Final Report
Project to Aid a Person with Disabilities: Lawnmower for Shane

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Abstract

For this project, a lawnmower is to be modified to fit the needs of a client who suffers from cerebral palsy and spastic quadriplegia. While most look at lawn care as another nagging yet essential household task, people continually take for granted what they are physically able to accomplish on a daily basis. Additionally, those who suffer from neurological disabilities lack a great deal of independence since they must rely on others to help them with many everyday tasks. Being able to mow the lawn by oneself certainty speaks to a level of independence that the client has not had thus far. In order to provide such independence to this individual, specific modifications will need to be made to the original ride on lawnmower.

The unique features of the lawnmower will revolve around the steering and acceleration of the vehicle. Since traditional wheel and pedal mechanisms do not suit the client, they will replaced by a single joystick. The horizontal movements will control steering, while the vertical movements of the stick will control acceleration and braking. This system must utilize microprocessing and programming in order to make the joystick design successful and safe for the client.

1 Introduction

1.1 Background

The client is Shane Davis, a 21 year old male with cerebral palsy and spastic quadriplegia. Spastic quadriplegia is a form of cerebral palsy in which all of the four limbs are affected. The condition is referred to as spastic rather than paralysis because the patient has some movement in all four of his limbs. Spastic is the tightness of skeletal muscle, which leads to imitation of his movements. Spastic quadriplegia can vary in severity. A person with moderate quadriplegia may be able to walk with a walker, unlike a patient with severe quadriplegia. Shane also has very limited hip movement and strength combined with severe quadriplegia which limits his movement to the wheel chair. Besides his limited movement, Shane is a typical college kid. He is an intelligent and energetic person. Shane wants to experience everything that life has to offer. He currently attends Manchester community college and loves extreme sports. He often visits Colorado during ski using a wheel chair. Shane is a very brave person and loves to push himself to the limit.

1.2 Purpose of the Project

The purpose of this project is to successfully implement a user-friendly joystick control on a ride-on lawnmower, which Shane can safely and easily use. This will give Shane the ability to help his family out by mowing the lawn, and also gain independence in doing so. Essentially, the project will allow Shane to use a ride-on lawnmower as if he did not suffer from any disabilities. The focus will be placed upon making all necessary modifications to the preexisting design. It is also very important to ensure that Shane’s modified lawnmower is just as safe, if not more, than the original lawnmower. By making
sure that Shane can get on and off the lawnmower and control all other necessary controls of the mower (forward/reverse, blades, engine on/off) the project will be completed successfully.

1.3 Previous Done by Others

The lawnmower for Shane Davis was a previous Senior Design project here at the University of Connecticut. Last year Randy Corrieveau, Ian Wallis, and Eric Nastuk worked on modifying the lawnmower. This design failed completely since the joystick never functioned correctly and the overall implementation of the control consisted of a flawed design. Therefore, the lawnmower was never even delivered to Shane. However, there are some modifications on the lawnmower that will be kept as long as they work. This includes the linear actuators set up to the pedals of the mower and the transferring platform that will make getting on and off of the mower easier for Shane. All circuitry will be stripped and redone.

1.3.1 Products

The most similar products to that of Shane’s lawnmower are other university funded projects by the National Science Foundation (NSF). Each year, there are multiple projects for those with disabilities that include the use of a more user-friendly vehicle by the use of a new control device that varies from the traditional pedal and steering wheel setup. AbleData is a company known for assistive technology and they provide information on many modified driving control systems by various manufacturers. For example, there are all-in-one gas and brake control systems and steering wheels that can be used by one hand. Also, there are multiple computer controlled devices that utilize a single joystick and can even control most of the essential buttons seen in an automobile.

While there are many automobile control systems for those with a disability that limits their dexterity and movement of limbs, secondary vehicles like a lawnmower get left behind since they are deemed less important.

