Assignment 5 - Testing Results

Date of submission: February 28th, 2022

Voice-Controlled Wheelchair

Team 13

Pho V Le

Waverly Hampton III

Erik Coleman

Shazib Naveed

Instructors: Russ Tatro, James Cottle

Table of Contents

Table of Figures

Table of Tables

Executive Summary

A. Societal Problem

The year is 2022 and access to mobility is a problem we all face. However, there are those who have less access than others. People with disabilities are limited in their range of motion, and worst of all, the products they rely on are limited as well. The next generation of mobility for those with disabilities starts with the wheelchair. A device that has, for decades, not been improved upon much, the wheelchair is due for an upgrade so that those with limited or no ability to move can be in motion once again.

B. Design Idea

To change the wheelchair, one must first change the way one thinks about what a wheelchair's function is when used. A wheelchair must move a load from point a to point b, assisted by some form of power. Our design is the next generation of the wheelchair. It not only uses voice commands to input directions and electric power to drive the motors, it is also equipped with sensors that give it the ability to detect objects around it and avoid collisions. Safety is the primary feature of our design, for our wheelchair will be able to measure its own speed and adjust its position so that it never puts the user in a dangerous position.

C. Work Breakdown Structure

This project will consist of a variety of tasks to complete, including but not limited to: Designing and building the electric drivetrain; programming the Raspberry Pi module for interfacing with the voice control module and sensors; programming the motor driver to control wheel speed and direction; demoing prototype, and revising its design; completing a market analysis; and lastly delivering the project on time.

D. Project Timeline

The project's timeline allows us to track our progress throughout the semester. During the second semester, we did change the timeline due to some parts of the project being pushed back. We had issues with movement during the first semester, so our timeline for some of the work packages for movement was pushed to the second semester. The project timeline allowed us to keep track of our work packages and make sure that we did not fall behind.

E. Risk Assessment

The Risk Assessment allows us to predict any risks that might occur throughout the semester. For the risk assessment we made a Risk Matrix that outlines the risks. The risks are then given a probability. This allows us to predict if the risks might happen and gives us the opportunity to create back up plans in case the risks occur.

G. Device Test Plan

Test Plan will be a beneficial tool to keep us on track of the project timeline. Since the project has lots of tasks that need to be completed, some functions will be changed overtime. A testing plan will make sure we give us an idea of how many hours we should spend on each task. Also help us predict what problems can happen during time. This senior project is 2-semester long. Our test plan in this second semester was changed so it is closer to the requirement and our expectation.

H. Market Review

The Market Review allows us to see other types of products that are offered for disabled people. There are various different mobility products for disabled people. For example, there are wheelchairs, electric wheelchairs, and other various tools that help the person that has difficulty moving. Looking at our market allowed us to understand the various different tools that are present to a disabled person and the differences between our wheelchairs versus the other products on the market.

I. Testing Results

The mission of team 13 project is to create a voice-controlled wheelchair which can improve the moving ability of people with disabilities. In this section of testing, we focused on our final result after the wheelchair is completely assembled with all components. There were some modifications made at the end to adapt to our current situation.

ABSTRACT

A. Societal Problem

We can see that the world is in a period of constant change, becoming more civilized and modern. The more modern life is, the more it cannot be without the presence of electronic devices. These devices appear everywhere to serve the interests of people, from daily life to production. Consumer electronic devices focus on accuracy and speed. And among them, the technology that was being developed and favored at that time was remote control technology. It has made a great contribution towards controlling devices for people who need to sit in place without physically operating equipment. Currently, the largest application for this electronic remote-control industry is integration with the design of smart homes, which is quite popular today.

B. Design Idea

We want to apply our programming knowledge to implement a meaningful design. That's why we chose the topic "Controlling an electric wheelchair by voice or smartphone" as our senior project. This is a meaningful topic for humanity, which will assist disabled people who are unable to control wheelchairs with their hands or feet.

C. Work Breakdown Structure

This project's timeline is from August 2021 to May 2021. Tasks include but are not limited to: coming up with a societal problem, designing a solution to the societal problem, creating a work breakdown structure to map the project, developing a prototype to demonstrate, redesigning prototype for any refinements, completing a market analysis, and delivering the project on time. The final prototype should be completed by the end of April.

D. Project Timeline

This project has several components that need to communicate with each other. To successfully complete this design, we came up with a timeline which describes each work package. This timeline will allow us to track our progress throughout the semester. This also allows us to see dependencies between components and ensures we notice any bottlenecks in our design approach.

E. Risk Assessment

This assignment attempts to identify any foreseeable risks with our project. This will allow us to be prepared to mitigate any issues that do arise. To stay on track, we need to be able to move forward no matter the issue. Identifying and describing any possible issues will help us do so.

G. Device Test Plan

Testing is one of the most important steps in this whole designing project. After completion with each feature we will execute some test for each part to make sure it is working properly before installation. The tests will be performed frequently before and after each demo. This will give us ideas of what needs to be improved or estimation of time the prototype would be completed. Also keep us on track in case there are any problems identified.

H. Market Review

Market research includes a number of analytical activities on: market competition, market development trends, market segments, buyer behavior and psychology, effective distribution channels and the benefit that the product will provide for customers. With the diversity in the wheelchair market, people with disabilities have a lot of good choices which serve their needs appropriately. Depending on the status of their disability, customers will make their selection. This project we are targeting the customer who can’t control their wheelchair with both hands and feet.

I. Testing Results

Testing is the most important step before we can complete our design. In reality, the testing is supposed to be executed throughout each task when they are completed. When all the individual features were tested successfully, they will be assembled. At this point the final testing is executed. The testing needs to be repeated multiple times to ensure the desired results are achieved. And depending on the result of each test, a new modification will be applied until the result is satisfied.

I. Introduction

A. *Societal Problem*

The world is in the wave of the industrial revolution 4.0. The technology of intelligent control and automatic control also develops, they are applied in many fields in industry, life and even medicine. According to Patric R. Spence, "Robots and other machine communicators are increasingly performing social and workplace roles such as teachers, caregivers, surveillance, decision-makers and personal companionship''. Recently, when people's living needs are improving day by day, these technologies are getting more attention. Speech recognition is a topic that has received the attention and research of many scientists over the past decades. Speech and writing are the two most basic components of language, speech formed before writing and developed throughout the history of human development. Voice is and will always be the primary tool of human communication because communication by voice is simple, natural and plays a key role in human life. Nowadays, along with the development of science and technology, scientists have created machines that gradually replace manual labor and the human brain, but human-machine communication is still popular. The operations are complex operations and require training. For that reason, the research and development of devices capable of communicating with people through voice has been receiving the attention of many scientists around the world, as well as consumers, but the level of popularity is still limited.

Biometrics - or technology that uses biological characteristics of people to identify is a very diverse field and has many important practical applications. In the field of biometrics, speech has received a lot of attention due to the naturalness of the voice, the ease of collecting and using the voice in the process of recognizing the speaker. Many methods have been studied and achieved certain effects in the process of speaker identification. Human speech recognition has been attracting the research attention of many scientists as automation technology has more and more applications in real life.

The goal of this topic is to use the voice recognition in the circuit and combine it with our smartphone control to apply it to wheelchair control. The wheelchair will be controlled by the user to be able to go forward, backward, turn left, turn right and accelerate and decelerate speed according to needs.

B. *Design Idea*

To accomplish the goal of creating the next generation of wheelchair, we decided to implement a variety of sensors, including Lidar, motion and a forward facing RGB camera to allow the wheelchair to be aware of its surroundings. The idea is that the next generation of wheelchairs will be responsive to the environment to create a safer experience for the user. Safety is the main feature of our design, because those with disabilities are already burdened enough, so our responsibility as engineers is to design a product that is ergonomic and makes their lives easier.

C. Work Breakdown Structure

The criteria for determining te22he status and expected delivery of this project will be based on breaking down the project features, listed in the design approach, into doable tasks, subtasks, and work packages. As shown in Table 3, located in Appendix D, the tasks will be defined as the Feature, the subtasks will be thought of as Requirements, and the work packages are the various assignments needed to be completed to meet each requirement. Each assignment has an anticipated due date, making it possible to chart a schedule for this project.

D. Project Timeline

We outlined our project timeline using a Gantt chart in Microsoft excel. We broke up our tasks to align with our work breakdown structure. Each feature is listed under its own section, along with work packages assigned. The course assignments for both semesters are listed under section 7 & 8, for Fall and Spring semester.

E. Risk Assessment

The voice-controlled wheelchair is prone to various risks. Most importantly, the wheelchair is powered by electricity and has a standby battery, prone to failure leading to inconveniences. The wheelchair depends on voice commands from the user, which could be contradicting if the user is in a noisy environment. Again, the wheelchair is not able to foresee danger ahead; this puts the user at risk of encountering dangers that might leave them hurt. In every street, some evil people are never passionate, and this being a mere chair puts the user at risk of being attacked by robbers or other evil-minded persons.

A broader technical risk related to our sensor system, is its ability to detect objects in our path. We are concerned with stationary and moving objects that could be in our intended path. We will need to test the Lidar's ability to detect these possibilities and determine if it will be sufficient to meet our intended design metrics.

G. Device Test Plan

We have devised several tests for our prototype. Each design element has a test to confirm its operation by itself.. Each feature has a series of tests, which will allow us to confirm the correct operation of our system. We have defined the tests with our environment and our own biases in mind. Once we confirm each part of our system is functioning as we expect, we have functional tests to observe the prototype as a whole unit. These tests will demonstrate our systems ability to perform based on our defined measurable metrics.

H. Market Review

With the variety of wheelchairs in the market, our voice-controlled wheel chair will be the unique product which supports disable patients. Wheelchair market with the diversity of price is a problem which we have to solve. The difference in price of technology wheelchair and traditional wheelchair is a barrier in the process of approaching customers. Market review is an important step in the whole project timeline

I. Testing Results

After about 32 weeks of researching and executing the project, team 13 has achieved the initial objectives which were suggested at the first semester. We have designed the wheelchair system with voice controls which can control the wheelchair to go forward, reserve , turn left, turn right , change speed and avoid collision. This is the topic that the team only did on an experimental basis and has not been applied in practice. So for this model to be more completed, there will be some options which we propose in the conclusion to improve the model and can be applied in practice.

II. **Societal Problem**

A. *First Semester Interpretation of the Societal Problem*

There are different types of disabilities that humans can develop. These different types of disabilities each have their own problems that the person tends to deal with daily. Humans develop mobility limitations when they are born or through an injury that leaves them unable to walk. "Mobility limitations are the leading cause of functional limitations among adults with an estimated prevalence of 40 per 1,000 persons aged 18 to 44 and 188 per 1,000 aged 85 years and older in the general population" [14].

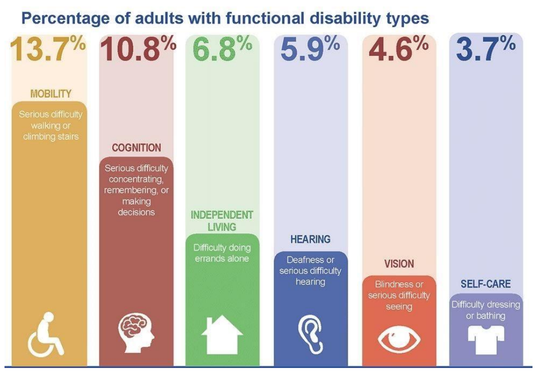


Figure 1 – Percentage of adults that have different disabilities [14].

Figure 1 shows the different types of disabilities that adults have. In the figure, mobility disabilities are the highest percentage that adults have. 13.7% of adults have mobility disabilities. Mobility disability requires a person to have some type of walking support for a person to get from point a to point b.

Alzheimer's disease is a type of disease in which people with the disease tend to use a wheelchair. People with Alzheimer's tend to lose functions such as language, motor skills, and perception. This disease causes people to develop mobility disability over time. As time goes on it becomes harder for them to get from point a to point b, as a result this always requires another person to help wheel them in the wheelchair from point a to point b.

