOMER SURVEY (WITH RESULTS)

I am a senior at the University of Cincinnati studying Mechanical Engineering Technology. The purpose of my senior design project is to create a mechanical assisted walker that will help people with partial paralysis walk independently. Please take a few minutes to answer the following questions.

How important is each feature to you for the design of a mechanical assisted walker? Please circle the appropriate answer. 1 = low importance 5 = high importance

<table>
<thead>
<tr>
<th>Feature</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
<th>Avg</th>
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<tbody>
<tr>
<td>Safety</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
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<tr>
<td>Durability</td>
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<td>4</td>
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<td></td>
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<tr>
<td>Portability</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Height Adjustability</td>
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<td>4</td>
<td>5</td>
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<tr>
<td>Ease of Operation</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Low Noise</td>
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<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Long Battery Life</td>
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<td>3</td>
<td>4</td>
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<td>Appearance</td>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>3.10</td>
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<tr>
<td>Low Cost</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>3.80</td>
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<tr>
<td>Accessories</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>3.00</td>
</tr>
</tbody>
</table>

How satisfied are you with your current walker? Please circle the appropriate answer. 1 = very UNsatisfied 5 = very satisfied

<table>
<thead>
<tr>
<th>Feature</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>Avg</th>
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<tbody>
<tr>
<td>Safety</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>4.10</td>
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<tr>
<td>Durability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>4.50</td>
</tr>
<tr>
<td>Portability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>4.20</td>
</tr>
<tr>
<td>Height Adjustability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>4.50</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
<td>4.22</td>
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<tr>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
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<tr>
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<td>3</td>
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<td>2</td>
<td>3</td>
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<td>4</td>
<td>5</td>
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</table>

What kind of walker do you use?

Do you have a handicap? If so, please describe it.

How much would you be willing to pay for mechanical walker?

| $100-$199 | $200-$299 | $300-$399 | $400-$499 | $500+
<table>
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Comments:

Thank you for your time.
### APPENDIX C: QUALITY FUNCTION DEPLOYMENT

<table>
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<th>Feature</th>
<th>Guarding</th>
<th>Speed</th>
<th>Motor Selection</th>
<th>Size</th>
<th>Weight</th>
<th>Manufacturability</th>
<th>Number of Components</th>
<th>Setup Time</th>
<th>Material Selection</th>
<th>Noise Level</th>
<th>Battery Capacity</th>
<th>Customer Importance</th>
<th>Designer’s Multiplier</th>
<th>Designer’s Importance</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement ratio</th>
<th>Modified Importance</th>
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| Abs. importance | 3.60  | 2.42  | 0.96  | 3.10  | 2.20  | 0.67  | 1.32  | 0.77  | 1.72  | 0.55  | 1.43  | 18.7            | 44.5             |
| Rel. importance | 0.19  | 0.13  | 0.05  | 0.17  | 0.12  | 0.04  | 0.07  | 0.04  | 0.08  | 0.03  | 0.08  | 18.7            | 44.5             |

Appendix C1
## APPENDIX D: SCHEDULE

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<th>Dates</th>
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<td>Customer Features</td>
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<tr>
<td>Safety</td>
<td>Oct 19-25, 10/19-25</td>
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<tr>
<td>Product Objectives</td>
<td>Oct 26-32, 10/26-32</td>
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<td>QFD</td>
<td>Nov 2-8, 11/2-8</td>
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<tr>
<td>Appendices</td>
<td>Nov 9-15, 11/9-15</td>
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<tr>
<td>Technical Drafts</td>
<td>Nov 16-22, 11/16-22</td>
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<tr>
<td>Final Reports</td>
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<td>Design</td>
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<td>Proof of Design Agreement</td>
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<td>Concept Sketches</td>
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<td>Motor and Drive Train</td>
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<tr>
<td>Braking</td>
<td>Dec 36-42, 12/36-42</td>
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<td>Controls</td>
<td>Dec 43-49, 12/43-49</td>
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<td>Assembly</td>
<td>Jan 2-8, 1/2-8</td>
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<td>Fabulous Parts Drawings</td>
<td>Jan 9-15, 1/9-15</td>
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<td>Jan 23-29, 1/23-29</td>
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<td>Jan 30-36, 1/30-36</td>
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<td>Lab Oral Presentation</td>
<td>Feb 22-28, 2/22-28</td>
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<td>Site Report</td>
<td>Feb 29-Mar 5, 2/29-3/5</td>
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<td>Testing</td>
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<td>Appearance Cleanup</td>
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<td>Demos to Student</td>
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<td>Demos to Faculty</td>
<td>Mar 41-47, 3/41-47</td>
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<td>Oral Final Presentation</td>
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## APPENDIX E: BUDGET