1.3.2 Patent Search Results

Currently, there are no patents for a modified ride-on lawnmower intended for the use of a disabled individual. However, there are patents for ride on lawnmowers that have modified control systems. The closest patent was created by Robert M. Wuertz and Terrance G. Benson in 2001 (Patent No. US 6,808,032). This design moves the throttle control to the side of the seat of the mower as well as the blade control and the engine on/off switch. Then there is a joystick which controls both steering and acceleration of the lawnmower, and like our design, it utilizes some sort of microprocessor.
2 Project Design

2.1 Introduction

This project requires the modification of a normal ride-on lawnmower, to one that can be controlled by a joystick, since it is intended for a client with Cerebral Palsy (CP). Shane Davis is a 21 year old who, due to his disabilities, suffers from a lack of mobility and relies on an electric wheelchair to get around. However, he does have sufficient use of his left hand and much better overall control of his upper body, as compared to his lower extremities. Therefore, the joystick control to the lawnmower will be located on the left side of the chair, along the armrest.

The current lawnmower being used was worked on by a previous Senior Design team; therefore there are some other modifications to the kart. The most noticeable modification is the platform which will allow Shane to get on and off the lawnmower more easily since the mower's seat rests much higher than Shane's wheelchair. After talking to the client, they have mentioned that there is also a small ledge at their home that will further allow Shane to easily transfer between the two vehicles. The lawnmower being used is also beneficial to Shane in that all of its controls, except for the steering and acceleration, are accessible to Shane since they are all in reach while sitting in the vehicle's chair. A final implementation to the lawnmower that will be left is the actuator motors used to control the acceleration of the mower. Although the joystick did not work; these actuators are set up successfully, just not controlled by the microprocessors properly. Unfortunately, the most important modification to the lawnmower, the joystick, failed to meet the needs of the client and was also unable to be driven. Consequently, this will be the focus of the lawnmower in order to design a successful finished product.

2.1.1 Alternative Designs

Alternative Design #1

Our first design will contain a system using all existing parts that are now being used by the go-kart, except for the joystick. Currently, the electric system of the go-kart is being controlled by an Arduino Uno microcontroller. Our group will keep the microcontroller and recode it to be able to receive the input from the new joystick. The dial to control acceleration will be removed from the go-kart and a multi-functional joystick will be used in its place.

Design 1 will use a basic bidirectional joystick to control steering a braking with these basic directions:

- Forward = Throttle, forward movement
- Backward = Braking, vehicle stops
- Left or Right = Steering, vehicle moves in corresponding direction
- Neutral position = vehicle remains still
The lawnmower will only be allowed to go from 0-5 mph, so a change in acceleration is insignificant. When the lawn mower is turned on and the joystick is pushed forward, the same speed will be outputted regardless of the force. Traveling at a maximum of 5 mph, acceleration is not needed and therefore we do not need to incorporate into our design; instead the lawnmower will automatically move at 5 mph when the joystick is pushed forward or 0 mph if the brakes are applied. A reverse function will not be applied because the backwards movement of the joystick corresponds to braking. The easiness of the basic controls will allow Shane to have great control of the lawn mower and ensure safety. The movements of the joystick will be inputted into an Arduino microcontroller and process to perform the necessary actions. The Arduino will still be used, rather than a Microchip, because the code currently programmed will not need to be greatly altered.

**Alternative Design #2**

Alternative Design 2 will use the same approach as Design 1 but the type of joystick will be changed. Design 1 uses a bidirectional joystick which does not have the ability for full control of the lawn mower. Our group will use a multidirectional joystick that will move the lawn mower in the corresponding direction the joystick is pushed. Rather than going backwards when the joystick is pulled back, that will apply the brakes and stop the lawn mower. Design 2 will add a new element of full, 360 degree control of the lawn mower as compared to Design 1. This multidisciplinary joystick will also be larger and less sensitive than the joystick in Design 1. A reverse function will not be applied because the backwards movement of the joystick corresponds to braking.