Amyotrophic Lateral Sclerosis is a neuron disease which causes people to degenerate motor neurons over time. As time goes on, this leads to weakness in pretty much the "The muscle weakness associated with ALS can interfere with an individual's ability to operate a wheel-chair in two ways: (1) weakness or fatigue in the arms and shoulders can prevent persons from completing long routes and (2) weakness in the neck muscles can make seeing obstacles behind or next to the wheelchair difficult or impossible … Every person diagnosed with ALS will eventually need a wheelchair" [14].

Cerebral Palsy is a brain injury occurring before cerebral development is complete. Cerebral Palsy can result in physical dysfunction. "Of individuals with CP, 86 percent use a wheelchair at least some of the time" [14]. This injury requires the person to use the wheelchair when traveling long distances.

Multiple sclerosis damages the myelin sheath surrounding nerve fibers in the central nervous system [14]. Symptoms include fatigue, tremors, and impaired reasoning. "Half of individuals with MS require the assistance of another person for everyday mobility … Of individuals with MS who use manual wheelchairs, 59 percent stated they did not feel their current wheelchair met their mobility" [14]. Many of these injuries and diseases cause people to lose mobility with a wheelchair being their only option to move around.

Spinal Cord Injury at or above fourth Cervical Vertebra can cause people to not be able to operate a manual wheelchair. Their lack of neck movement makes it impossible for them to see obstacles behind or next to them. "SCI at any level has been estimated to be prevalent in 200,000 to 288,000 people living in the United States with an SCI" [14].

Figure 2 – Different types of people with disabilities based on race, gender, and age [15].

The figure above demonstrates that 40% percent of adults that are 65 years and older have a disability. It shows that 1 in 4 women have a disability, and that 2 in 5 for non-Hispanic American Indians/ Alaska Native have disabilities. This proves that there is a huge need for consumer products that provide aid to these marginalized groups. One of the most popular of these products is the wheelchair.

A wheelchair is a chair with wheels that is used when walking is difficult or impossible due to illness, injury, or disability. Wheelchairs come in a variety of formats to meet the specific needs of the user. These can include specialized seating adaptations, individual controls, and can be specific to specific activities, as seen with sport wheelchairs and beach wheelchairs. The most widely recognized distinction is between powered wheelchairs ('electric vehicles'), in which propulsion is provided by batteries and an electric motor, and manual wheelchairs, in which propulsion is provided. provided by the user, the wheelchair user pushing the wheelchair manually ('self-propelled') or pushed from the back by an attendant ('steward push').

The earliest records of wheeled furniture are an inscription found on a stone slab in China and a children's bed depicted in a Greek vase painting, both dating from 6th to 5th centuries BC. The first records of wheeled chairs used to transport people with disabilities date back to three centuries later in China; The Chinese used wheelbarrows early to move people as well as heavy objects. A distinction between the two functions was not realized for another few hundred years, until around AD 525, when images of chairs with wheels were introduced, and specially designed chairs made to carry people began to appear in Chinese art.

Although the Europeans eventually developed a similar design, this method of transportation did not exist until 1595 when an unknown inventor from Spain built one for King Phillip II. Although it was a complex chair with both armrests and footrests, the design was flawed as it did not have an effective push mechanism and therefore required support to push it. This makes the design more like a modern or portable armchair for the rich people than a modern wheelchair for the disabled.

In 1655, Stephan Farffler, a 22-year-old Paraplegic watchmaker, built the world's first self-propelled chair on a three-wheel chassis using a shaft and gear system. However, the device has the shape of a hand bike rather than a wheelchair because the design includes cranks mounted on the front wheel.

In 1887, wheelchairs were introduced to Atlantic City for tourists. You can rent them to enjoy the Boardwalk. Soon, many healthy tourists were also renting decorated "wheelchairs" and servants to push them as a display of decadence and treatment they could never experience.

In 1933 Harry C. Jennings, Sr. and his disabled friend Herbert Everest, both mechanical engineers, invented the first lightweight, steel, folding, portable wheelchair. Everest had previously broken his back in a mining accident. Everest and Jennings saw the business potential of the invention and went on to become the first mass-market wheelchair manufacturer. Over the years since then, a variety of wheelchair types have been introduced.

First, the Manual Wheelchair: A manual wheelchair combines a frame, seat, one or two legs (legroom) and four wheels: usually two wheels in the front and two large wheels in the back. There will also generally be a separate seat cushion. Larger rear wheels usually have a push rim of a slightly smaller diameter, extending beyond the tire; these allow the user to control the seats by pushing on them without requiring them to grip the tire. Manual wheelchairs usually have load-bearing brakes on the tires of the rear wheels; however, these are only parking and motion brakes provided by the user's palm directly on the pusher rim. As this causes friction and heat build-up, especially on long descents, many wheelchair users will choose to wear wheelchair gloves.

Figure 3: Patience Wheelchair [6]

Second, the Patience Wheelchair: A patience wheelchair is similar to a manual wheelchair, yet it has small diameter wheels on both front and rear.

The chair is driven and controlled by a person standing in the back and pushing the handle integrated into the frame. Brakes are provided directly by the valet, who will usually be provided with a foot or manual parking brake.

Third, the Power Wheelchair: A power wheelchair, commonly referred to as an “electric wheelchair", is a wheelchair that incorporates a battery and an electric motor into the frame and is controlled by the user or attendant, most commonly via a small joystick, mounted on the armrest or on the upper rear of the frame. For users who cannot manage manual joysticks, head switches, chin joysticks, sip-and-puff controls, or other expert controls that can enable independent operation of the wheelchair. Ranges of more than 10 miles, 15 kilometers are generally available from standard batteries. Powerchairs are often divided according to their accessibility. An indoor chair can only reliably pass over perfectly flat surfaces, limiting them to household use. An indoor-outdoor chair is less restrictive, but may have a limited range or ability to cope with slopes or surfaces not flat. An outdoor chair is more capable, but will still have a very limited ability to deal with rough terrain. A very few specialist designers offer a true cross-country capability.

Figure 4: Standing Wheelchair [8]

Fourth, the Standing Wheelchair: A standing wheelchair is one that supports the user in an almost standing position. They can be used as both a wheelchair and a standing frame, allowing the user to sit or stand in the wheelchair at will. Some versions arfully manual, others have a manual seat stand, while others have full power, tilt, recline and variations of the stand function available. The benefits of such a device include, but are not limited to: supporting independence and productivity, enhancing self-esteem and psychological well-being, enhancing social status, expanding access, reducing pressure, relieve pressure ulcers, improve function, improve respiratory function, reduce occurrence of UTIs, improve flexibility, help maintain bone mineral density, improve passive range motion, reduce Abnormal muscle tone and spasticity, and bone deformities. Other wheelchairs provide some of the same benefits by raising the entire seat to raise the user to standing height

Figure 5: Sports Wheelchair [9]

Last, but not least, the Sports Wheelchair: The sports wheelchair is used in competition. A variety of disability sports have been developed for athletes with disabilities, including basketball, rugby, tennis, racing and dance. Wheelchairs used for each sport have evolved to fit the specific needs of that sport and are often no longer the same as their everyday cousins. They usually do not fold (to increase stiffness), providing stability and useful for making sharp turns, and are usually made of lightweight, composite materials. Even the seating position can be completely different, with racing wheelchairs often used in a kneeling position. Sports wheelchairs are rarely suitable for daily use and are often a "second" seat exclusively for sports use, although some users prefer sport options for everyday use. Some people with disabilities, specifically the lower limbs, can use wheelchairs for sports, but not for everyday activities.

Each of these different wheelchairs have one thing in common: They all require some form of manual input from the user. For those with severe disabilities and limited range of motion or use of their hands, a modern wheelchair is not advanced enough. We strive to solve this problem by asking the question: In today's world of Roombas and robots, why is it that wheelchairs still require the user to lift a finger?

B. *Second Semester Interpretation of the Societal Problem*

After testing our initial design, we realized there were a number of things we should have done differently. Our prototype used a L289n motor driver to supply power to our DC brushed motors. While testing, we determined the continuous current output from the driver was not sufficient to overcome the stall current of the motors. This caused our motors to stall if there was any weight set on them.

We then bought a high power motor driver from Pololu. Its twin discrete MOSFET H-bridges support a wide 6.5 V to 36 V operating range with a continuous current of 18A. This should be more than enough power for our design. After doing the initial setup and testing, we confirmed the motor driver was operating correctly. Our prototype was able to traverse across the room, with one caveat. The weight of our 12V lead acid battery was too much for the motors to handle.

Our research has shown that our motors do not have enough torque as is. Drive systems typically take advantage of gears to provide higher torque to the wheels. Having enough torque is critical for our design, in order for a person to ride on the wheelchair.

III. **Design Idea**

A. *Design Philosophy*

Our design will allow disabled people to navigate an electric wheelchair, without the need for manual control. We will be giving the user the ability to control the wheelchair using simple voice commands. To ensure the safety of the user, we have a sensor to allow the wheelchair to traverse through a hospital-like setting and avoid object collision.. The core functionality of our design will be mobility, voice control, and object detection.

It was always the intention for the electric wheelchair to be battery-powered and chargeable. The main operating control system consists of a microprocessor, a microphone, speed controllers, LiDar sensor, and two DC motors. The LiDar sensor is fixed to the front of the wheelchair, to determine the wheelchair's distance from an object in its path. This is necessary since the DC brushed motor does not have speed control. Magnets will be fixed equidistant along the circumference of the wheel, which will enable the Hall effect sensor to trigger a signal to the Raspberry PI. In between signals a timer will be counting, which will help us determine how fast we are moving. We will be using a pulse width modulated signal to control our speed and direction of the DC motors. Based on our current position and command, we will vary the voltage sent to the H-bridge, to control the direction our wheelchair will move.

We are going to have a microphone connected to the Raspberry Pi, which will record the user's speech in real time. We then will use speech recognition to determine the intended movement from the user. To utilize Google's speech API, the raspberry pi will need to have a constant internet connection. We will need to determine if this will fit our use-case, if not another speech recognition method will need to be implemented. We intend to have our wheelchair accept numerous user-friendly commands for operation. When the user intends to move forward,commands such as 'go,' 'forward,' 'straight' should all cause the wheelchair to move in a forward fashion. If the user wants to maneuver around a turn, they will need to give a stop command and then a command to turn either left or right. If a left turn is occurring, the raspberry pi would send a positive voltage to the right wheel and a negative voltage to the left wheel. This will allow our wheelchair to have a smaller turn radius.

Figure 6 - Flowchart of control system design. Designed using app.diagrams.net

Commands will not be executed if something is blocking the path, or a fall would potentially occur. These scenarios will be detected by either our camera or lidar sensors. The wheelchair would then be put into an idle state, waiting for input from the user. This will prevent an accident from occurring. The primary concern of this design is the safety of our user, so this will need to be tested thoroughly. Another reason for a command to potentially be blocked is if the voice is not recognized. Malintent from another person is a potential cause of disaster. If our wheelchair could easily take commands from anyone within speaking distance, this would allow our system to behave in unintended ways. We will need to verify the command is in fact being issued by the owner of the system.

Sensors on our system will allow us to react to unforeseen circumstances that may arise. We plan to equip the wheelchair with an RGB camera facing forward, to detect any obstruction in our path. The control system will then decide to either maneuver around the object or pause and wait for further direction. Two lidar sensors will need to be used, facing directly in front and behind the wheelchair. These will be used to determine if a ledge is about to occur.