### Preliminary

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<th>Purchased Parts</th>
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<td>Walker (Frame)</td>
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<tr>
<td>Motor(s)</td>
<td>$100</td>
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<tr>
<td>Battery</td>
<td>$80</td>
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<tr>
<td>Controller</td>
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<tr>
<td>Brakes</td>
<td>$50</td>
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<tr>
<td>Cables, Belt(s), and Gears</td>
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<tr>
<td>Raw Stock</td>
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<td>Nuts, Bolts, and Screws</td>
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<td>Miscellaneous Parts (15%)</td>
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<table>
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<td>Plasma Cutting, Welding, &amp;</td>
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<tr>
<td>Machining</td>
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<td><strong>Total Fabrication Costs</strong></td>
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### Actual

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<td>Motors</td>
<td>$210</td>
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<td>Batteries</td>
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<td>Controller Components</td>
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<td>Brakes</td>
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<table>
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<tr>
<td><strong>Total Fabrication Costs</strong></td>
<td><strong>$0</strong></td>
</tr>
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</table>
APPENDIX F: CALCULATIONS

1.) Speed of User:

\[ \text{Velocity} = \frac{\text{Distance}}{\text{Time}} = \frac{20 \text{ ft}}{25 \text{ sec}} = 0.8 \text{ ft/sec} \]

2.) Angular Velocity (for Motor):

\[ \text{RPM} = \frac{\text{Velocity}}{\text{Wheel Circumference} \times 60 \text{ sec}} \times 0.8 \frac{\text{ft}}{\text{sec}} \times \frac{12 \text{ in}}{5 \text{ in} \times \pi} \times 60 \text{ sec} = 36.67 \text{ RPM} \]

3.) Pulse Per Second (Stepper Motor Speed):

\[ \text{PPS} = \frac{\text{RPM}}{60 \text{ sec/min}} \times \frac{360^\circ}{\text{step angle (°)}} = \frac{36.67 \text{ RPM}}{60 \text{ sec/min}} \times \frac{360^\circ}{1.8^\circ} = 122.23 \frac{\text{Pulse}}{\text{sec}} \]

4.) Force to Overcome Friction:

\[ F_{\text{friction}} = \text{Weight}_{\text{Walker}} \times \mu_f (\cos \theta + \sin \theta) = 18 \text{ lbs} \times 0.5 (1 + 0) = 9 \text{ lbs} \]

5.) Torque:

\[ \text{Torque} = \text{Force} \times \text{Distance} = 9 \text{ lbs} \times 2.5 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 1.875 \text{ lb} \times \frac{16 \text{ oz}}{1 \text{ lb}} \times \frac{12 \text{ in}}{1 \text{ ft}} = 360 \text{ oz} \times \text{in} \]

6.) Determining Required Torque per Motor:

\[ \text{Torque Per Motor} = \frac{\text{Total Torque}}{\# \text{ of Motors}} = \frac{360 \text{ oz} \times \text{in}}{2 \text{ Motors}} = 180 \text{ oz} \times \text{in} \]

7.) Current Draw:

\[ \sum I = \text{Motors} + \text{Motor Driver} + \text{Uno & Brick Shield} + \text{Potentiometers (Est)} \]

\[ \sum I = (2)3.1 A + (2)0.07 A + (2)0.05 A + (2)0.1 A \text{ (Estimated)} = 6.64 A \]

8.) Run Time:

\[ \text{Run Time} = \frac{\text{Battery Capacity}}{\text{Total Current Draw}} = \frac{8.8 \text{ Amp} \times \text{Hours}}{6.64 \text{ Amps}} = 1 \text{ Hour 20 min} \]
APPENDIX G: ASSEMBLY AND DETAIL DRAWINGS

