Optimal Design

Shampoo/Conditioner Identification Device & Backpack Lever Arm System

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1. Optimal Design

1.1 Introduction

Introduction

Novel healthcare devices can be used to aid individuals with physical and psychological limitations; primarily, the goal is to help them independently perform certain tasks. The client’s specific symptoms have resulted in an inability to differentiate between certain items, and have led to greater reliance on others. Mrs. Smith wishes to be more independent in terms of being able to differentiate between shampoo and conditioner bottles in the shower. Despite having mild cognitive impairment and reduced visual acuity, Mrs. Smith desires to remain self-reliant in carrying out her daily routine.

This optimal design plans to incorporate ideas that were brought to the team’s attention by comments and suggestions from alternative design reports. Previous designs have involved the attachment of accessory speakers onto a touch-sensitive belt, or a belt with several buttons along the circumference of the bottle. These serve as mechanical stimulation points, which the client must use to activate subsequent parts of the system and result in an auditory output. In the proposal as well as the first alternative design, small speakers were attached to the belt itself. Thus, the need for an additional station or base was eliminated. However, it quickly became clear to the group that such a device (which requires components such as a speech synthesizer, speakers, a battery, and other circuitry) would be difficult to produce in terms of being able to adhere to dimensional and weight requirements. Even if the device were light, the volumetric bulk would make the instrument impractical to use.

In alternative design two, the entire system was incorporated into one unit. The shampoo/conditioner was dispensed based on voice-activation (rather than a mechanical stimulus). This product would eliminate the need for the client to physically carry any object in her hand. This was a major advantage, as reduced visual acuity, when trying to grip and carry a heavy shampoo/conditioner bottle carries an element of risk. However, the method of delivery in this case is different from what the client originally requested; upon correspondence with the client’s representative, the team found that the change in design was not desired.
Given suggestions and comments on the alternative designs, the team has decided to have a separate wall unit, in which appropriate circuitry, speakers, and an infra-red wireless receiver can be placed. The belts will merely consist of a touch-buttons and an infra-red wireless transmitter. Once a mechanical stimulus is detected, an infra-red signal will be sent to the base wall unit. Upon receiving this, the speaker on this base will emit an auditory output, indicating the product that Mrs. Smith has in her hands.

Figure 1. Flow Chart for Device Operation

Figure 2. Visual representation of the product
1.2 Subunits

1.2.1 Pushbutton Switch

The activation of the system will work through pushbutton switches that will surround each bottle. There will be 6 buttons that are connected in parallel across the battery source. When any of the 6 buttons are pushed the input signal is initiated and the microcontroller will send a signal to the synthesizer which will output a vocal prompt. The design should be quite effective because it will allow for a button every 60 degrees around a bottle of shampoo or conditioner. In this way it will be easy for our client to activate the device at her convenience. The advantage of using push buttons is that they only activate on the push sequence and they will not continue to be activated if they are not released.

1.2.2 Main Voltage Regulator

The power delivery for this kit will provided by two 9V battery routed through a voltage regulator. The voltage regulator used will be a 7812 chip. This chip is ideal because it has a max voltage rating of 11.5 volts and a typical voltage of 12 volts. The current out of the voltage regulator is also set at 500mA. The chip is small and quit cheep to buy. A block diagram describing the voltage regulator is given bellow.

![Figure 3. Voltage Regulator](image)

1.2.3 Microcontroller

The microcontroller that is ideal for application to this project is the PIC18F1230. This chip offers the ability to of customization and self programming based on the mode that it is put into. It also features pin break-out so that it is easy to use with a protoboard. There is also a built in potentiometer that is used to control a 10-bit analog-to-digital input channel. The microcontroller consists of two external
clock modes and two external RC modes. However the two most pertinent aspects of this chip are the internal oscillator and the flash memory module. The microcontroller will only be used to access memory and output a specific voice prompt from the text to speech module.

The V8600A Speech synthesizer is one of the most convenient and compact speech synthesizers on the market. It is ideal for our application because it only uses 5 volts to power the entire chip. The V8600A is designed to be piggy-backed onto a host PCB, such as a microcontroller. An eight-bit bidirectional data bus and read/write control pins enable the V8600A to allow for easy manipulation of the chip's parameters via our microcontroller. The voice output is controlled through software. The speed and pitch can be dynamically controlled by embedding the parameters in the text input. The volume will be controlled by using a 10kΩ potentiometer connected between the line pin and ground. Adjusting the potentiometer clockwise will increase the volume and counterclockwise will decrease the volume.

Figure 4. Microcontroller Pin outs

1.2.3 Text to Speech

The V8600A Speech synthesizer is one of the most convenient and compact speech synthesizers on the market. It is ideal for our application because it only uses 5 volts to power the entire chip. The V8600A is designed to be piggy-backed onto a host PCB, such as a microcontroller. An eight-bit bidirectional data bus and read/write control pins enable the V8600A to allow for easy manipulation of the chip’s parameters via our microcontroller. The voice output is controlled through software. The speed and pitch can be dynamically controlled by embedding the parameters in the text input. The volume will be controlled by using a 10kΩ potentiometer connected between the line pin and ground. Adjusting the potentiometer clockwise will increase the volume and counterclockwise will decrease the volume.