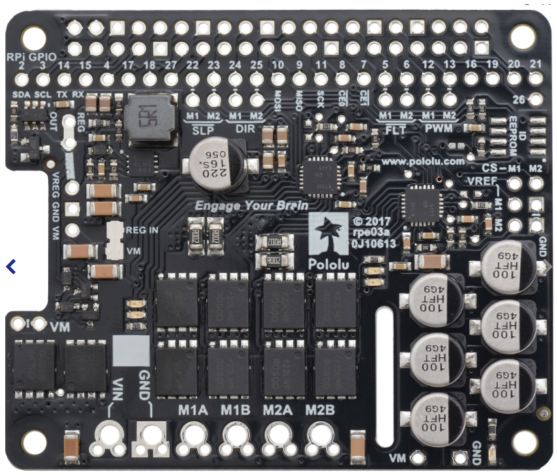


Figure 7 - Dual G2 High-Power Motor Driver from Pololu (24v18 for Raspberry Pi)

The dual motors can be controlled independently. Each motor has 4 GPIO pins associated with it. A fault pin, PWM input, enable, and a direction pin. These can be seen in the table below. We are using the Broadcom chip-specific pin numbers(BCM).

Value	GPIO Pin (BCM)
Motor 1 Fault	5
Motor 2 Fault	6
Motor 1 PWM	12
Motor 2 PWM	13
Motor 1 Enable	22
Motor 2 Enable	23
Motor 1 Direction	24
Motor 2 Direction	25

We are sending a 20kHz hardware based pulse width modulated (PWM) signal using the PiGpio Python library. We can control the speed of our wheelchair by adjusting the duty cycle of our PWM signal. The direction pin can be toggled, which will change the direction our motors spin. ee

Figure 8 – Electric DC Motor (24V)

In this version of the project we are using a built-in gearbox motor with 24V power. This type of motor is a DC motor with 10:1 metal gearbox and integrated quadrature encoder that provides a resolution of 64 counts per revolution of motor shaft. With the old version we have faced challenges of getting the wheelchair to move because of the torque issue. The power of 24V in this motor along with a built-in gearbox, we believed will solve the problem of getting the wheelchair to move due to the heavy load. Another application of this new motor is the CPR encoder. The encoder will send feedback signals that can be used to determine position, speed and direction.

Final Design

B. Specific Design Components

Electric Drivetrain: The electric drivetrain feature will be developed using four dc motors, one H-bridge motor driver, and one twelve-volt battery. Pulse Width Modulation will be used to adjust the speed of the motors. Team member Pho will be responsible for implementing the electric drivetrain. His background and education in electrical engineering will be useful in designing the proper circuit diagram and building out the drivetrain. This feature should take an estimated 15 hours to complete. For the feature to be considered complete the wheelchair's wheels must rotate when a voltage is applied to the dc motors.

360 Degree Turning: The turning feature will be developed using a single wheelchair, its four wheels, four motors, and a voice command. Team member Shazib will be responsible for the task of implementing the turning feature. His background and education in computer engineering will be useful in designing the state diagram that will be used to program the wheelchair to turn on command. This feature should take an estimated 20 hours to complete. For the feature to be considered complete the wheelchair must have a turning radius of 360 degrees.

Collision Avoidance and Object Detection: The features of Collision avoidance and object detection will be developed using one RGB camera, two motion sensors, and two Lidar sensors. Team member Waverly will be tasked with building out the sensor control system. His background and education in electrical and electronics engineering will allow him to apply knowledge of control systems, signals, microcontrollers, and circuit design to develop the feature so the wheelchair will be able to detect objects surrounding it and avoid them. The feature should take an estimated 48 hours to complete. For the feature to be considered complete the wheelchair must detect objects and then halt or change direction when objects are in its path.

Forward and Reverse Acceleration and Speed Detection: The features of acceleration and speed detection will be developed using Pulse Width Modulation and an accelerometer. For backup, two hall effect sensors with magnets will be utilized in case the accelerometer is not functioning. All team members will be responsible for developing these features. Our backgrounds and education in electrical and computer engineering allow us to assemble all the previous features together to enable acceleration and speed detection to happen. These features would take an estimated 96 hours to complete. The features will be considered complete when the wheelchair can change positions and adjust its speed based on the position of surrounding objects.

Voice Control: The voice control is running locally on the Raspberry PI4. We are running Coqui STT (Speech-to-text), which allows us to stream audio from the USB microphone, to our transcriber. Once we identify a command in the audio stream, our key value is updated. This key value is shared between our multiple processes.

The main commands we plan on featuring are forward, reverse, turn left, turn right, stop, increase and decrease speed. Alternative keywords can be used, such as go, start, begin, speed up, faster, slow, slower.

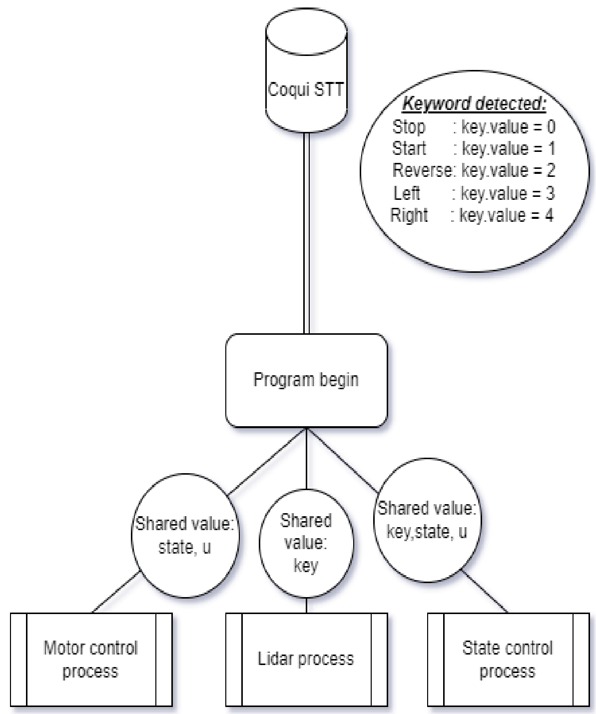


Figure 9 - Flowchart diagram of Python processes to control motors and sensors.

We choose to use multiprocessing to allow our code to run in parallel across all four cores of the Raspberry Pi 4. The main function creates 3 new processes, and then begins to stream audio to the transcriber. Once a command keyword is detected, the key value is updated. This value is used to determine which state the motors should be in.

lidar function

```
print ('Lidar running')
while(1):
    if((sensor.distance<150) and ((key.value == 1) or (key.value == 3) or (key.value == 4))) :
        temp = key.value
        key.value = 8
        print ('Object detected')
    if((sensor.distance>150) and key.value == 8):
        key.value = temp
```

Figure 10 - Lidar function which implements object detection. Once a value below the threshold is returned, we set a key value of 8 and start braking.

Figure 11 - State control function shown below that takes our key value and outputs a state value to our motor control function.

state_control function

```
while(1):
    if(key.value == 0 or key.value == 8):
        state.value = 0
        u.value = 0
    if(key.value == 1):
        state.value = 1
```

```
def control_M(state, u):
    try:
        motors.enable()
        motors.setSpeeds(0,0)
# Set up sequences of motor speeds.**********
        test_forward_speeds = list(range(0, MAX_SPEED, 1))

        test_reverse_speeds = list(range(0, -MAX_SPEED, -1))


# State used to set current command
# U is used to determine if max speed has been reached, and then maintains desi

    while(1):

        while(state.value == 0):
            motors.forceStop()

        while(state.value == 1):
            print('Moving forward now')
            if(u.value == 0):
                for s in test_forward_speeds:
                    motors.setSpeeds(s,s)
                    raiseIfFault()
                    time.sleep(0.005)
                    if(s == MAX_SPEED-1):
                        print('Max speed reached')
                        u.value = MAX_SPEED-1
## Once max speed is reached, we maintain it here. Until a state change is issu
            else:
                motors.setSpeeds(u.value, u.value)
                time.sleep(0.005)
                raiseIfFault()

       while(state.value == 2):
            print('Moving backwards now')
            if(u.value == 0):
                for s in test_reverse_speeds:
                    motors.setSpeeds(s,s)
                    time.sleep(0.005)
                    if(s == -1*(MAX_SPEED-1)):
                        print('Max speed reached')
                        u.value = s
            else:
                motors.setSpeeds(u.value, u.value)
                time.sleep(0.005)
                raiseIfFault()


    except DriverFault as e:
        print("Driver %s fault!" % e.driver_num)

    finally:
    # Stop the motors, even if there is an exception
    # or the user presses Ctrl+C to kill the process.
        motors.forceStop()
```

Figure 12 - This program describes our motor state. With the state value, our continuously running while loop determines which state to be in. Once we reach Max speed, this speed is kept until a change of state is issued.

Feature	Requirement	Measurable Metrics	Measurements for Success
Voice Control	Wheelchair must be capable of moving using input voice commands	Wheelchair's position before and after input of voice commands	Speech recognition can identify command keywords and send the corresponding action to the control until.
Electric Drivetrain	Wheelchair's wheels must be powered by an electric battery	The rotation of wheels when a voltage is applied	The wheelchair must have the ability to move in a smooth, straight fashion.
360 Degree Turning	Wheelchair must have a turning radius of 360 degrees	The starting angle of position of the wheelchair's front before and after turning command is input	The wheelchair should be able to make a full 360° turn, while using minimal amount of space.
Collision Avoidance	Wheelchair in motion must not hit another object	Force applied to wheelchair after coming to a complete stop	The wheelchair must stop once an object is detected.
Forward and Reverse Acceleration	Wheelchair must be capable of accelerating forward and in reverse	Wheelchair's position before and after input of commands for moving forward and in reverse	The wheelchair should be able to traverse safely in a forward and reverse type motion. This should be a smooth motion.
Speed Detection and Measurement	Wheelchair must be capable of detecting and measuring its own velocity	Wheelchair's velocity with respect to another object moving at a constant speed	The system must be able to calculate the current speed at which it is traveling. We can verify this by measuring speed with alternate methods.
Object Detection	The wheelchair must be capable of sensing objects around itself	Wheelchair's response to presence object in front, behind, and on its sides	The sensor system on board can identify objects in path.

Table 1: Punch List of Feature

IV. Funding

Table 2 is a Funding Table listing all items to be purchased and an estimated total cost of $433.00 to complete the project. Total cost will be divided amongst the four team members. Each member will be tasked with purchasing and delivering assigned items for final assembly. The working budget for this project is $1000.00, therefore this project is currently under budget. Remaining funds not spent building prototype will be set aside for purchasing tools and miscellaneous costs.

Item	Quantity	Cost Estimate Per Unit	Manufacturer	Supplier
Wheelchair	1	$110	TBD	TBD
Brushless DC Motor	2	$35	TBD	TBD
Microcontroller (Raspberry Pi 4)	1	$70	TBD	TBD
Lidar Sensor	2	$15	TBD	TBD
LiPo Battery	4	$20	TBD	TBD
VESC	2			
	Budget	$1000	TBD	TBD
	Total Cost Est.	$433	TBD	TBD

Table 2: Funding Table

V. Work Breakdown Structure

This project has approximately thirty-three weeks of activity, from inception of the societal problem to the delivery of the final design idea prototype. To successfully approach the development of the final prototype, the design approach has been broken up into features. Those features were then divided into subtasks based on the requirements needed to complete each feature. The subtasks were then divided into work packages filled with assignments needed to be completed.

VI. Project Timeline and Milestones

In Appendix E, we outline our tasks for the entire project. Each task is assigned to either an individual teammate, or to the entire team. This can be changed, if timing or scheduling issues arise. We made sure to give enough time, to account for any personal timing issues. Having this timeline will allow us to stay on track and complete each assignment in a timely manner. We made sure to align the project timeline with our Work Breakdown structure, splitting up the sections by our feature set and assignments.

VII. Risk Assessment

As described in the introduction, our design has multiple possible risks associated with it. These vary from specific technical risks to broader technical risks as well as systematic risks.

A broader technical risk is related to our wheelchair's drivetrain. We want the wheelchair to be able to maneuver around corners with a smooth motion. Our current design approach is including two brushed DC motors, with one on each side. Our design is going to be two-wheel drive. We plan on varying the speed of each motor, to allow the wheelchair to go around corners. It is a possibility that our turn radius will not be small enough, which would prevent us from turning smoothly. To mitigate this issue, we would add additional motors, and make the final design a four-wheel drive vehicle. Allowing us to control each wheel rather than the two-wheel drive approach. This would add extra components and increase our power requirements. We will need to test the performance of our design and determine if two motors will be sufficient.