**Alternative Design #3**

Alternate Design 3, will not focus on the microcontroller used, but rather key in on replacing the current joystick. The current joystick is too small and too sensitive to use for a person with Shane’s disabilities. We believe the largest problem is that the range of motion for the current joystick is very small, so any type of movement will dramatically change the input. Using a larger and less sensitive joystick will allow more incremental changes in the input.

Our approach will include a larger, less sensitive joystick as well as a button top of the handle to make driving easier on Shane. The joystick used will be very similar to a Spobu V-NS0K, this joystick seems to mimic Shane’s wheelchair joystick, is larger in size, and contains a button on top.

This button will be will be a major change in the design of the lawn mower, and pending if Shane is able to use the button should allow several more features for the user. The button will used to switch the vehicle from “Drive” to “Reverse.” The microcontroller will be programmed to understand the following functions:

1. When go-kart is on and joystick is pushed in any direction (except backwards), vehicle will move in corresponding direction.
2. When joystick is pulled backwards, brakes will be applied.
3. When button is pushed and held down the vehicle will switch to “Reverse”. With button still held and the joystick pushed forward, the vehicle will move backwards.
2.1.2 Optimal Design Selection

One single optimal design was not chosen for Shane’s lawnmower, as it was decided that by combining components and features from each of the three alternative designs, the final product will be the most successful in terms of all-around performance and safety. Since the lawnmower is in need of a new joystick, this issue will be addressed in the optimal design. Also, the lawnmower has its own reverse function by the use of lever; therefore, the joystick will not contain a button to change the drive from forward to reverse. This optimal design combination was also chosen in order to meet many of the realistic constraints that come along with creating such a vehicle. For instance, the optimal design will have all electrical components completely protected. This will provide a safer environment for the user and also allow Shane to use the vehicle if the ground happens to contain some moisture. Since this design is so client specific, all of the modifications should last sometime after completion of the project. A larger, sturdier joystick was chosen for this reason as well as thicker gage wire to prevent any burning out of the wiring or other electrical components within the circuit.

2.2 Optimal Design

2.2.1 Objective

The optimal design chosen for this project will be a combination of the alternative designs, taking positive ideas and components from each of the three designs. A new joystick must be used since the previous one made it difficult for Shane to control the acceleration of the mower due to the dial configuration. The new joystick will control steering and acceleration, with steering being a side to side movement and acceleration being the up and down movement of the stick. This design will also allow for there to be a neutral position, safely bringing the mower to a stop if the joystick is not pushed. To address the sensitivity of the joystick, there will be a larger joystick used in this design, than the previous one. After bringing this change to the client, this was encouraged since it allows Shane more control of the lawnmower. In order to have this joystick control function; it must be wired to a microcontroller, which can process the signals from the joystick and correctly steer and turn the mower as well as accelerate it. The programming of the microcontroller is essential since it cannot contain any bugs and must also be able to effectively control the mower according to the movements of the joystick. Without proper coding, the lawnmower is basically useless. In addition to these components, there will need to be electric actuators that will provide the mechanical force in order to change either the direction of the mower or the speed of the vehicle. These will be controlled by the output signals of the Arduino board, based upon the inputs from the joystick. Figure 1 shows the system that will be wired in order to make this design successful. This optimal design has been chosen as a combination of the alternative designs since there need to be changes made to both the joystick and the microcontroller, which are present in separate alternative designs. By choosing the best combination of a joystick and microcontroller, the mower has the greatest upside, and therefore, can be the most successful when finished. A simplified flow chart of the optimal design’s system can be seen below (Figure 1).
2.2.2 Subunits

2.2.2.1 Lawnmower

As previously stated, the lawnmower to be modified came from an existing Senior Design project, where the group was able to receive a donated mower from Ellington Agway Power Equipment. This Troy-Bilt lawnmower (Figure 2) contains a 42 inch mowing deck and a 17 horsepower engine with various speed settings as well as reverse.

Before making any modifications to the lawnmower, it will be tested to make sure that all functions of the lawnmower run properly and that there is no leakage issues when it comes to the working fluids within the engine. The last set of tests for the complete lawnmower will, of course, take place when the modifications to the controls are complete.
After testing each of the subunits individually, the complete system will be checked by the team before delivering it to the client.