Figure 5. Text to speech Synthesizer
The microcontroller and speech synthesizer should work well together because they both have the same voltage requirements. The main advantage of not controlling the voice prompt by the microcontroller is that it has less potential of complications. The memory on the microcontroller only needs to have one object stored, the ASCII text for “shampoo” or “conditioner.” The rest of the system is controlled by the speech synthesizer. This is far superior because the V8600A is a dedicated to only one task, voice output. So any manipulation of the output can be controlled through this device by embedding commands through the input text.

1.2.4 Wireless Transmitter

The wireless receiver and transmitter devices should be relatively easy to build. A schematic of the general circuit is shown below. The circuit is powered by a 5V at .5A. This will be provided by a 7805 voltage regulator connected to a PP3 9V cell. The signal for this system is provided by a PIC12C508 microcontroller. Each bottle will have a transmitter system and the base will have two receivers. The bottles will be differentiated by the frequency of the signal that is outputted through the infrared transmitter. For the shampoo bottle the frequency will be 38kHz and for the conditioner the frequency will be 40kHz.

![Figure 6. IR Transmitter](image)

The transmitter basically works by continually having a signal at a constant frequency connected to one end of a NAND gate. The other input to the NAND gate will be a from a switch (for this project size parallel switches. Based on the way that a NAND gate function that is only one case where it’s output is Low. That is when both inputs are High. When the output is low the
transistor will allow 5 volt to flow through the infrared LED lights and they will illuminate at the same frequency as the input on pin 1 of the NAND gate.

The signal for this system is provided by the PIC12C508 microcontroller configured as shown in the circuit diagram below. The 8-pin PIC12C508 is pre-programmed to generate our 38KHz carrier frequency by simply pulsing I/O-pin GP1. The PIC will generate either 38KHz or 40kHz, depending on the state of GP3 when power is first applied. This will be vital for the system to differentiate between the different bottles of washing liquid. If GP3 is connected to ground, then power is applied to the circuit, the frequency will be 40kHz. If on the other hand the GP3 pin is left floating the default setting implements a 38kHz signal from the internal oscillator.

![Circuit Diagram](image)

**Figure 7.** PIC12C508 with connections

GP0 is used to inhibit the carrier output this way when GP0 is connected to ground, the PIC will stop generating the carrier frequency. This will be used during power saving mode when the bottle is place on the base. When the pin is left floating the PIC starts the carrier frequency again. The final piece of the circuit is the 4 MHz oscillator which is used as the clock signal for the system.
1.2.5 Receiver

The receiver circuit will be a simple implementation of the IR Receiver Modules made by Vishay Semiconductors. The company sells many different versions of this module, however the project will only be using the 38kHz and 40kHz variety. The model numbers for these are TSOP4838 and TSOP4840 respectively. The modules work by detecting a single at a specific frequency and then outputting a logic High at pin 1. The devise will then be connected to the microcontroller which will output the desired prompt.

Figure 8. Block Diagram for TSOP48--

1.2.6 Belt

Taking into consideration the environment in which the device will operate, there are certain requirements that have guided us in choosing the appropriate materials for the belt. Given the properties of water and proximity to electrical parts, all measures should be taken to ensure that any possibility of contact is eliminated. This will be carried out through a waterproof casing to maintain client’s safety. In addition to making the device shock-proof, corrosion resistance is absolutely necessary for daily use and long-term product life. In making sure that these requirements are met, there is a need to ensure that the weight of the entire device is still kept within a reasonable limit. A device that is light in weight would reduce risk of injury to the client, in-case the bottle/device falls.
An appropriate material to use in the manufacturing of this device would be similar to that of a hose. The ‘Roll a Hose’ Flat Hose is only 12mm in diameter, increasing the total diameter of the shampoo bottle 2.4 cm. This is a manageable width, and will not make the device too bulky. In the optimal design, since all other system components are incorporated in the base (e.g. speech synthesizer, speakers), a belt of this diameter will only include small touch buttons and an infra-red LED. Therefore, the hose’s width will be sufficient. In terms of material properties, the hose is made of rubber, and soft PVC. In addition, it is covered with a layer of nylon and cotton. This satisfies the requirement of making the belt resistant to water, and corrosion. The high strength of the hose will ensure that the electrical components inside are protected. In addition, since hoses cater to water running at high speeds, the type of environment subject to the hose-made belt will cause negligible weathering.

Six holes can be made along the line of the hose and evenly spaced to incorporate the buttons. The buttons will be covered by an additional insulating layer from the inside to ensure that no water leaks into the inner circuitry, located within the hose (belt). An additional hole will be made for the small speaker output, from which the client will receive an auditory signal.

To be able to customize the belt to various bottle sizes, the group will create a watch belt type of mechanism. Here the hose (belt) will extend, as if it were a strap. The strap will have additional small holes and a buckle (the same
concept as a watch belt) to change the bottle – diameter on which the belt can fit.

The 6 buttons on the belt will essentially be ‘normally-open, soft-touch momentary switches’. These push buttons are small, with dimensions that allow them to fit into a circular hole that is 9.5 mm in diameter. Therefore, since the diameter of the hose is 12mm, it is clear that the buttons will fit and still leave space to accommodate the circuit wires.