A specific technical risk is related to our chosen microphone's speech recognition software and keyword identification. On the product description, it claimed to have offline keyword identification and preset commands available to program with. This functionality seems to be removed from their current software package. To mitigate this issue, we will be using another approach for speech recognition. This adds time needed to develop a solution for speech control.

A voice-controlled wheelchair cannot foresee dangers ahead. Although the wheelchair is fitted with a Lidar sensor to detect objects, it cannot predict the movement of obstacles in the path. The wheelchair user will thus have to be very keen to avoid any risks [16]. A specific technical risk is related to the accuracy of our Garmin Lidar sensor. We will need to test the Lidar in certain operating environments, to determine if it is able to detect objects in varying lighting conditions. To mitigate this issue, we could either add motion sensors, ultrasonic sensors, or a RGB camera. This will add additional complexity to the system. A potential broader technical risk related to the Lidar sensor, is having the ability to distinguish between moving and stationary objects. We will need to test this functionality and see if it is sufficient for our purpose. If the machine is unable to tell the difference, our plan of action is to add additional sensors, such as a motion sensor on the left and right side of the chair, and possibly an ultrasonic sensor.

A broader technical risk is our ability to adjust the speed of our wheelchair. DC motors have no inherent method to determine current speed. If our motors are not identical, we might experience a stray in our motion over time. If this is experienced, we will need to add the ability to determine our speed, and adjust using a feedback control loop, such as a PID controller. Sensor data from hall effect sensors will determine our current speed and adjust our output to maintain our desired speed. This would add additional sensors and possibly a microcontroller to our design.

Confusing voice commands occur when the user is in a noisy environment, which makes it challenging to recognize voice commands. In addition, while in a noisy environment, the voice systems are likely to respond to unwanted voice commands and head the user in an unexpected direction if no further control is done [16]. The wheelchair's system motors might misbehave due to high input, which speeds the wheelchair beyond control and may cause accidents in a busy road.

The wheelchair user is vulnerable to attack by outsiders; - the wheelchair is just open, which puts the user at risk of being attacked by evil persons they cross on their path. Besides, the user is disabled and might not fight back the attacker unless somebody comes to their rescue [17].

A systematic risk associated with doing teamwork is preventing possible Covid-19 exposures and practicing preventative measures. We are following all guidelines, including wearing masks when in close contact. If anyone on our team is experiencing symptoms, we insist they stay home and not come to campus. This ensures we are not contributing to any possible spread of the virus.

Other possible systematic risks include environmental disasters such as fires and flooding. If these were to occur, we would continue to work remotely to ensure the safety of our team. These have a low probability of occurring but could still potentially be an issue.

The impact on the matrix is the amount of money needed to mitigate the risk. This cost is an estimation based on extra components potentially needed.

	Potential Risk:	Probability	Impact	Risk value
1	Turning ability insufficient	0.3	4	1.2
2	Speech recognition setback	1	1	1
3	Speed Control required	0.5	3	1.5
4	Attaching wheel to shaft	1	3	3
5	Object detection insufficient	0.5	4	2
6	Fire	0.1	5	0.5
7	Flooding	0.1	5	0.5
8	Possible component failure	0.3	3	0.9
9	Possible Covid illness	0.2	3	0.6
10	Battery life not sufficient	0.3	2	0.6

Figure 13 - Risk matrix showing associated risk value with identified risks.

VIII. Deployable Prototype Status

Test ID	Test Description	Expected Results	Actual Results	Pass/Fail
1	Check Raspberry Pi OK/ACT LED status on boot. A flashing pattern at boot indicates an error with the SD-Card.	A consistently lit green light.	The raspberry pi is powering on as expected and the green LED is consistent.	Pass
2	Check the Raspberry Pi Power LED on boot. If the LED is blinking, that indicates a low power source. If it goes out, this is considered a “brownout”.	A consistently lit red light. This indicates the RPi is receiving adequate power. If the power supply goes below 4.63V, the LED will blink.	The RPi shows a consistent red LED once powered on. We are receiving adequate power.	Pass
3	Run the microphone V.A.D. streaming python program on the RPi 4 and verify keyword detection. This will verify Coqui S.T.T is installed properly and the microphone is functioning. Speak into the microphone from 18”-36”. Speak each keyword 3 times and verify the transcribed text on the monitor.	The external USB sound card should have a blinking blue LED. Any detected words should output to the terminal. The keywords will be detected in the order they are spoken.	Once the program is launched, the LED on the USB adapter begins to blink. In the terminal, a listening prompt is shown, along with a spinning bar. Any spoken words are shown transcribed in the terminal output.	Pass
4	Run the motor control program. Verify functionality of forward and reverse voice commands. Run the program for 5 minutes, varying direction every 30 seconds.	Both motors should respond accordingly to voice commands. When a reverse command is given, both motors should spin in the opposite direction.	When given a forward command, both motors begin to spin forward and the chair begins to move.	Pass

5	Run the motor control program. Verify functionality of turning commands. Run the program for 5 minutes, issue multiple left and right turn commands.	Both motors should respond to the voice commands. When a left turn is issued, the left wheel will go in reverse, while the right wheel goes forward.	Once a command is issued, both motors spin in the correct direction. This causes our chain to spin and propel our chair forward.	Pass
6	Run the motor control program. Verify the functionality of the stop command. While moving forward, issue a stop command. Do another test while in reverse.	Once the stop command is issued, the motors should come to a stop in less than 3 seconds.	The motors respond to stop commands when issued. Another alternative command is ‘kill’.	Pass
7	Run the motor control program. Verify the functionality of the stop command. While performing a turn, issue a stop command. Do a test while turning left and right.	Once the stop command is issued, the motors should come to a stop in less than 3 seconds.	Once the stop command is issued, both of the motor’s come to a complete stop in 3-5 seconds depending on the speed.	Pass
8	Run the motor control program. Verify the functionality of every command. Start moving forward, do multiple turns and reverse movements. Verify the stop command is functional while performing any movement.	The wheelchair should respond to any defined command given by the test user. A stop command should bring the chair to a halt at any time.	Once a command is issued, the motors respond correctly. The chair has the ability to move forward, reverse, turn left or right. This is behaving as intended.	Pass
9	The Motor Driver (VESC) powers on when 12 Volts is applied to it.	The LED indicating power-on emits a green light	Once power is applied to a VESC, the green LED is illuminated.	Pass

10	The Motor Driver sends a signal via pulse-width modulation to the motors	The motor shaft rotates at the rpm specified by our motor control.	Once a RPM command is sent to a VESC, the motor spins accordingly.	
11	The 12 V DC Motor shaft rotates when 12 volts is applied to them	The motor shaft rotates at max rpm	This test is not applicable, as we are using BLDC motors instead now.	N/A
12	The wheels are properly attached to the motor shaft	The wheels rotate at the same rpm as the motor shaft	After grinding flat spots for our set screws on wheels and axle sprocket, we confirmed our torque is transferring as expected.	Pass
13	Both VESC communicate with Raspberry Pi 4 tool	When a VESC receives a signal from the RPI, the corresponding motor is powered.	Once a command is sent to the VESC, the motor spins up to the set RPM.	Pass
14	The Motor Driver is electrically connected to the motors	A voltage can be seen at all the points of contact between the Motor Driver and leads to the motors	The motors are connected correctly, and receive the correct signals.	Pass
15	The Motor shaft rotates bi-directionally	The motor shaft rotates clockwise when a positive voltage is applied and counterclockwise when a negative voltage is applied	After calibrating the motors with the VESC tool, we set the motor orientation. The motors spin in the correct direction.	Pass
16	Check distance for lidar by inputting 150 cm into code and then measuring the distance when the motors stop running.	Our expected result is 4.9 feet. Motors should stop when an object is detected less than or equal to 4.9 feet	Motors stop when an object is less than or equal to 4.9 feet. Tested by using the hand and then measuring the	Pass

			distance between the sensor and hand.	
17	Check voltage for lidar using voltmeter	Voltage for lidar should be 3.3V	Voltage for lidar is 3.3V	Pass
18	Check stop time after detection	Stop time should be instant	Once a speed of zero is applied, the motors brake instantly.	Pass
19	Check if lidar changes the key value by displaying key value each time it changes	Lidar should change the value to 8	Lidar changes value to 8	Pass
20	Check if lidar changes the state value by displaying state value each time it changes	Lidar should change the state value to 0	Lidar changes state value to 0	Pass
21	Check if lidar is running with other devices	Lidar should display an object detect text string.	When object is in front of sensor, it displays text string	Pass
22	Check if lidar is always running by inputting a text string under the code to see if it is being accessed.	Text string should display “Lidar Running”	Lidar sensor continuously running, it shows that the Lidar is Running via text string	Pass
23	Check if lidar has priority over voice commands and motors	Lidar should be able to stop the motors instantly when an object gets detected	Lidar has priority and can stop motors instantly	Pass
24	Check If motor one receives forward state 1 by issuing the correct voice command in pi	Motor 1 is going forward	Motor goes forward	Pass
25	Check If motor two receives forward state 1 by issuing the	Motor 2 is going forward	Motor goes forward	Pass

	correct voice command in pi			
26	Check If motor one receives reverse state 2 by issuing the correct voice command in pi	Motor 1 is going in reverse	Motor goes reverse	Pass
27	Check If motor two receives reverse state 2 by issuing the correct voice command in pi	Motor 2 is going reverse	Motor goes reverse	Pass
28	Check if both motors stop by issuing the correct vice command in pi	Motor 1 & 2 both stop instantly	Motor 1 & 2 both stop instantly	Pass
29	Check if motors move forward while on the ground	Both motors move forward at same speeds, resulting in the chair moving forward	The chair is able to move forward in a straight fashion while bearing low weight.	Pass
30	Check if motors move in reverse while on the ground	Both motors move in reverse at same speeds, resulting in the chair moving forward	The chair is able to move in a reverse fashion.	Pass
31	Check state value logic by printing text strings for each state in order to check and see if each state is being accessed at the correct time	Text string correspond correctly to the state value	Each state is behaving as intended. When a command is issued, the appropriate action is taken.	Pass
32	Check if lidar, voice, and motors are running at the same time by printing text strings within each	The text strings should correspond to either voice, lidar, or the motors	Each process is running as expected. When a command or object is noticed,	Pass

	multiprocessor		action is taken.	
33	Check if universal key value is correctly being updated by displaying value	The key value should correspond with the voice commands	Once a defined command is issued, the key value is updated.	Pass
34	Check u value by displaying the value and seeing if it matches the MAX_SPEED	U value should be set to MAX_SPEED	Once max speed is reached, our u value is set. The chair will remain at max speed until a new command is issued or an object is encountered.	Pass
35	Check if multiple processes are running at same time. Check the running processes with the top command.	It should display the different processes running simultaneously	The different processes are seen running alongside each other.	Pass

IX. Marketability Forecast

In our initial research into this problem, we discovered that spinal cord injuries have been estimated to be prevalent in 200,000 to 288,000 people living in the United States. The higher up the spine the injury takes place, more of the body is affected. With quadraplegic and paraplegic patients, the ability to move their head and face muscles remains.

Alternate approaches to this problem for wheelchair control have used head motion to identify user commands. This type of control would not work if they are unable to move their neck. A researcher at North Carolina State University has designed a Tongue Drive System(TDS). This allows the user to control their wheelchair by moving their tongue. This is done by putting a metal piercing on the person's tongue, and fixing a small sensor inside of the mount. This technology is described by Patent US8044766B2. This approach requires implanting hardware inside the user's mouth, which isn’t always possible.