Assembly Drawing

<table>
<thead>
<tr>
<th>Item No.</th>
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<th>Description</th>
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<tr>
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<td>1</td>
<td>TOP PLATE</td>
<td>2.5 x 0.25 AL BAR 2'</td>
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<tr>
<td>2</td>
<td>2</td>
<td>SIDE PLATE</td>
<td>2.5 x 0.25 AL BAR 4.75'</td>
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<tr>
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<td>2</td>
<td>MOTOR PLATE</td>
<td>2.5 x 0.25 AL BAR 2.5'</td>
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<tr>
<td>4</td>
<td>1</td>
<td>ROUND 1</td>
<td>1 OD AL ROUND X 1</td>
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<td>5</td>
<td>2</td>
<td>BRUSHING 1</td>
<td>1/2&quot; ID BRONZE BRUSHING</td>
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<td>6</td>
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<td>MOTOR</td>
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<td>7</td>
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<td>MOTOR SPACER</td>
<td>2.5 x 0.25 AL BAR 2.6&quot;</td>
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<td>8</td>
<td>1</td>
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<td>9</td>
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<td>ADJUSTABLE FOOT TUBE</td>
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<td>TUBE CAP</td>
<td>1/2 OD PLASTIC CAP</td>
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<td>11</td>
<td>4</td>
<td>FLANGE BOTTOM BOLT</td>
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<td>12</td>
<td>4</td>
<td>CAP HEAD BOLT</td>
<td>10-32 SC X 3/4&quot;</td>
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<td>13</td>
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<td>DRIVE WHEEL</td>
<td>5&quot; DIA RUBBER WHEEL</td>
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Appendix G1
Top Plate Drawing

6 x Ø 0.15 THRU ALL

2.00

0.25

2.25

1.25

0.13

1.00

1.88

0.24

2.50

0.5

Appendix G2
Complete Assembly

Appendix G9
APPENDIX H: PURCHASED COMPONENTS

Seeedstudio Joystick
Seeedstudio Rotary Sensor
Seeedstudio Electronic Brick
Arduino Shield

Arduino Uno Microcontroller
Rugged Motor Stepper
Motor Driver
Danaher CTP22 Stepper
Motor

Li-ion 18650 14.8V
4400mAH Battery
Carex Single Button
Folding Walker
Invacare Platform
Attachment

Rear Glide Brakes with 3” Wheels
# APPENDIX I: BILL OF MATERIALS

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<thead>
<tr>
<th>ITEM #</th>
<th>PART NAME</th>
<th>Part #</th>
<th>Vendor</th>
<th>Material</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
<th>Cost/PER</th>
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<td>1</td>
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<td>BAR04</td>
<td>UC</td>
<td>T6 AL</td>
<td>2.5&quot; X .25&quot; AL BAR 22&quot;</td>
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<td>SDE PLT</td>
<td>BAR01</td>
<td>UC</td>
<td>T6 AL</td>
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<td>BAR02</td>
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<td>T6 AL</td>
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<td>4</td>
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<td>RB01</td>
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<td>UC</td>
<td>1015 CRS</td>
<td>2.5&quot; OD SHAFT 22.5&quot;</td>
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<td>$0.00</td>
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<td>7</td>
<td>SOCKET HEAD SCREW</td>
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<td>MCMASTERTAIX</td>
<td>STEEL W/BLK OXIDE</td>
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**APPENDIX II**
APPENDIX J: ARDUINO UNO PROGRAM

// Includer stepper library
#include <Stepper.h>

#define STEPS_PER_REVOLUTION 200

// Enable (PWM) outputs
#define EN1_PIN_L 9
#define EN2_PIN_L 10
#define EN1_PIN_R 3
#define EN2_PIN_R 11

// Direction outputs
#define DIR1_PIN_L 14
#define DIR2_PIN_L 15
#define DIR1_PIN_R 12
#define DIR2_PIN_R 13

// Fault inputs, active low
//#define FAULT1_PIN 5
//#define FAULT2_PIN 8

// Global variables
unsigned RPM = 10;
unsigned PWM = 25;

// Pin definitions
int JOYPINX = 3;
int JOYPINY = 4;
inTPOTPIN = 2;
inTREAD_DLY = 10;
injoystickX = 0;
injoystickY = 0;
int pot = 0; // 0 - 1023

// NOTE: for left wheel, counterclockwise is forward
// for right wheel, counterclockwise is backward
int enableMove_R = 0; //
int enableMove_L = 0;
unsigned DIR_L = 1; // negative = clockwise, positive = counterclockwise
unsigned DIR_R = 1;
int movingForward = 1;