![Figure 10. Small, normally-open soft-touch momentary switch](image)

1.2.7 Outer Structure - Base

The base - wall unit will be modified from a product, available in the market by the Velleman Corporation. It is simply a box, manufactured from a material called ABS, or Acrylonitrile butadiene styrene. This is a commonly used thermoplastic in the manufacturing of lightweight, rigid and customizable molding products. The advantage of using ABS is that it combines the high strength and rigid nature of acrylonitrile and styrene polymers with the toughness of the polybutadiene rubber. In addition, ABS is resistant to various aqueous environments (acidic and basic), making it a durable material and viable choice for this product. [2].

![Figure 11. ABS casing, for ‘Base Unit’ of Shampoo/Conditioner Device](image)
The box shown above is black in color (displayed on the company website). A small hole will be drilled in the area where the infra-red receiver is supposed to be placed. This will allow the signal be transmitted without hindrance. Since material properties of this product suit the team’s requirements in terms of being resistant to various temperature and chemical, this seems to be an ideal choice. Portions of the box can be cut and manipulated to incorporate the speakers, which will slightly protrude from the box. However, in order to ensure that no water leaks or comes on contact with any circuitry, the inside of the container will be covered with an additional sheet of PLAS-TEX® PolyWall by PLAS-TEX®. This is a propriety technology, and is manufactured by using a combination of polyethylene and polypropylene. Parkland’s PLAS-TEX® material is 100% waterproof, and proven to resist mold and mildew; in addition, it will not rot, swell or support bacterial growth. These unique properties help increase durability and life of the product.

The dimensions of the ABS box are 160x95x55mm. Given the size of the speakers, voice synthesizer circuit, and wireless receiver, this amount of volumetric space should be sufficient to hold the necessary components. The weight of the container is approximately two pounds. This will increase with the components that will go inside of it. Wall brackets can be bought, so that the container can fit into corners or flat walls in a bathroom setting. Alternatively, it may be placed on the ground immediately outside of the shower.

One limitation of this design is that the base unit must be close (an estimated 1 meter) to the wireless transmitter. It is vital that this condition is met, to ensure that the infra-red signal is optimally transmitted and received.

To maximize power efficiency, when bottles are placed in holders on the base, the unit will be turned off. When bottles are removed, the unit will be turned on. Depressed buttons (when bottles are placed in the holders and not being used), will prevent the unit from being powered, thus not draining the battery. This mechanism is explained in detail in the section of the report describing power supply to the wall unit.

1.2.8 - Speakers

The speakers that will be attached to the Shampoo/Conditioner bottles need to be small and light to minimize the device. The IPod NANO portable mini speakers seem to be very suitable for this project because of their petite size and low voltage requirements.
They have a dimension of 8cm in length, 5cm in height, 2.4cm in width, and a light mass of 38 grams. Since to minimize the total amount of weight of the device is one of the main goals of this project, the power source for the speakers becomes very important. These speakers only require two small AAA batteries. The speaker will be connected to the output of the voice synthesis chip that is part of the base unit circuit because they are compatible with all audio output signals, and costs about $17 per piece. These great qualities are ideal for the Shampoo/Conditioner Identification device.

![Figure 12. iPod NANO Portable Mini Speakers](image)

### 1.2.8 - Battery Holders

Three 9V battery holders are required for the Shampoo/Conditioner Identification device. One of the batteries is for the shampoo bottle to power the infrared LED, another one for the conditioner bottle for the same purpose, and the third one for the base to power the electrical components of the circuit and the speakers.

Since the device will be operated in a wet environment, all the components have to be water-proof. Therefore, the team has chosen the Bulgin 9V battery holder (BX0023). It is made of glass filled nylon which will prevent water from contacting the battery.
2. Realistic Constraints

Engineering Standards must be taken into consideration when designing and developing new products. Some of organizations that specializing in creating and monitoring engineering standards include American National Standards Institute (ANSI), American Society for Quality (ASQ), Association for Advancement of Medical Instrumentation (AAMI), International Organization of Standardization (ISO), and National Institute of Standards and Technology (NIST).

The Shampoo/Conditioner Identification device must meet or exceed the engineering standards and guidelines provided by the standard organizations because not only do they ensure the safety of the users, but they also enhance the quality of the product.

Several standards that are relevant to this project specifically are EN 1441:1997 Medical Devices (Risk Analysis), and EN 868-1:1997 (standardized packaging). \[11\]

In terms of economic constraints, the primary limitation is the allotted budget of $750. The device designed should be as affordable as possible, as it may hold potential to serving a larger population of senior citizens at some point. Families that require this device will vary in income levels. The solution will satisfy this fundamental condition.

The shampoo and conditioner identification device is essentially an adaptation of a touch sensitive device that generates a voice output through a speaker that is placed on a separate unit. Striving for the highest quality; the
device will be designed and assembled in manner with which it is economical
to produce.

With reference to the environment, all measures will be taken to ensure
that the device causes negligible or no harm to the surroundings. Specifically,
this involves adequate disposal of batteries, and the waterproof nature of this
system (to avoid leakage of toxic substances from the battery into the
surrounding). Construction materials of the device will account for the client’s
health and safety.