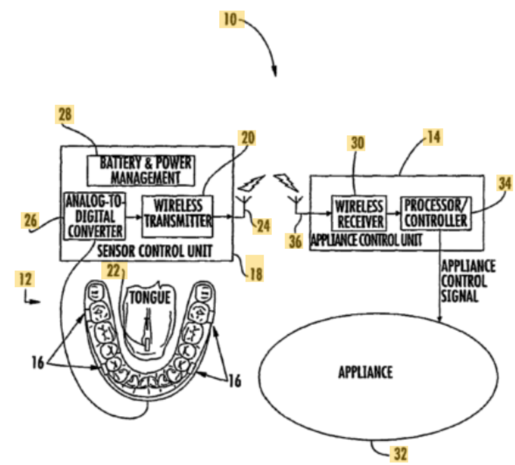


Figure 14 - Tongue drive system

Another design approach has been described in Patent US5812978A. The commands described and capabilities are similar, with a few key differences. Our design incorporates a Lidar sensor to detect objects in our path and stop when necessary. Their design does not include such a feature. The patent also describes using a throat microphone (laryngophone) compared to our standard sound wave microphone. This would allow the system to detect commands by vibrations of the throat, effectively ignoring any background noise. The downside of this approach is this technology is not widespread and compatibility with Unix may vary.

Figure 15 - Image showing a person pushing a wheelchair by themself. [19]

In our research, our wheelchair is taking the regular wheelchair and expanding the ability for mobility. The problem with a regular wheelchair is that in order to get mobility you must have someone who is willing to push the wheelchair for you, or be able to do it yourself which requires you to be able to use your arms and hands. This works for people that are unable to move but have function for their hands and arms but this does not work for someone that has lost the ability to use their hands or arms. As shown in figure 13, in order for a person to push themself in a regular wheelchair they must have function of their arms and hands.

Figure 16 - A person pushing disabled person [20]

Another issue is that in order to have mobility another person must be present in order to give you mobility on the wheelchair. As shown in figure 15, another person is needed in order to push the person in the wheelchair. This limits mobility because the disabled person's mobility depends on when another person is available.

Figure 17 - A person pushing disabled person [21]

The electric wheelchair is another competitor in the market. They are an option to a disabled person that does not have function to their arms but has function to their hands. The issue with electric wheelchairs is that it still requires use of hands in order to move the wheelchair by using the joystick. Our wheelchair allows the person to control the wheelchair with just their voice without needing another person the use of hands or arms.

SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis:

Strengths of the product include its usability, efficiency, and comfortability. Our wheelchair benefits from being voice-controlled, which gives it a lower barrier-to-entry for users with a wide range of disabilities. Our wheelchair benefits from being electric powered, which makes it more efficient than a manually operated wheelchair. A user of our wheelchair could cover twice the distance in half the amount of time as a user of a non-electric product. Our wheelchair benefits from being ergonomic. The use of a microphone that is positioned near the mouth to speak into, as opposed to a larynx microphone that is positioned at the throat to pick up vibrations, is more comfortable for users. Additional strengths of the project include the use of low-cost materials and technologies for easy assembly, such as pre-build microcontrollers and motor-drivers, along with an aluminum frame. On top of all that, our team possesses skilled computer and electrical engineers that have developed the code so the chair adapts to its environment. The chair stops when obstacles are present, and in the future our engineers could develop a method to make the wheelchair self-driving.

Weaknesses of the product include safety risks and potentially high-cost of manufacturing. Our wheelchair currently lacks a seatbelt for securing the user in the seat. This is dangerous, especially if the user is accelerating at a speed of three to five miles per hour. Our wheelchair also could be costly to acquire. The average consumer would likely not be able to afford the initial version of the product without a way to subsidize the cost.

Opportunities of the product include patentability, licensing, and adaptability of the control system to various models. Our wheelchair is uniquely designed. This opens the door for patentability with the United States Patent and Trademark Office (USPTO). The USPTO allows the registration of design patents that show novelty in the orientation or arrangement of an invention. Our wheelchair's system is engineered using an assortment of many technologies that make it a novel representation of a wheelchair. With a patent, we could then license our design to wheelchair manufacturers. The crux of our product would be its control system. There are many existing products that would be improved by equipping a voice-control drive system, i.e. cars, shopping carts, bikes, and robots.

Threats to our product include market oversaturation and obsolescence. Our wheelchair is essentially a rendition of an already existing product. There are many models of wheelchairs on the market, at different price points, which makes the possibility that our product would be lost in all the noise very high. To mitigate this, our team would work to make our product stand out by including additional features in an updated model, such as bluetooth connectability, smart-device integration, and battery charging. Making our product more technologically compatible, would allow our customers to integrate the current devices they use on a regular basis with our wheelchair, making it more attractive. The additional upgrades would likely keep our product in the market long enough before the second threat completely makes it obsolete. New technologies are being developed every day, so the use of a wheelchair may very well become a thing of the past as medical science advances. Once that happens, there is really no way to alter our product to address the needs of our customers.

X. Conclusion

A. Societal Problem

People with disabilities exist. They are a large part of our high-tech society and therefore they deserve high-tech solutions that make their lives easier. The wheelchair is one of those solutions, yet its current incarnation does not address the needs of all people with disabilities. There are many types of wheelchairs, differing by the method of propulsion, control mechanism and technology used. Some wheelchairs are designed for general everyday use, others for single activities or to address specific accessibility needs. Innovation in the wheelchair industry is common, but many innovations end up in a state of underdevelopment, either by over-specialization, or by not bringing an idea to market at accessible prices. Our project is an introduction to the next generation of wheelchairs.

B. *Design Idea*

Our design prototype is going to implement various sensors, with the goal of making a voice-controlled wheelchair. Safety is going to be a primary concern, so certain features will need to be implemented. We plan to include a microphone in our system, which will allow our users to input voice commands. These commands will allow the wheelchair to be controlled hands free. This will allow disabled people to go about their day-to-day life. We plan to focus on core functionality for our initial prototype, with the plans to add additional control features in the future.

The Raspberry Pi onboard will allow us to implement other hardware components if necessary. Open-source libraries will also allow us to easily communicate with any other sensors we may need.

We are envisioning our design to be implemented in a hospital type environment, where patients are often transported with personnel assistance. This technology would allow hospital workers to focus on other tasks at hand, which could improve efficiency in daily operations. With employee shortages being seen in most sectors, this technology makes sense from a cost standpoint. Technology allows us to tackle challenges that would otherwise be impossible. If this device can make someone's life a little easier, it will provide a great deal of value.

C. Work Breakdown Structure

This project consists of various assignments that need to be completed by their respective due dates to meet the delivery date of May 2022. The Work Breakdown Structure Table, shown in Appendix D, is a detailed list of all assignments needed to be completed to meet the requirements that make up each feature of the prototype. Each team member has accepted assignments that relate to the designing and building of the prototype features based on their skills and capabilities. This guarantees that each feature will be completed with efficiency and competency, on time for delivery.

D. Project Timeline

This timeline will be a tool that we utilize and maintain through the design process. Visualizing our assigned tasks will allow us to align our workload with the assignments, ensuring we fulfill the requirements. Defining our work packages and assigning a timeline will ensure any bottlenecks or complications in our design will be managed in a timely fashion. Major Milestones are defined as our prototype presentations.

E. Risk Assessment

The risk assessment matrix is a tool we used to identify any risks that we as a team might face. The risks taken in account were environmental risks and project risks. Having a risk matrix allowed us to develop mitigations for each risk in our risk matrix. This allows us as a team to make sure that if we do run into any problems, we have a backup plan to solve that problem. For each risk on our matrix, we have the probability of the risk occurring.

G. Device Test Plan

The test plan goes through each element in our feature set, and demonstrates the functionality of our system. Testing each individual component initially, this allows us to confirm the operation of our devices. Once we confirm the pieces work, we run tests which incorporate the entire system. These tests include issuing voice commands and verifying the movement of our motors. At any time, the stop or ‘kill’ command which brakes both motors.

H. Market Review

This project is for the purpose of testing and exploring. Therefore focussing on market analysis at this time is not an urgent step. In the future when we have completed the final product review, another market review will be executed before the product is launched to the customer's market. After the review, we have decided the targeted customers, price analysis and level of customers’ needs.

I. Testing Results

After the testing, team 13 has completed the initial objectives which was listed in the punch list as: Control wheelchair go forward, reverse, turn left, turn right and adjust the wheelchair speed through adjusting RPM and voltage supplied. Compared to our previous model of PVC wheelchair, there are some improvements which we were able to achieve in this semester. With the new frame we were able to secure the wheelchair with a heavy load on it. The new motors were strong enough to move the wheelchair with heavy load, this solved our torque issue which we mentioned at the beginning of second semester. The Lidar sensor was able to recognize objects in front of the wheelchair and stop the wheelchair before collision.

In addition to the obtained results, the model has the following limitations:

There is still a delay in the control from voice control to the motor. Voice control is not optimized, the delays happen while receiving and transcribing. data. This can be because of the objective factors. Our speech to text is running a tensorflow lite model, which is a CPU intensive task. With future improvements in speech models and computing power, this could be a more reliable method of control.

The lidar sensor is working well so far when there's an object detected in front of the wheelchair. However to optimize the ability of collision avoidance, the wheelchair needs to be able to detect objects from every direction. This could be improved by adding more lidar sensors at different positions of the wheelchair.

The wheel is not currently receiving all of the torque produced by the motor. During testing, our drive system was able to move up to 35 lbs of additional load. Once we attempted to add another 10 lbs, the sprocket began to slip on the motor shaft. This is due to the fact we are using a sprocket that is 2mm too large for our motor shaft. Due to this shipping error and delayed replacement, we attempted to fix the issue by increasing our motor shaft diameter with aluminum foil tape. This issue should be resolved with a proper fitting sprocket.

REFERENCES

	Article	Journal	Citation
] 1	Human-machine communication	Computer in Human Behavior Volume 90, January 2019, Page 285-287	Patric R. Spence *Human-machine communication* https://www.sciencedirect.com/science/article/pii/S0747563218304540
2	BASICS OF UART COMMUNICATION	Circuit Basis	Scott Campbell, *Basics of Uart communication* https://www.circuitbasics.com/basics-uart-communication/
3	Wheelchair History	Wheelchair History	https://en.wikipedia.org/wiki/Wheelchair
4	History of the Wheelchair	History.Phiso	Glenn Ruscoe, *History of wheelchair* https://history.physio/history-of-the-wheelchair/
5	Who was the first individual to invent the wheelchair?	Sport News	*Sports News* *January 29, 2021* https://sportsnewsstar.blogspot.com/2021/01/who-was-first-individual-to-invent.html
6	Narrow Wheelchairs for Tight Spaces and Skinny Doorways	Grayingwithgrace.com	Scott Grant *https://www.grayingwithgrace.com/wheelchairs-narrow-doorways/*
7	Jazzy 600 ES	Spinlife	*https://www.spinlife.com/Pride-Jazzy-600-ES-Full-Size-Power-Wheelchairs/spec.cfm?productID=103386&adv=googlepla&utm_medium=CSE&utm_source=googlepla&utm_term=&utm_campaign=11097663967&gclid=Cj0KCQjwnoqLBhD4ARIsAL5JedL82bvVIob0x2ehL23l8kgU8tqBwk7LdDPNllz9QrUT__MlcEEfOYAaArx-EALw_wcB*