Stepper stepper(STEPS_PER_REVOLUTION, DIR1_PIN_L, DIR2_PIN_L);
Stepper stepper_R(STEPS_PER_REVOLUTION, DIR1_PIN_R, DIR2_PIN_R);

void setup() {

  // Now enable PWM and start motion
  analogWrite(EN1_PIN_L, PWM);
  analogWrite(EN2_PIN_L, PWM);

  analogWrite(EN1_PIN_R, PWM);
  analogWrite(EN2_PIN_R, PWM);
}

void loop() {
  //digitalWrite(DIR_R, wheelDirR);
  //init_motors();

  read_inputs();

  set_dir();

  get_turn();

  set_speed();

  move();
}

void read_inputs() {
  pot = analogRead(POTPIN);
  delay(READ_DLY); // might not need this much delay, but we'll see ...
  joystickX = analogRead(JOYPINX);
  delay(READ_DLY);
  joystickY = analogRead(JOYPINY);

  pot = map(pot, 0, 1023, 5, 1);
}

  // forward or backward?
void set_dir() {
  enableMove_R = 1;
  enableMove_L = 1;
// Set the forward and backward wheelDirR
if(joystickY > 550) {
    // move forward
    //DIR_R = 1;
    //DIR_L = -1;
    movingForward = 1;
}
else if(joystickY < 450) {
    // move backward
    //DIR_R = -1;
    //DIR_L = 1;
    movingForward = 0;
}
else
{
    // don't move
    enableMove_R = 0;
    enableMove_L = 0;
}
}

void get_turn()
{
    // TURN RIGHT
    if(joystickX > 900) {
        if (movingForward == 1)
        {
            enableMove_R = 0; // lock right wheel
            enableMove_L = 1; // left wheel goes forward (counterclockwise)
            DIR_L = -1;
        }
        else
        {
            enableMove_R = 0; // lock right wheel
            enableMove_L = 1;
            DIR_L = 1;
        }
    }
    // TURN LEFT
    else if(joystickX < 100) {
        if (movingForward == 1)
        {
            enableMove_R = 1; // right wheel goes forward (clockwise)
            DIR_R = -1;
            enableMove_L = 0; // lock left wheel
        }
else
{
    enableMove_L = 0; // lock left wheel
    enableMove_R = 1; // right wheel goes backward (counterclockwise)
    DIR_R = 1;
}

// GO STRAIGHT
else
{
    if (enableMove_L == 1 && enableMove_R == 1)
    {
        if (movingForward == 1)
        {
            DIR_R = -1;
            DIR_L = -1;
            //DIR_L = 1;
        }
        else
        {
            DIR_R = 1;
            DIR_L = 1;
            //DIR_L = -1;
        }
    }
}

void set_speed()
{

    // If we are turning
    if ((enableMove_R == 0 || enableMove_L == 0) && !(enableMove_R == 0 && !enableMove_R == 0 && enableMove_L == 0))
    {
        if (joystickX > 855)
        {
            RPM = 20;
            // delay_speed = 1490;
        }
        else
        {
            RPM = 15;
            // delay_speed = 2500;
        }
    }
}
else
  {// we are not turning
    if(joystickY > 855) {
      RPM = 40;
    }
    else if(joystickY > 685) {
      RPM = 20;
    }
    else if(joystickY > 550) {
      RPM = 5;
    }
    else if(joystickY > 450 && joystickY < 550) {
      //don't move
      enableMove_R = 0;
      enableMove_L = 0;
    }
    else if(joystickY > 335) {
      RPM = 5;
    }
    else if(joystickY > 165) {
      RPM = 20;
    }
    else {
      RPM = 40;
    }
  }

RPM = (int) RPM/pot;
//RPM = pot;
stepper.setSpeed(RPM);
stepper_R.setSpeed(RPM);
}

int inputs_changed()
{
  //int tmpPot = pot;
  int tmpJoystickX = joystickX;
  int tmpJoystickY = joystickY;
  //tmpPot = analogRead(POTPIN);
  delay(READ_DLY); // might not need this much delay, but we'll see ...
  tmpJoystickX = analogRead(JOYPINX);
  //delay(READ_DLY);
  tmpJoystickY = analogRead(JOYPINY);

  /*if (tmpPot >= pot + 100 || tmpPot <= pot - 100)
{  
    return 1;
}
*/
if (tmpJoystickX >= joystickX + 100 || tmpJoystickX <= joystickX - 100)
{
    return 1;
}
if (tmpJoystickY >= joystickY + 100 || tmpJoystickY <= joystickY - 100)
{
    return 1;
}
else
{
    return 0;
}
}

void move()
{
    while(1)
    {
        // see if inputs changed
        if (!inputs_changed())
        {
            // set step
            if (enableMove_L == 1)
            {
                // do not step if wheel is locked
                stepper.step(DIR_L);
            }
            else
            {
                twistStep(DIR_R);
            }
        }
        else
        {
            break;
        }
    }
}