In terms of sustainability, the device will have to be capable of
withstanding a variety of temperatures and a moist environment, which it will
be constantly exposed to. Selection of appropriate materials for this device will
be essential for corrosion resistant properties. In case of unintentional damage,
the device must have accessible electrical test points for checking or repairing
its operation.

Considering the properties of this device and its application, its
manufacturing will involve a detailed consideration of each component. The
safety measures will be central to the manufacturing decisions. Other factors
will be based upon ergonomics and client convenience. It is expected that the
circuitry and design to be relatively easy to replicate, in case a larger market
opens up for this type of product.

In addition to using insulating and airtight material in a wet
surrounding (to make the device shock-proof), low-voltage power sources are
used to make sure that all electrical components work according to the
simulated model, we will ensure that the working life will be optimized.
Materials with rough edges or sharp protrusions will not be incorporated to
abide by the underlying values, which is to guarantee the safety of the client.

There is one social constraint, which is that the device might need to be
removed and attached to other shampoo and conditioner bottles. This will
require someone to periodically visit Mrs. Smith and do the needful. Therefore,
a minute element of dependency on another individual still exists.

3. SAFETY ISSUES

The main safety concerns of the Shampoo/Conditioner Identification
device are due to the unusual environment that it will be operated in – shower.
The device includes electrical circuits which contain parts that will cause shock
when exposed to water, therefore the entire device will be enclosed with
insulating material to prevent water from entering. The security of the
attachment of the device is another critical safety constraint because it will be placed on a relatively wet and slippery surface.

The shower has limited space, hence it is likely that the user could accidently run into the device. The device should have as few sharp edges as possible to avoid potential harm. Minimize the size of the device also increases the available space to the user in the shower, thus the device need to be very compact.

The device has a lot of electrical components, so the reliability of these parts will be very important. The batteries which act as the power source of the entire device will need to be small yet powerful enough to prevent operational failure, which consequently may result in inconvenience or even injuries to the user.

4. IMPACT OF ENGINEERING SOLUTIONS

It is clear that engineering solutions impact humanity at multiple levels, and can be seen in almost any activity carried out on a daily basis. Engineering has the potential to transform the way in which humans live their lives, and also advance knowledge and practices in a manner that is unimaginable.

Based on an optimal design for the shampoo/conditioner identification device, it is obvious that a significant impact can be made at a global level, for clients with cognitive impairment, or reduced visual acuity. Memory loss is a major symptom of patients with Alzheimer’s disease, a health condition that is most common in individuals above the age of 65. At present, more than 5 million Americans are estimated to have Alzheimer’s disease. By the middle of the century, it is estimated that 14.3 million Americans will have the disease. Therefore, it is clear that a large market for this kind of device will develop over the course of the next few decades.

This product can be used for patients with low visual acuity, which may be caused by a disorder, or during healing time after ophthalmic surgical procedures. Patients (especially those that are single) may need temporary assistance in recognition of items within their household. Thus, a device such as the shampoo/conditioner identifier will provide assistance in doing so. The current project is catered to the identification of specific bottles of hair products for use in the shower. However, it is possible to diversify applications using the same concept. A recognition device can be used in the kitchen for beverage bottles or food containers.
When discussing engineering solutions in an economic context, it is natural to analyze the market and customer base. Generally, a conservative estimate is taken, in which it is projected that 10% of the customer base will be using the product within five years of release. However, this may change depending on company strategy and the method of marketing used. There would be two customer bases, one that would need this device permanently (individuals with Alzheimer’s disease), and post-ophthalmic surgery patients, that would require it temporarily. Thus, it may be beneficial for a company that was responsible for manufacturing and selling this product to have two separate marketing and sales strategies. In the first case, the product would be sale. In the second case, the product would be rented out to the consumer. Depending on factors such as total costs, and the profit margins desired, a price for both schemes could be determined.

However, it is vital to evaluate whether this type of product would be successful in a global scale (by analyzing cultural norms). In developing countries, it would be hard to imagine this sort of device being successful. In many developing countries, it is customary to see elderly parents living under the same roof as their son and his family. It is also common to see domestic help around families that are middle to upper class. Therefore, even if this device was made affordable, the group feels that cultural norms would prevent it from being a financially lucrative product to produce in this type of market.

In an environmental context, engineering solutions such as this do not seem to pose much of a threat. In terms of manufacturing a device such as the shampoo/conditioner identification device for a market of this size, the amount of pollution caused to the environment (land, air, water) is negligible in comparison to production of other products, in which harmful fumes or toxic wastes may be emitted. An optimal design plans to use a small dc power source (battery). Inadequate disposal of the batteries is the only other cause of concern to the environment. However, it is unlikely that this problem will be significant enough to threaten natural surroundings in any way.

5. LIFE-LONG LEARNING

For this project, the majority of what the team has learned involved comments on previous alternative design reports and other peoples’ experiences in designing the same device. In spring 2007, one senior design group created a shampoo/conditioner identification device for the same client. However, their design did not meet the specifications of the client, and unfortunately, could not be utilized. Through comments from the adviser,
reviews from the client, and research, the group have learned about what constitutes an excellent design and what sort of features can lead to problems.