8	Draco (Electric Standing Wheelchair)	Living Spinal	https://livingspinal.com/active-mobility/standing-wheelchairs-and-frames/draco-electric-standing-wheelchair/
9	Designing the world's fastest Wheelchair	Viterbi Magazine	*Daniel Druhora* *https://magazine.viterbi.usc.edu/spring-2017/alumni/designing-the-worlds-fastest-wheelchair/*
10	Arduino based voice-controlled wheelchair	IOP Science	Tan Kian Hou et al 2020 J. Phys.: Conf. Ser. 1432 012064 https://iopscience.iop.org/article/10.1088/1742-6596/1432/1/012064/pdf
11	Voice Controlled Intelligent Wheelchair using Raspberry Pi	International journal of engineering research and technology	Naeem, A., Qadir, A., & Safdar, W. (2014). Voice Controlled Intelligent Wheelchair using Raspberry Pi. International journal of engineering research and technology, 2.
12	Control Systems and Electronic Instrumentation Applied to Autonomy in Wheelchair Mobility: The State of the Art	*Sensors* **2020**, *20*(21), 6326	Callejas-Cuervo M, González-Cely AX, Bastos-Filho T. Control Systems and Electronic Instrumentation Applied to Autonomy in Wheelchair Mobility: The State of the Art. Sensors. 2020; 20(21):6326. https://doi.org/10.3390/s20216326
13	Low-cost sensor network for obstacle avoidance in share-controlled smart wheelchairs under daily scenarios	Journal article	Pu, Jiangbo & Jiang, Youcong & Xie, Xiaobo & Chen, Xiaogang & Liu, Ming & Xu, Shengpu. (2018). Low cost sensor network for obstacle avoidance in share-controlled smart wheelchairs under daily scenarios. Microelectronics Reliability. 83. 180-186. 10.1016/j.microrel.2018.03.003.
14	How many people would benefit from a smart wheelchair?	Journal Article	Richard C. Simpson, PhD, ATP; Edmund F. LoPresti, PhD; Rory A. Cooper, PhD, Department of Rehabilitation Sciences and Technology; University of Pittsburgh, PA, JRRD Vol. 45 pgs. 53-72

15	Disability Impacts	Government website	https://www.cdc.gov/ncbddd/disabilityandhealth/infographic-disability-impacts-all.html
16	Hacking the brain: brain-computer nterfacing technology and the ethics of neurosecurity.	Ethics and Information Technology	Ienca, M., Haselager, P. Hacking the brain: brain–computer interfacing technology and the ethics of neurosecurity. Ethics Inf Technol 18, 117–129 (2016). https://doi.org/10.1007/s10676-016-9398-9
17	Hate crime or mate crime? Disablist hostility, contempt, and ridicule: Pam Thomas	Book	Thomas, P. (2012). Hate crime or mate crime? Disablist hostility, contempt, and ridicule: Pam Thomas. In Disability, Hate Crime and Violence (pp. 140-151). Routledge.
18	Head-motion controlled wheelchair	Journal Article	S. Prasad, D. Sakpal, P. Rakhe and S. Rawool, "Head-motion controlled wheelchair," 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2017, pp. 1636-1640, doi: 10.1109/RTEICT.2017.8256876.
19	How to use a Wheelchair	Webpage	https://www.wikihow.com/Use-a-Wheelchair
20	Wheelchair Patient	Webpage	https://www.clipartmax.com/middle/m2i8i8N4b1b1d3Z5_wheelchair-patient-nursing-clip-art-push-wheelchair/

21	Electric Wheelchair	Webpage	https://www.kindpng.com/imgv/iTJioxm_null-electric-wheelchair-clip-art-hd-png-download/

Glossary

BCM: Broadcom chip-specific pin numbers
PWM: Pulse width modulated

Coqui STT: Coqui Speech-to–text

NEED TO FILL IN

Appendix A. Hardware

Appendix A. Hardware

Block diagram & documentation at block level.
Schematics and documentation to component level.
Test plan and test results for hardware.
Page numbers for this appendix start with “Appendix A-1”
Figures and table numbering restarts. “Figure A1. Title”

NEED TO FILL IN

Appendix B. Software

Appendix B. Software

Block diagram & documentation at block level.

Flowcharts, pseudo-code, and documentation to subroutine level.

Test plan and test results for software.

Page numbers for this appendix start with "Appendix B-1"

Figures and table numbering restarts. "Figure B1. Title"

NEED TO FILL IN

Appendix C. Mechanical Aspects

Appendix C. Mechanical Aspects As appropriate to your project - Drawings, load calculations, ISO compliance data, and/or other documentation for the mechanical aspects of your deployable prototype. Page numbers for this appendix start with "Appendix C-1" Figures and table numbering restarts. "Figure C1. Title"

Appendix D. Work Breakdown Structure

Level 1	Level 2	Level 3
Voice Control		
Wheelchair must be capable of navigating in response to voice commands. This task will be assigned to Erik Coleman, with help from the group for testing. Shazib will assist if further implementation is needed for speech recognition.	Subtask 1.1: Stream user audio to voice recognition software. Subtask 1.2: Take user commands detected from speech recognition software to send to our motor controller.	Work Package 1.1.1: Setup microphone and verify correct functionality. Time estimated: 2 hours Status: Complete Work Package 1.1.2: Verify speech recognition software provided with the microphone will work for our purpose. Once confirmed, included in the final design. Time estimated: 4-6 hours Status: Complete Work Package 1.2.1: Develop python code to trigger an action in our motor controller, based on user input from the microphone. Time estimated: 4 hours Status: Complete Work Package 1.2.2: Test our voice controller by using this functionality in a real-world environment, with multiple users. When this feature is working, demonstrate ability in the prototype presentation. Time estimated: 2-4 hours Status: In progress

Electric Drivetrain		
Wheelchair will be powered by an electric battery. The 12V battery will provide power to our DC motors, allowing the wheelchair to maneuver itself. This task will be assigned to Waverly, with assistance from Pho with circuit construction. The entire team will be involved with testing.	Subtask 2.1 Power motors using an electric battery Subtask 2.2 Build frame to house the battery Subtask 2.3 Use motors to rotate two back wheels	
In the new version of the project for second semester we replaced the old motors 12V with the built-in gear box motor 24V to increase the torque power. Encoder will be an add-on application which will assist Shazib and Erik with the programming.	Subtask 2.4 New motor with built-in gear box will increase torque power Subtask 2.5 Encoder application is explained in Work Package 6.1.3	2.4.1 Swapping out the old motors with new motors Status: In Progress
Battery will be upgraded to 24V. Our plan is to connect a new 12V battery in series with the old battery which we have right now in case we need.	Subtask 2.6 The series of 12V battery will supply stronger power to run the two new motors	2.6.1 We will test the new version of the wheelchair with a 12V battery. In case it doesn't supply enough power, the series of 12V batteries will be a back-up plan. Status: Testing
		Work Package 2.1.1 Research parts and suppliers for motors, batteries, and wheels. Time estimated: Status: In progress

		Work Package 2.1.2 List parts in Assignment 3 – Design Approach Time estimated: Status: In progress
Turning		
Wheelchair must have a turning radius of 360 degrees.	Subtask 3.1 Design a method for the wheelchair to turn.	
		Work Package 3.1.1 Calculate rotation speed needed to turn wheels. This task will be assigned to Waverly and Pho. Time estimated: 2-4 hours Status:In progress Work Package 3.1.2 Program motor-driver to regulate motor speed. This task will be assigned to Erik. Time estimated: 2-4 hours Status: Complete
Collision Avoidance		
The wheelchair must be capable of sensing objects around itself. Once an	Subtask 4.1 A lidar sensor will be used to detect objects and humans	

object is determined to be in our path, we must stop and wait for user action.		
		Work Package 4.1.1 A lidar sensor is to be attached to the wheelchair and connected to the Rpi4. Set up the lidar sensor to detect objects within a 5ft radius. Wheelchair stops when an object is detected. This task will be assigned to Shazib. Time estimated: 2-4 hours Status: Complete Work Package 4.1.2 Verify the sensor operates correctly in a crowded environment with multiple objects at a time. This task will be assigned to the entire team, with continuous testing. Time estimated: 4 hours Status: In progress

Forward and Reverse Acceleration		
The wheelchair must be capable of accelerating in a forward and reverse motion.	Subtask 5.1 Test motor driver functionality with our electronics and motors. Subtask 5.2 Test motor functionality while attached to our prototype frame and wheels.	Work Package 5.1.1: Attach the motor driver to Raspberry Pi, power the motor driver with the 12V battery. Power the RPI with a separate battery pack. This task will be assigned to Waverly and Pho. Time estimated: 2-4 hours Status: Complete Work Package 5.1.2: Test the motor driver functionality by sending a PWM signal, in both forward and reverse direction. Verify the motors switch direction. This task will be done by the entire team. Erik and Shazib will focus on the software. Time estimated: 2 hours Status: Complete
		Work Package 5.2.1: Assemble the frame for the prototype, securing our electronics to our chosen frame. This task will be completed by the entire team. Time estimated:4-6 hours Status: Complete Work Package 5.2.2: Test our prototype by sending forward and reverse commands, verifying the correct

		movement is taken. Once this is verified, our design is ready for Technical Evaluation (Assignment 7). This task will be completed by the entire team. Time estimated: 2 hours Status: Complete
Speed Detection		
Wheelchair must be capable of detecting and measuring its own velocity.	Subtask 6.1 An encoder is used to measure the moving velocity of a motor shaft.	Work Package 6.1.1 Find a supplier for a motor with encoder, and then purchase it. This task will be assigned to Pho. Time estimated: 2 hours Status: Complete
	Subtask 6.2 Pulse Width Modulation adjusts the output voltage of the load based on the change in the width of the pulse sequence. This will allow us to adjust speed as needed.	Work Package 6.1.2 Determine correct method to adjust PWM duty cycle to allow the user to vary the wheelchair speed. This task will be done by the entire team. Time estimated: 2 hours Status:In progress

		Work Package 6.1.3 Implement a PID control loop to adjust motor speed. Our goal is to minimize drift and to maintain a consistent speed. The error is calculated between our target speed and actual speed, which is then used to adjust the motors voltage accordingly. An encoder is used to provide sample values from our motor. These ticks are used to calculate error. This will be implemented by Shazib and Erik. Time estimated: 4 hours Status:In progress

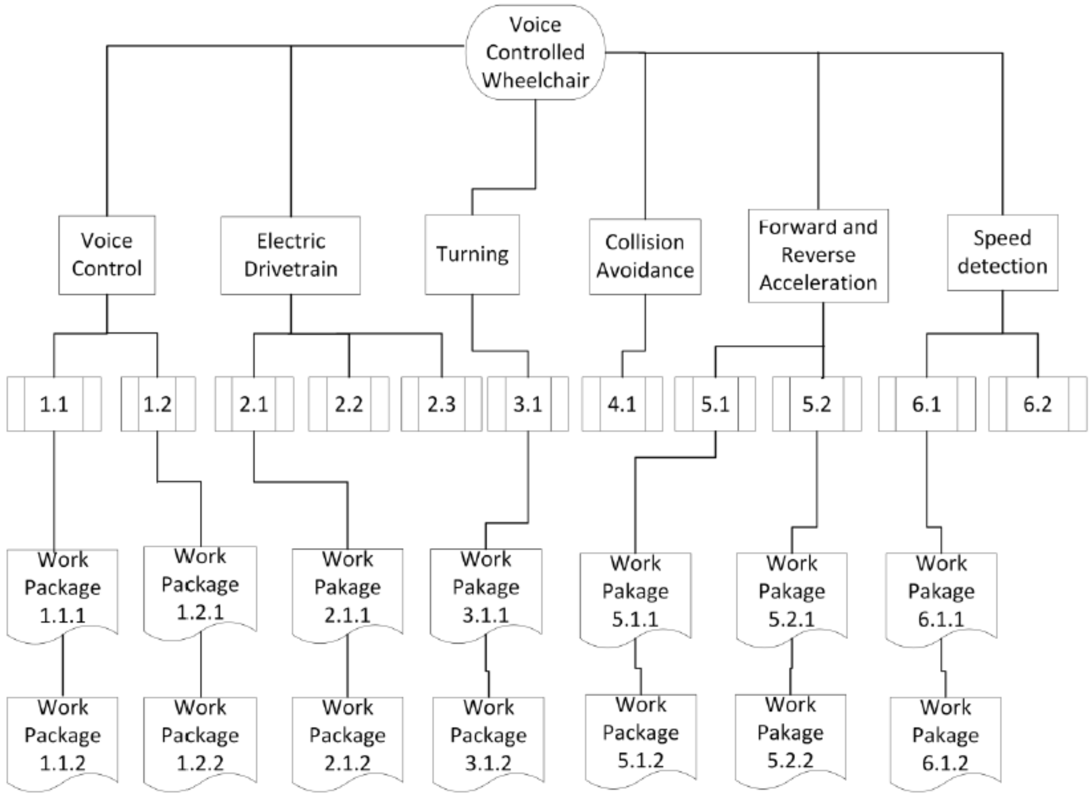


Figure 2: Flowchart diagram illustrating work breakdown structure.