Figure 2: Troy-Bilt lawnmower to be modified for Shane.

2.2.2.2 Joystick

The joystick chosen for this project is the Suzo-Happ Competition Joystick (Figure 3). The joystick has 8-way directional operation due to the bi-axial design. In both the horizontal (X) and vertical (Y) directions, the joystick has a potentiometer. When moved from the center, these potentiometers vary the output from the joystick, based upon how far the stick has moved from its origin. This variation in output will allow for the vehicle to turn or change speeds according to the movement of the joystick. Unlike the previous design, this joystick is much larger in size and will therefore provide a better user interaction since the sensitivity of the joystick will not cause any sporadic movements by the vehicle. The shaft of the joystick measures at 3.66 inches, which will allow Shane to easily grasp it and move it appropriately.
The first series of testing in order to ensure that this device will work properly will actually not involve the use of the joystick. A rotary potentiometer will be used in place of the joystick. From here, a simple circuit will be constructed using a protoboard and any necessary electrical components. LEDs will then be used to light up and dim according to the potentiometers movement, mimicking that of the joystick. Secondly, before putting the physical circuit together for the joystick, the circuit design will be tested using Multisim. This will be crucial in verifying our design to make sure the circuit will work when put together from the lawnmower to the joystick. In Multisim, it will be verified that there is a varying output coming from the joystick, with a reasonable magnitude as well.

Once complete, the joystick's function will be as follows:

1. Forward movement – controlled by pushing the joystick forward
2. Steering – controlled by side to side movement of the joystick.
3. Braking – controlled by moving the joystick backwards

### 2.2.2.3 Microcontroller

The microcontroller chosen for this design project is an Arduino Mega 2560 (Figure 4). This board was decided upon because it is user-friendly when it comes to programming the controller, as opposed to microchips which use the C programming language. The Arduino company offers free programming software available by download through their website and free tutorials as well. Importantly, the Arduino Mega is much faster than the other Arduino products, such as the Uno, and has plenty of I/O pins. This will effectively be able to handle the various inputs it will be receiving from the joystick and quickly process these to the steering column and actuators that control the acceleration of the mower. Fourteen of these pins can utilize Pulse Width Modulation (PWM) signals, which will greatly help with the success of the vehicle. By being able to use these types of pins, the Arduino will be able to process varying analog signals. This will allow the lawnmower to accelerate and steer according to how far the joystick has been moved in either the
horizontal or vertical direction. This is far more safe and effective than having the lawnmower only being able to turn or accelerate to its full extent, which had been a problem in years past when it came to vehicle control modifications.

![Arduino Mega 2560 microcontroller](image)

Figure 4: Arduino Mega 2560 microcontroller.

To test the microcontroller, the procedure will be similar to that of the joystick, since both of these devices will be the essential parts of the modification circuitry. Before placing the microcontroller into the actual mower’s circuit, it will be tested using a protoboard. By attaching the Arduino board to a protoboard, the coding of the microcontroller can be tested. Along with a rotary potentiometer, the Arduino will be attached to a series of LEDs and any other necessary electrical components if needed. This will allow us to see whether the input from the joystick is being correctly processed when run through the microcontroller. If possible, a computer simulation program will be run in order to test that the circuitry design is capable of working. Tests will also need to be run to check whether the PWM signals provide a smooth control of the vehicle. This will take place once the coding for the varying inputs is complete. From here, any tweaks to the coding of the Arduino can be made according to the test results.

The programming of the microcontroller will rely on the Arduino software, downloaded from the company’s website. The board can then be attached to the computer using a USB cable and will need to have to most up to date drivers available to ensure that there are no bugs within the board’s basic coding. It will be important to properly code the microcontroller so that the joystick works correctly when hooked up to the lawnmower. The board will also need to be powered, which will come from the battery of the lawnmower if possible. If this voltage is too high then the input voltage to the microcontroller will simply come from an outside source (smaller battery).