Last year, although the previous design group incorporated a clever idea, it did not meet the expectations of the client. The instrument functioned in a manner that involved lifting the bottle off of a base, which then output an auditory signal. This was not what the client had asked for, since Mrs. Smith wanted to rely on a mechanical stimulus (squeezing the bottle) rather than having an adjunct base, for which she would need to find a vacant space in the shower. In addition, the device attached to the shampoo/conditioner bottle in order to make this work exceeded the weight limit, in terms of what was reasonable for the client to handle.

Primarily based on a critique of last year’s product from an engineer, the team has decided to eliminate having multiple components on the belt material, which would potentially increase volume and weight, beyond what is acceptable for the client. However, after analysis of the client’s health conditions, the team feels that a base terminal, which manages every aspect of the system except the mechanical stimulus would be most convenient for the client to operate. Carrying a heavy shampoo/conditioner bottle and managing a potentially cumbersome belt would be an unnecessary hassle and possible safety hazard to the client. In addition, the team has made sure to take the client’s exact request into considering, that is, the application of pressure to the bottle (on soft-touch momentary switches) should result in the emission of an auditory signal.

In terms of new skills acquired, the machine shop course has progressed into teaching about in lays and on lays. So far, this course has been helpful in learning how to cut and shape metal to various specifications. By emphasizing accuracy of design (to the nearest thousandth of an inch), the team is confident that this course will prove to be valuable, when it comes time to actually develop the device. These skills are also helping this semester, as it is possible to imagine which tools/instruments can be used to make a device of certain dimensions.
6. REFERENCES

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Backpack Lever Arm System

1. Optimal Design

1.1 Introduction

For individuals with physical limitations, which may be caused by debilitating health conditions, innovative biomedical devices can be used to aid in carrying out certain tasks. The client’s symptoms have resulted in an increased dependency on others; he desires to be more self-reliant in terms of accessing his possessions without external assistance. Specifically, this refers to being able to place and remove objects from his back pack, which is usually attached to the wheelchair.

The device is essentially a backpack lever arm, capable of moving the client’s belongings to an accessible position. The product will be designed in a manner that takes advantage of Mason’s functional right arm. In addition, the device will remain in close proximity to his wheelchair at all times; it will be located on the right-hand side to utilize his arm’s reaching capability. Designing this device on the opposite side of the wheelchair may cause Mason difficulty, as he may have to inconveniently stretch; therefore, this option has been ruled out. A switch mechanism will be used to position the device at Mason’s lower thoracic/upper abdominal level for optimum comfort. One of the clients’ requests is that the backpack be brought close to the body’s midline. This design will allow us to meet the requirement.

The foldable arm will involve two hinge joints at appropriate positions on the arm to allow for horizontal planar motion. These hinges will connect the three segments of the lever arm. One limb will remain attached to the back of Mason’s wheelchair (at a height level that approximately 6 inches above that of his arm rest) and the others will rotate in a manner that unfolds the compact arm and brings the backpack to the desired position.

When the backpack lever arm is not being used, the arm folds and is in a compacted at the back of the client’s wheelchair. In this design, there are 3 limb segments. Limb 1 is attached to the rear of the wheelchair, and is placed perpendicular to the arm-adjustment poles. To describe the functioning of the device in sequence, it starts with a user stimulus. When Mason wishes to obtain items from his backpack, he will turn the switch located on a remote controller (which is attached by a Velcro strap to the right arm-rest). Firstly, limb 2 rotates
180 degrees in a counter-clockwise direction about the first joint. Following this, limb 3 rotates 90 degrees in a clockwise direction. At this position, Limbs 1 and 2 are continuous (in terms of begin in-line with one another). Finally, Limb 2 rotates 90 degrees in a counter-clockwise direction about the first hinge to bring the backpack to Mason’s midline.

Once he has removed/replaced desired items from his backpack, Mason will turn the switch in the opposite direction. This will reverse the movement of limbs to fold individual segments and return to the initial position.

Figure 1. Flow Chart for device operation

### 1.2 Subunits

#### 1.2.1 Stepper motors

The stepper motor we are planning to use is the 10A-TTL-3SW-42 by Excitron. This motor is very versatile and will allow us to make precise movements without the need of an angle measuring device. This motor moves .9 degrees per step. The motors will be precisely controlled by the microcontroller. A given number of pulses will be sent to the motor so as to ensure it only moves the proper amount. To operate our setup we will be using two motors, one for each hinge. These are idea for our setup because they provide the correct amount torque to ensure that the arm rotates out consistently and without complication such as overheating of gear shredding. These motors only require 12 volts to operate, however 24 volts is recommended. This should be easily provided by our client’s wheelchair. Since there will only be one motor working at a time there should be no extra strain on the wheelchair battery. The motor is also relatively light at 1 pound so it should not put any extra strain on the actual lever arm assembly.
1.2.2 Microcontroller

The microcontroller that is ideal for application to this project is the PIC18F1230. This chip offers the ability to of customization and self programming based on the mode that it is put into. It also features pin break-out so that it is easy to use with a protoboard. There is also a built in potentiometer that is used to control a 10-bit analog-to-digital input channel. The microcontroller consists of two external clock modes and two external RC modes. However the two most pertinent aspects of this chip are the internal oscillator and the flash memory module.