Appendix E. Timeline Charts and PERT Diagrams

Gantt Chart - Smart Wheelchair Timeline

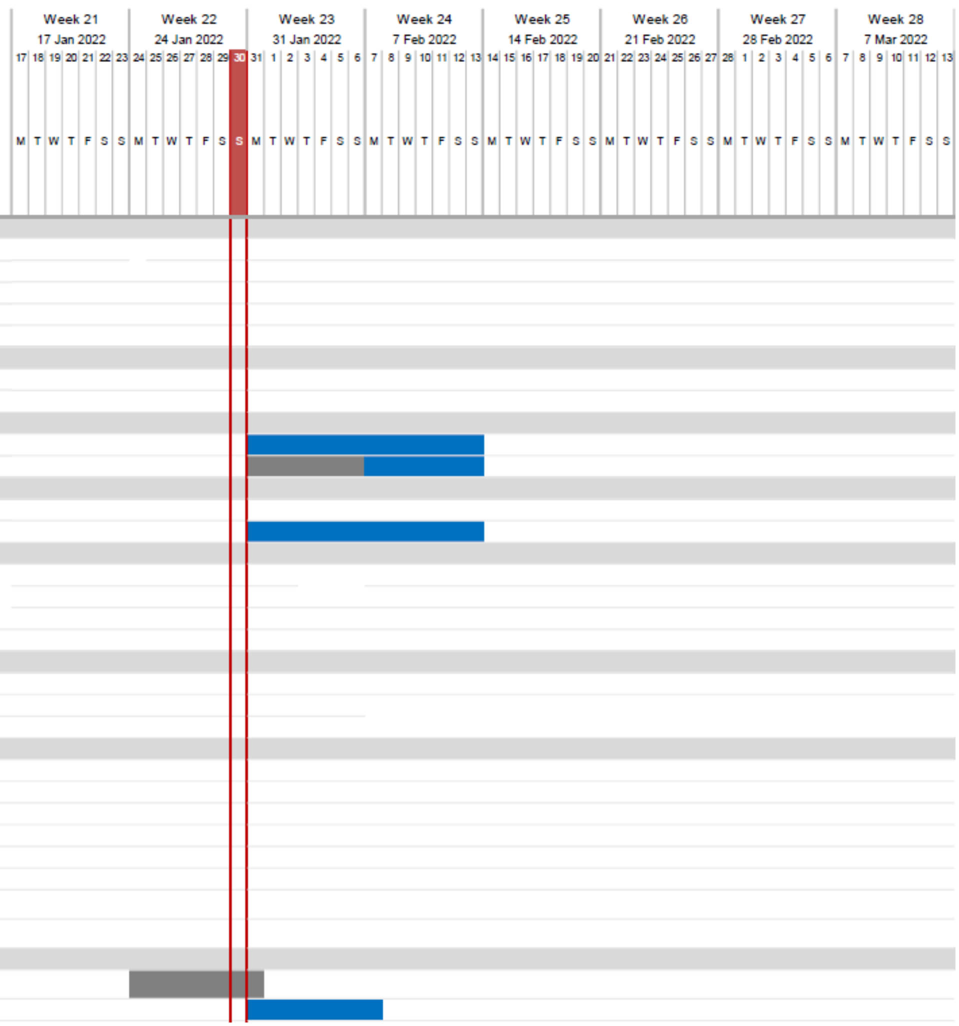
Team 13

Project Start Date: 8/30/2021 (Monday)

Project Lead: Erik Coleman

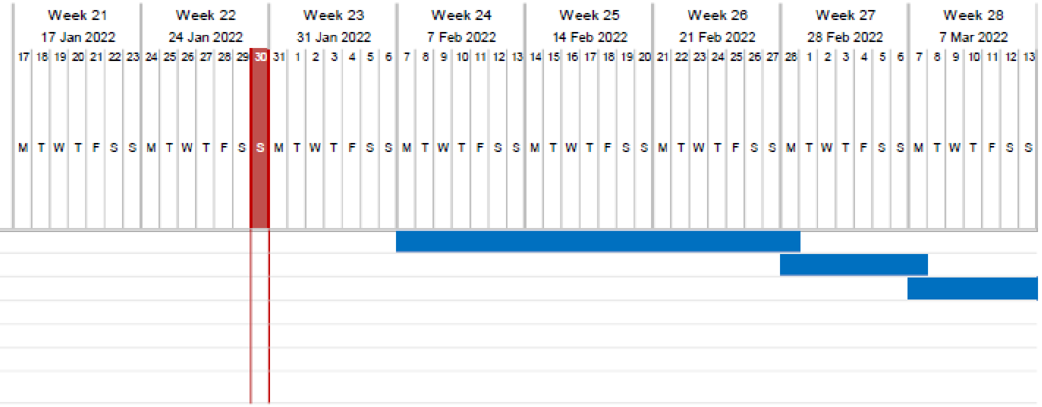
Display Week: 21

WBS	TASK	LEAD	START	END	DAYS	% DONE	WEEK DAYS
1	**Voice Control**			-			-
1.1	Work Package 1.1.1	Erik C.	Mon 10/18/21	Sun 10/24/21	7	100%	5
1.2	Work Package 1.1.2	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.3	Work Package 1.1.3	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.4	Work Package 1.2.1	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.5	Work Package 1.2.2	Erik C.	Wed 11/10/21	Sun 11/14/21	5	100%	3
2	**Electric Drivetrain**			-			-
2.1	Work Package 2.1.1	Waverly H.	Tue 9/28/21	Mon 10/11/21	14	75%	10
2.2	[Work Package 2.1.2	Pho L.	Tue 9/28/21	Mon 10/04/21	7	100%	5
3	**Turning**			-			-
3.1	Work Package 3.1.1	Waverly/Pho	Mon 1/31/22	Sun 2/13/22	14	0%	10
3.2	Work Package 3.1.2	Erik C.	Mon 1/31/22	Sun 2/13/22	14	50%	10
4	**Collision Avoidance**			-			-
4.1	[Work Package 4.1.1	Shazib N.	Mon 11/01/21	Mon 11/15/21	15	100%	11
4.2	[Work Package 4.1.2	Team	Mon 1/31/22	Sun 2/13/22	14	0%	10
5	**Forward and Reverse Acceleration**			-			-
5.1	Work Package 5.1.1	Waverly/Pho	Wed 11/03/21	Tue 11/09/21	7	0%	5
5.2	Work Package 5.1.2	Erik/Shazib	Wed 11/03/21	Tue 11/09/21	7	0%	5
5.3	Work Package 5.2.1	Team	Wed 11/03/21	Sun 11/14/21	12	0%	8
5.4	Work Package 5.2.2	Team	Wed 11/03/21	Sun 11/14/21	12	0%	8
6	**Speed Detection**			-			-
6.1	Work Package 6.1.1	Pho L.	Sun 11/07/21	Sat 11/20/21	14	100%	10
6.2	Work Package 6.1.2	Team	Sun 11/07/21	Sat 11/20/21	14	100%	10
	Work Package 6.1.3	Shazib/Erik	Fri 1/07/22	Thu 1/13/22	7		5
1	**Assignments - Fall '21**			-			-
1.1	Individual Societal Problem		Mon 8/30/21	Mon 9/13/21	15	100%	11
1.2	Team Societal Problem	Team	Mon 9/13/21	Mon 9/27/21	15	100%	11
1.3	Design Idea Contract	Team	Mon 9/27/21	Mon 10/04/21	8	100%	6
1.4	Work Breakdown Structure	Team	Mon 10/04/21	Mon 10/25/21	22	100%	16
1.5	Project Timeline	Erik C.	Mon 10/25/21	Mon 11/01/21	8	100%	6
1.6	Risk Assessment	Team	Tue 11/02/21	Mon 11/08/21	7	100%	5
1.7	Project Technical Evaluation	Team	Sat 11/20/21	Mon 12/06/21	17	100%	11
1.8	Laboratory Prototype Presentation	Team	Tue 11/30/21	Thu 12/09/21	10	100%	8
2	**Assignments - Spring '22**			-			-
2.1	Revised Problem Statement	Team	Mon 1/24/22	Mon 1/31/22	8	100%	6
2.2	Device Test Plan Report	Team	Mon 1/31/22	Mon 2/07/22	8	0%	6



Project Start Date	8/30/2021 (Monday)
Project Lead	Erik Coleman
Display Week	21

WBS	TASK	LEAD	START	END	DAYS	% DONE	WEEK DAYS
2.3	Market Review	Team	Mon 2/07/22	Mon 2/28/22	22	0%	16
2.4	Feature Report	Team	Mon 2/28/22	Mon 3/07/22	8	0%	6
2.5	Testing Results Report		Mon 3/07/22	Mon 4/04/22	29	0%	21
2.6	Assignment 6: N/A			-		0%	-
2.7	Deployable Prototype Eval.		Mon 4/04/22	Mon 4/25/22	22	0%	16
2.8	End of Project Report		Mon 4/25/22	Mon 5/02/22	8	0%	6
2.9	Deployable Prototype Public Presentation		Mon 5/02/22	Fri 5/13/22	12	0%	10



Gantt Chart - Smart Wheelchair Timeline

Team 13

Project Start Date: 8/30/2021 (Monday)

Project Lead: Erik Coleman

Display Week: 29

Week 29	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35	Week 36
14 Mar 2022	21 Mar 2022	28 Mar 2022	4 Apr 2022	11 Apr 2022	18 Apr 2022	25 Apr 2022	2 May 2022
14 15 16 17 18 19 20	21 22 23 24 25 26 27	28 29 30 31 1 2 3	4 5 6 7 8 9 10	11 12 13 14 15 16 17	18 19 20 21 22 23 24	25 26 27 28 29 30 1	2 3 4 5 6 7 8
M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S