The internal oscillator block can provide an 8 MHz clock as well as a range of six selectable frequencies between 125kHz to 4MHz. This feature will
easily be utilized for providing the correct movement sequence to the stepper motors that are involved in the joint articulation. A specific interval of time can be programmed for each of the stepper motors to be active. This way there will be precise, repeatable movements of the lever arm.

1.2.3 Lever Arms

The foldable arm will involve single-hinge joints at appropriate positions on the arm to allow for horizontal planar motion. The arm will have two joint, connecting three limbs. Limb one will be attached to the back of Mason’s wheelchair (at a height level that approximately 6 inches above that of his arm rest) and the others (limb two and three) will rotate to bring the backpack to the front as close to the client’s mid-line as possible. The backpack will be fastened to the lever arm via an attachment accessory, such as a clipper.

To describe the functioning of the device in sequence, it starts with a user stimulus. When Mason wishes to obtain items from his backpack, he will turn the switch located on controller (which is attached by a Velcro strap to his right arm chair). This will trigger the step motors to rotate the lever arm.

First, Limb two will rotate about hinge one 180 degrees in a counter-clockwise direction from the folding position. Then limb three will rotate 270 degrees counter clockwise about hinge two to the right of limb two to form an L-shape. After that, limb two will rotate once again about hinge one 90 degrees clockwise to bring the backpack that is attached to limb three as possible to the client’s mid-line as possible. The final positions of three limbs after the rotations are limb one remains attached to the back of the wheelchair, limb two is 6 inches directly above the right arm rest, and limb three is in front of Mason with the backpack attached to it.

Once he has removed/replaced the desired items from his backpack, Mason will turn the switch to reverse the sequence of the rotations described previously to bring the backpack to the back of the wheelchair.

The followings are visual representations of how the device is supposed to function. Figure 3 illustrates the Lever Arm System and its rotation mechanism. The upper block diagram indicates the movement to bring the backpack from its initial position at the back of the wheelchair to the front – to our client’s mid-body level. The lower block diagram shows how, upon stimulus, the backpack returns to its initial position behind the wheelchair, followed by folding of the arm into a convenient and ‘collapsed’ position.
Figure 4. Top View of the Lever Arm System
In terms of exact location and of the device, dimensions of the client’s wheelchair, the Quickie-500, must be taken into account. The seat has an adjustable width of between 12”-14”; the depth of the seat is adjustable between 10”-15”. Taking these figures into account, it becomes easier to specify lengths of the individual arm components. In this design, limb one that is attached to the back of the wheelchair is 14 inches in length. Limb Two will be about 20 inches in length and limb three will be 9 inches in length. The height of these steel rods (used to form the limbs) will be 2 inches, and the width will be 7/8”.

As far as determining the placement of the hook that will attach the backpack to limb three, torque must be taken into account. Client requested a device that will hold approximately 30 lbs, thus the torque will be calculated based on that weight. Torque is the measurement of the force acting on an object causing it to rotate. It is the cross product of distance vector and force vector.

$$\tau_0 = r \times F$$
As mentioned previously, the length of limb three is one foot or 0.3048 meters. Hinge two acts as the pivot point, and weight of the backpack 30 lbs is the only force that will produce the torque. The following torque calculations were made based on the free body diagram.
The backpack is hanging $\frac{3}{4}$ away from hinge two,

$$\tau = r \times F$$

$$\tau = \frac{3}{4} (0.3048) \times (13.64)(9.8)$$

$$\tau = 30.56 \text{N} \cdot \text{m}.$$  

The foldable arm itself will be made of low carbon steel because of its light, malleable and inexpensive. These properties are extremely critical because the addition of the device should not affect the balance of the wheelchair. The project has a relatively low budget of $750, therefore the inexpensive nature of low carbon steel is also important. The team has decided to use the hot rolled square low carbon steel bars from Chapin & Bangs. They are $7/8''$ in size which fits the requirements of the design.

1.2.4 Hinge

The backpack lever arm system requires two hinges, one attaches limb two to limb one, the other connects limb two and three. Please refer to figure ? for the specific placements of the two hinges. These hinges need to have the capability to rotate 270 degrees both counter clock and clock wise to satisfy the forward and reverse movements of the lever arm.

The team decided to use 270 degree overlay hinge supplied by the Hardware Source. It is made of brass, and costs $17.97 each. The dimensions of the hinge are 1-9/16” tall, 1” deep, and 1-3/8” long. It has a 7/8” limitation on the thickness of the bar attached. Therefore, the height of the lever arm cannot exceed 7/8”.

Limb two is attached to the moving attachment piece of the hinge. The fixed part of the hinge will be mounted to the end of the front right side of Limb One. In its closed state, the limb two remains rested parallel to limb one at the back of the wheelchair. The fixed part of the hinge two will be mounted to the other end of limb two, and the moving part will be attached to one end of limb three. When Mason wants to access his backpack, he will turn the switch. And the moving part of the hinge will allow limb two and three’s forward and reverse movements described in the Lever Arm section.
1.2.5 ATTACHMENT TO WHEELCHAIR

The component used to attach the device to the wheelchair is a vital part of the system. It is absolutely necessary that it be placed at locations that provide maximum stability. In addition, materials that form the support must possess high mechanical strength. The team plans to use low-carbon steel to build an attachment/support device, which will provide adequate strength to the design.

After a careful analysis of the client’s wheelchair and the environment in which the device plans to operate (on the basis of pictures sent by the client’s family as well as a review of on-line information posted by the manufacturer), it seems appropriate to incorporate a horizontal bar support at the back of the client’s wheelchair. Since Quickie Z-500’s seat width is (12-14 in.), the horizontal support bar will be adjustable to accommodate sizes in between. This will be taken care of by inserting rods of varying lengths into the vertical adjustment holes, based on the client’s requirement. The bar will be locked on both sides to the vertical adjustment pieces, generally used to adjust the height of armrest clamps.

If the wheelchair needs to be adjusted, the support can be removed and placed at a level that the client feels is appropriate. The horizontal support will serve as the location to which the first segment (path for the wheel) is attached. The support piece will be attached to the path at four points, equidistant from each other along the path. Screws will be placed on each to ensure that fixation has taken place.
Primarily, the vertical adjustment holes will bear the greatest force, which will be in the downwards direction. It is also essential that the rods inserted in the vertical adjustment holes have sufficient shear strength, since this is the type of force they will be experiencing. The team plans to use 304 stainless steel, as it will be more than sufficient in meeting strength requirements. The shear strength of 304 stainless steel has been noted to be 186 MPa. [2]

Figure 9. Visual representation (back view) of the wheelchair with lever arm.
1.2.6 ATTACHMENT OF BACKPACK TO DEVICE

The H.B. Clipper Quickdraw will be used to hold the backpack in place. In addition to being capable of supporting a heavy load, this will enable convenient attachment/detachment of the backpack in case there is a need. In terms of materials, the clippers are made of stainless steel, which is corrosion-resistant. This will improve the safety and product life the device. The two clippers are connected by a strong, 13 cm nylon string. Since this device is meant to be used for climbing, it is capable of handling various degrees of strain, as well as different climatic conditions. This durability will prove to be a positive feature of the device. In addition, it is essential to realize that the H.B. Clipper Quickdraw is light in weight, and will not significantly add to the weight of the entire device. It is a mere 4.8 oz, which is great when attention is directed to the amount of strength that it adds to the entire system.
In terms of the exact location on the backpack lever arm, the H.B. Clipper Quickdraw will be attached to Limb 3, which is the segment that comes closest to the client’s midline. One clipper will be used to attach the backpack whereas the other will be used to attach to the limb. This will be done by making a small circular hole with a 1 inch diameter into one side of the limb.

3. REALISTIC CONSTRAINTS

In today’s age it is not enough to just build an object, the affect it has on its surrounding must also be taken into account. Engineers are instructed to make sure that the products they design meet specific standards. Above all else their creations must do not harm others. They must also be efficient and affective for the potential users. In order to ensure that new products on the market adhere to all of the requirements there are engineering standards that are predetermined.

These guidelines are setup up by the government and engineering organizations. Some of organizations that specializing in creating and monitoring engineering standards include American National Standards Institute (ANSI), American Society for Quality (ASQ), Association for Advancement of Medical Instrumentation (AAMI), International Organization of Standardization (ISO), and National Institute of Standards and Technology (NIST). The approval of these groups is vital in the potential market reaction to any new product.11

For the Backpack Lever Arm System this means that it must meet all the standards of any product on sale today. Since this is not just a prototype that will be used for testing, but instead a device that will directly impact the life of another person it must meet or exceed the benchmark that consumers have come to expect. The most relevant standards that this project must meet are specifically the ISO 9001:2000 Quality Management Systems (Requirements which provides systematic methods for managing all aspects of manufacturing a device), EN 1441:1997 Medical Devices (Risk Analysis), and EN 868-1:1997 (standardized packaging). However, these are not the only constraints that have been put on or project.

In terms of economic restrictions, the primary limitation is our allotted budget of $750. The device that we plan to create must be affordable because it may hold potential to serve not only Mason, but other people living with cerebral palsy. The consumer market for a product such as ours will greatly
vary in financial flexibility. So our charge is to design a device that is both effective and cost conscious. In this way we will ensure that the product will have a wide consumer base.

Our device is essentially an electrically operated mechanical limb, capable of moving Mason’s belongings to an accessible position. Given that we are combining two types of engineering into one device we must take care to ensure that these vastly different fields mesh together properly. This is not an easy task as there have been many instances where the outcomes of endeavors such as ours have been less than ideal.

4. SAFETY ISSUES

Ideas related to this design have been formed, taking into account the environment in which the device will operate. Primarily, this refers to the populated classroom/school setting, which will not only contain a higher density of individuals around the client, but other objects such as desks or learning materials. To avoid swinging metallic parts (lever arm) around the client’s periphery, the team has decided to minimize the range of the rotational motion by limiting the length of the limbs as short as possible so that injury to others is considerably reduced.