WBS	TASK	LEAD	START	END	DAYS	% DONE	WEEK DAYS
1	**Voice Control**			-			-
1.1	Work Package 1.1.1	Erik C.	Mon 10/18/21	Sun 10/24/21	7	100%	5
1.2	Work Package 1.1.2	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.3	Work Package 1.1.3	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.4	Work Package 1.2.1	Erik C.	Wed 11/03/21	Tue 11/09/21	7	100%	5
1.5	Work Package 1.2.2	Erik C.	Wed 11/10/21	Sun 11/14/21	5	100%	3
2	**Electric Drivetrain**			-			-
2.1	Work Package 2.1.1	Waverly H.	Tue 9/28/21	Mon 10/11/21	14	75%	10
2.2	[Work Package 2.1.2	Pho L.	Tue 9/28/21	Mon 10/04/21	7	100%	5
3	**Turning**			-			-
3.1	Work Package 3.1.1	Waverly/Pho	Mon 1/31/22	Sun 2/13/22	14	0%	10
3.2	Work Package 3.1.2	Erik C.	Mon 1/31/22	Sun 2/13/22	14	50%	10
4	**Collision Avoidance**			-			-
4.1	[Work Package 4.1.1	Shazib N.	Mon 11/01/21	Mon 11/15/21	15	100%	11
4.2	[Work Package 4.1.2	Team	Mon 1/31/22	Sun 2/13/22	14	0%	10
5	**Forward and Reverse Acceleration**			-			-
5.1	Work Package 5.1.1	Waverly/Pho	Wed 11/03/21	Tue 11/09/21	7	0%	5
5.2	Work Package 5.1.2	Erik/Shazib	Wed 11/03/21	Tue 11/09/21	7	0%	5
5.3	Work Package 5.2.1	Team	Wed 11/03/21	Sun 11/14/21	12	0%	8
5.4	Work Package 5.2.2	Team	Wed 11/03/21	Sun 11/14/21	12	0%	8
6	**Speed Detection**			-			-
6.1	Work Package 6.1.1	Pho L.	Sun 11/07/21	Sat 11/20/21	14	100%	10
6.2	Work Package 6.1.2	Team	Sun 11/07/21	Sat 11/20/21	14	100%	10
	Work Package 6.1.3	Shazib/Erik	Fri 1/07/22	Thu 1/13/22	7		5
1	**Assignments - Fall '21**			-			-
1.1	Individual Societal Problem		Mon 8/30/21	Mon 9/13/21	15	100%	11
1.2	Team Societal Problem	Team	Mon 9/13/21	Mon 9/27/21	15	100%	11
1.3	Design Idea Contract	Team	Mon 9/27/21	Mon 10/04/21	8	100%	6
1.4	Work Breakdown Structure	Team	Mon 10/04/21	Mon 10/25/21	22	100%	16
1.5	Project Timeline	Erik C.	Mon 10/25/21	Mon 11/01/21	8	100%	6
1.6	Risk Assessment	Team	Tue 11/02/21	Mon 11/08/21	7	100%	5
1.7	Project Technical Evaluation	Team	Sat 11/20/21	Mon 12/06/21	17	100%	11
1.8	Laboratory Prototype Presentation	Team	Tue 11/30/21	Thu 12/09/21	10	100%	8
2	**Assignments - Spring '22**			-			-
2.1	Revised Problem Statement	Team	Mon 1/24/22	Mon 1/31/22	8	100%	6
2.2	Device Test Plan Report	Team	Mon 1/31/22	Mon 2/07/22	8	0%	6

Project Start Date	8/30/2021 (Monday)		Display Week	29
Project Lead	Erik Coleman			

WBS	TASK	LEAD	START	END	DAYS	% DONE	WEEK DAYS
2.3	Market Review	Team	Mon 2/07/22	Mon 2/28/22	22	0%	16
2.4	Feature Report	Team	Mon 2/28/22	Mon 3/07/22	8	0%	6
2.5	Testing Results Report		Mon 3/07/22	Mon 4/04/22	29	0%	21
2.6	Assignment 6: N/A			-		0%	-
2.7	Deployable Prototype Eval.		Mon 4/04/22	Mon 4/25/22	22	0%	16
2.8	End of Project Report		Mon 4/25/22	Mon 5/02/22	8	0%	6
2.9	Deployable Prototype Public Presentation		Mon 5/02/22	Fri 5/13/22	12	0%	10

Week 29 — 14 Mar 2022; Week 30 — 21 Mar 2022; Week 31 — 28 Mar 2022; Week 32 — 4 Apr 2022; Week 33 — 11 Apr 2022; Week 34 — 18 Apr 2022; Week 35 — 25 Apr 2022; Week 36 — 2 May 2022

PERT Diagram

Critical Path Method

© 2010-2021 Vertex42 LLC

HELP

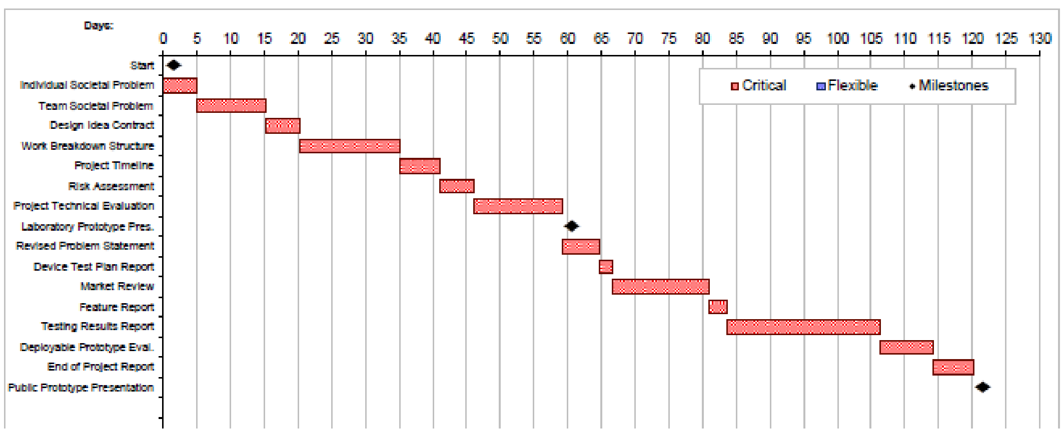
Start Date: 8/30/2021
Finish Date: 2/15/2022

Days to Completion: 120.33

Critical tasks
No successor defined yet

Times (in Days)
Time Distribution: Triangular

ID	Task Name	Predecessors (Enter one ID per cell)	O (min)	M (most likely)	P (max)	Duration (exp. time)	ES	EF	LS	LF	Slack
10	Start					0.00	0.00	0.00	0.00	0.00	0.00
100	Individual Societal Problem		3	5	7	5.00	0.00	5.00	0.00	0.00	0.00
110	Team Societal Problem	100	7	10	14	10.33	5.00	15.33	0.00	0.00	0.00
120	Design Idea Contract	110	3	5	7	5.00	15.33	20.33	0.00	0.00	0.00
130	Work Breakdown Structure	120	9	14	21	14.67	20.33	35.00	0.00	0.00	0.00
140	Project Timeline	130	4	6	8	6.00	35.00	41.00	0.00	0.00	0.00
200	Risk Assessment	140	3	5	7	5.00	41.00	46.00	0.00	0.00	0.00
210	Project Technical Evaluation	200	9	14	17	13.33	46.00	59.33	0.00	0.00	0.00
220	Laboratory Prototype Pres.	210				0.00	59.33	59.33	0.00	0.00	0.00
230	Revised Problem Statement	220	3	5	8	5.33	59.33	64.67	0.00	0.00	0.00
240	Device Test Plan Report	230	1	2	3	2.00	64.67	66.67	0.00	0.00	0.00
250	Market Review	240	7	14	22	14.33	66.67	81.00	0.00	0.00	0.00
260	Feature Report	250	3	5		2.67	81.00	83.67	0.00	0.00	0.00
270	Testing Results Report	260	14	25	29	22.67	83.67	106.33	0.00	0.00	0.00
280	Deployable Prototype Eval.	270	5	7	12	8.00	106.33	114.33	0.00	0.00	0.00
290	End of Project Report	280	4	6	8	6.00	114.33	120.33	0.00	0.00	0.00
300	Public Prototype Presentation	290				0.00	120.33	120.33	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
						0.00	0.00	0.00	0.00	0.00	0.00
1000	Finish	290				0.00	120.33	120.33	120.33	120.33	0.00



Appendix F. Resumes

Erik Coleman

Employment History

California Department of Transportation (June 2018 – August 2019)

Student Assistant

Database specialist

· Implemented several databases to record incidents and analyze data.

· Created training presentations documenting safety procedures and protocols.

· Various office tasks (Inventory, scanning, filing, etc.)

Northern California Power Agency (N.C.P.A) (August 2019 – October 16. 2020)

IT Systems Administration Intern

· Setup machine and workstation following company standards.

· Manage Active Directory and Azure Active Directory users and groups for internal and extranet permissions.

· Write PowerShell scripts to automate tasks and track machine health.

· Assist users remotely with troubleshooting network and device issues.

Skills

Problem Solving

Troubleshooting

RTL design and verification

Digital circuit analysis

Access database design

Network configuration

Docker container management

<u>Languages:</u>

C

Verilog

V.H.D.L

PowerShell

C++

Python

Assembly

Projects

· At Sacramento State, I was a part of a team responsible for designing and simulating a 5-stage pipelined processor in Verilog. We programmed it modularly and ran test benches verifying each component in simulation.

· While working at N.C.P.A, I configured a deployment server to automate Windows 10 O.S. deployment and software installation using MDT/WDS over PXE boot.

· I programmed a traffic light state machine in VHDL while at Yuba College.

· While at Yuba College, I programmed a 5-axis robot to draw on a whiteboard. The code was written in C++ and converted into G-code. It was then outputted over serial to the mechanical robot.

Waverly Hampton III, EIT

Employment History

Ambulnz Health, LLC + First Rescue Ambulance (December 2016 – October 2017)

Emergency Medical Technician

- Assessed, treated, and transported the sick and injured to required medical facilities

Private Tutor + Chaffey College (October 2017- July 2019)

Math & Physics Tutor

- Tutored grade school, high school, and college students in mathematic subjects, ranging from Algebra to Differential Equations. Included Physics lessons for certain clients, which involved building model rockets and battery-powered toy cars.

Start-up (August 2019-Present)

Chief Executive Officer

- Manage operations and execute strategies for small businesses

Skills

Office: MS Word, Powerpoint, Excel, Google Docs, Pages, Numbers, Keynote **Virtual:** Zoom, MS Teams, Google Meet, FaceTime

Design: Solidworks, Adobe Photoshop, Adobe Illustrator, Adobe Dreamweaver, Adobe XD, Adobe

Languages: Python, C++, Java, HTML5, Swift, Pascal

Shazib Naveed

Employment History

Cell Phone Shop (December 2017 – October 2019)

Repair Technician & management

- Repaired cell phones and figured out solutions to software related problems for customers.
- Managed inventory of the cell phone shop

Small business (January 2020- June 2020)

Online computer & cell phone repairs

- Maintained an online shop using various social media to help customers with phones and computers online.

Volt (August 2021-Present)
Cell Phone Repair Engineer

- Working with apple phones to fix and repair hardware or software related issues.

Skills

Office: MS Word, PowerPoint, Excel, Google Docs

Languages:

C, C++
Verilog
V.H.D.L
Python
Assembly
Java
HTML

Pho V Le

Employment History

Assistant Store Manager, O'reilly Autopart, Florin Rd, Sacramento CA
Sept 2020-Sept 2021

- Assisting the district manager in supervising and scheduling store team members.
- Responsible for understanding cost control, the store's P&L, and how to operate a profitable store
- Supervise the professional and retail operations of the store and team members involved
- Coaching new team members
- Learn to manage key components of gross profit
- Monitoring/reinforcement of safety expectations

Sales Manager, AutoZone Inc., Fruitridge Rd, Sacramento CA May 2018 – Aug 2020

- Assisting the store manager in supervising and scheduling store AutoZoners.
- Assisting customers in finding parts and products using electronic or paper catalogs.
- Operating cash registers and following established cash handling duties, including but not limited to deposits, petty cash, and lane accountability.
- Ensuring store merchandising tasks, including but not limited to stocking the store, are completed in a timely and accurate manner.
- Processing returns and managing inventory.
- Conducting and reviewing all opening and closing procedures.

Customer Services, AutoZone Inc., Fruitridge Rd, Sacramento CA Sep 2017 – May 2018

- Operated cash registers and followed established cash handling procedures
- Ensured that merchandise was restocked and placed in their respective areas.
- Helped customers to diagnose automobile problems and recommended solutions.

- Provided customers with product knowledge and current promotions through AutoZone systems.
- Communicated with managers regarding customer concerns and employee matters.

Skills

- MS Word, PowerPoint, Excel, Google Docs
- Programming language (C++, Python).
- Photoshop using Adobe Acrobat

Projects

- Building Traffic light using Microcontroller (STM32 Nucleo F303K8)
- Learning UART/USART and applying in building Project (through MobaXterm)
- Build optocoupler circuit, apply sensor in the circuit and simulation.
- Integrate system with a Heartbeat Measurement Circuit.
- Building “wheel of fortune” arcade game. An arcade with 3 lights and a button so when the light spins in a circle which every light was landing on after hitting the bottom will tell us how many tickets we will get. (Raspberry Pi, STM32 and Finite State Machine was applied)