However, it is vital to examine the actual components of the device, in relation to the external environment (not necessarily indoor), and what repercussions changes in weather would have on the device’s functioning. It is necessary to make sure that mechanical and electrical components are reliable. The device might be exposed to heavy rain or other harsh weather conditions; to protect electrical components and ensure a long product-life, Teflon tape will be used to insulate. In addition, Neoprene rubber will be used to cover the device from the outside, eliminating water contact with internal components of the device. Nylon may also be used to cover the rotational and extension arm, as its properties make it resistant to abrasion and chemicals. These protective measures will make sure that the client is safe from electric and any injury associated with corrosion of device parts.
4. IMPACT OF ENGINEERING SOLUTIONS

Obviously any engineering solution that has been developed throughout history impacts humanity in many ways. These solutions are used so frequently that we can forget how much of they affect our daily lives. In the modern age not only do new products have the ability to make life easier, but they also are a testament to the technological advances that have been made in our time.

The project discussed in this design paper is yet another indication of just how far engineering has come in the modern age. Creating a backpack transferring system that will assist the client in performing daily tasks will greatly improve his quality of life. Those around him may also begin to see the client in a different way. Without the need of others help the user will develop a sense of independence and accomplishment.

The impact can stretch much further to change the life of his family and potential many other individuals living with cerebral palsy. This global influence can even encompass persons with varying levels of cognitive impairment or physical limitation. There are close to 100 million people with disabilities living in America today. Of those roughly 500,000 have cerebral palsy.

Involuntary movements and poor motor skills are the typical symptoms of cerebral palsy. At present, about 2 out of 1000 children born in this country have some form of cerebral palsy. The trend is slowly decreasing, but the trend is still prevalent. Therefore the need for a device such as the one purposed in this text would bring great benefit to this community. However, this device is not limited to only persons with cerebral palsy. The system can be implemented by anyone who uses a wheel chair and has trouble with manipulation of heavy objects.

This device will bring independence to any client who wants it. Clients who live by themselves will benefit from the ability to transfer object to a position where they can use them. Our current project will be catered to or specific client and will be use to move a backpack to a comfortable position for him. However, it is definitely possible to diversify applications using the same basic concepts. A transfer device can be used in the home, office, workplace, or educational facility.

When discussing engineering solutions in an economic context, it is natural to analyze the market and customer base. Generally, a conservative estimate is taken, in which it is projected that 10% of the customer base will be
using the product within five years of release. This means that the potential number of clients for our product will be somewhere in the range of 50,000 people. This number may vary depending on the way that our product is marketed. As stated before the customer bases for our device should be quite extensive because of the potential applications. Depending on factors such as total costs, and the profit margins desired, a price a proper marketing approach could be decided upon.

The next step in to look at when bringing a new product to consumers is the global potential. The main issue to consider is financial flexibility of people outside our own economy. This problem however, should not be too detrimental as the estimated cost for our project will certainly be less than $750 US. This is a price that should be relatively affordable for a majority of people outside the United States. The last impact that needs to be addressed is that of the environmental aspect.

In an environmental context, engineering solutions such as this do not seem to pose much of a threat. The materials planned for this device are all either made from recycled material are themselves recyclable. There is also no extra environmental concern about batteries since we plan on use the battery already implemented on the wheelchair. An optimal design plans to use a small voltage of 12 volts. Therefore, it is unlikely that this problem will be significant enough to threaten natural surroundings in any way.

5. LIFE-LONG LEARNING

Life-long learning is a process that every individual experiences, whether by choice, or sub-consciously. It has the potential to strongly influence one’s perspective; here, what one learns through research and the input of others can significantly impact decisions that are made with regard to design.

Based on input, questions, and suggestions after three alternative designs, the team has decided on an optimal design for the backpack arm. Advice that the team received gave a strong indication that the design should involve a single-switch, for ease of operation and minimize moments about the joints at which horizontal rotation occurs.

One of the designs was free of any electrical components, and made entirely mechanical. The team realizes that there are advantages and disadvantages to any purely electrical or mechanical design. By creating a purely mechanical design, the team is assuming that the client’s physical
symptoms will never be so debilitating, as to prevent him from being able to operate low-force input backpack transfer design.

However, the team does not want to take a chance in producing a device that will be difficult to operate, since a sufficient amount of mechanical force is required to operate the design. In addition, the team thought that having an electrically controlled device would make the device increasingly convenient and user-friendly, as operation would only involve turning a single switch ‘on’ or ‘off’ for operation. This method of operation is incorporated in the optimal design.

In one alternative proposal, the team attempted to utilize space above the client, which is more likely to be vacant, except in the case of a low-ceiling room or another close-packed environment. Although this design seemed to be efficient in terms of space utilization, two factors contributed to its elimination from the optimal design. Since the device was being manufactured to operate in the maximum number of environments possible, it was unreasonable to assume that the client would always be in an environment where ceilings would be high enough to not hinder the upward movement of the device. Secondly, this design was not aesthetically pleasing.

In terms of the design advantages that were present previously, the group has managed to ensure that all important features have remained. An ability to bring the backpack to the client’s midline, and a collapsible capability to form a compact structure are two main aspects that differentiates the current project from the ‘Backpack Transfer Device’ by students of Mississippi State University. By incorporating rotating and collapsible limbs, the ability to fold into a convenient storage position has been maintained. By sequentially moving the limbs, the team has made sure that the backpack reaches the specified and desired position.
6. REFERENCES

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