ThoughtChair: Prototype Final Documentation

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ABSTRACT

Immobility in America has been lightly highlighted as a major problem and those who suffer from quadriplegia do not have many affordable and effective wheelchair selections. To draw attention and strive for a clear, safe, and affordable alternative solution for people suffering from immobility, we decided to develop an EEG controlled wheelchair deployable prototype as part of our two-semester senior design project which began and ended in August 2017 to May 2018. In this paper, we will be discussing the full life cycle of our project, the ThoughtChair. To successfully complete the project the team needed a clear idea of what key features our project would need to satisfy the needs of those who suffer from immobility. Those features were then developed in our design idea contract which emphasized on safety and user to machine responsiveness. Once the design was completed, the team worked on a funding proposal with the intention to receive grants and donations for the project. During this time, the team also developed project milestones, created and work breakdown structure, and analyzed the risk and mitigation within our work breakdown structure. This served as a way for the team to foresee upcoming goals and set the pace as to where the team's progress should be as well to plan effectively for possible risks. This paper also covers mid-project design overview which was done to adjust the fine details of the projects hardware, software, and mechanical aspects. The final status of the deployable prototype is discussed detailing all the features completed, and features that may have fallen short. Finally, we will discuss the effort needed to refine our ThoughtChair to achieve a marketable final product.

Keywords: **Risk Assessment, Quadriplegia, Microcontroller, Electroencephalogram, Immobility**

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EXECUTIVE SUMMARY

Immobility is a major societal problem that can vastly affect the quality of life for an individual and those around them. The team's goal was to create an EEG sensor-controlled wheelchair prototype, the ThoughtChair, to bring attention and hopefully push a solution of the issue of immobility and improve the quality of life for those who suffer from quadriplegia. Following a developed project lifecycle, we were able to successfully build an EEG sensor-controlled wheelchair prototype, the ThoughtChair, that would grant simple wheelchair mobility to those who have quadriplegia. The work done in the project lifecycle was composed of meaningful documentation, excellent team planning, budget allocation & funding, as well as hundreds of work hours.

To begin creating a prototype, the team worked on creating a design idea focusing on the features. The features that the team decided to include in the prototype features were EEG sensor-controlled wheelchair movement, hardware obstacle avoidance, battery safety and rear-view awareness.

With the feature set in mind, the team was able to come up with an affordable design well within our internal budget of $4,000. Over the course of the project, we were able to obtain outside sources which ended up saving us $3,000. Having a budget and a list of

For us to achieve a complete product, there were several milestones along the way which guided the team into completing the project. To better organize ourselves, the team created a work breakdown structure for the Fall '17 and Spring '18. The Fall semesters goal was to create a lab prototype proving the theory of our design, with the Spring semester implementing the theory of our design. The team also performed risk mitigation in efforts to find all possible risk and come up with a way to reduce possible damage. The biggest problem the team faced was not accounted for during the risk assessment as we did not suspect it as a possible issue. The problem we faced was that an electromagnetic magnetic brake issue. This problem took the team two weeks to find and was quickly resolved by removing the brakes. This occurrence served as a valuable lesson.

In the end, we were able to implement our design idea successfully. The deployable prototypes features were fully implemented. The ThoughtChair takes the user's thought patterns and turns that pattern into an ascii key which is then interpreted as a motor command moving the wheelchair to forward, left, right, and stop in less than a second once the thought is received. The deployable prototype also implemented obstacle avoidance by integrating IR sensors. The IR sensors detected possible objects and once an object was detected within 5 feet, the motors would receive a serial command to stop. The battery safety feature was completed and tested to protect the user from possible battery expansion with the user of an FSR sensors and used a temperature sensor to kill motors if temperatures over 120°F was detected. Rear view awareness was achieved by attaching mirrors strategically to provide the user 90° rear vision.

Although the final product was completed according to our design features, there can be vast improvements to the hardware and software. With a marketable product, this design can initially generate between $750,000,000 to $1,500,000,000.

Finally, what we have found while working on the ThoughtChair is that this product is not for the faint of heart. It is targeted for those who are willing to do extensive training as a form of rehab in efforts for those individuals who desire a form of mobility.

I. INTRODUCTION

For an engineering team to create a successful product, it is important to for the team to have a well-developed plan. There are many factors in producing a product such as considering the use of the product, the appeal to the targeted consumer, risk mitigation to account for potential dangers, and product design. Most importantly, it is important to secure the customers safety while still maintaining an efficient product that is still profitable. In this paper we will be going over the life cycle of our thought-controlled wheelchair prototype, the ThoughtChair which we worked on from August 2017 to May 2018.

The first step the team took to start the project was to explore and learn more about the societal issue. The main goal and purpose of our prototype was to tackle the social issue of immobility, specifically complete quadriplegia. What we were able to learn was that people with immobility suffer from many different problems than those who can move freely. Individuals with quadriplegia cannot move from one side of the room to the other without any help, and their independence is almost nonexistent. We also found that quadriplegics cannot use tradition joystick wheelchairs leaving them with few affordable and limited options [1]. We also found that there are over 300,000 people with quadriplegia and that over 15,000 people become or are born quadriplegic each year. What we found most astonishing was that we found that 52% of the people who become quadriplegic due to a spinal cord injury do not have health insurance, which means that the person who became quadriplegic would have financial trouble obtaining an affordable wheelchair that would grant them simple mobility. After analyzing these findings, the team had an enough information to come up with a design prototype.

With our main goal to give individuals with quadriplegia basic mobility, the team came up with a design features that would be implemented. The features would include EEG sensor-controlled movement, obstacle avoidance, battery safety, and rear-view awareness. The EEG sensor would be the core feature for movement, using a combination device such as an EEG Headnet, microcontrollers, motor controller and an electric wheelchair. The obstacle avoidance feature would focus detecting obstacles and controlling the wheelchair for safety reasons as it was found that 15 minutes on the floor from a fall could be highly fatal for someone who is quadriplegic. The battery and safety feature would focus on battery life, battery temperature, and battery expansion. Lastly, the review awareness feature will give at least 90 degrees worth of rear view vision. With the main four features set, EEG sensor-controlled movement, obstacle avoidance, battery safety, and rear-view awareness, the next step was to come up with a funding and budget allocation.

Funding and budget allocation would be essential to successfully create an EEG-sensor controlled wheelchair prototype. The team had agreed on allocating $4,000 for internal funding. With the $4,000 budget, the team then carefully created a list of items and devices that we would need to successfully complete the design feature set. The list of items will be items needed and used will be listed in section IV. In efforts to reduce the amount of internal money spent, the team also developed a funding proposal which successfully was able to grant the team two outside sources of funds which greatly helped the team potentially save over $3,000. With the budget allocated and the list of items needed to complete the ThoughtChair, the next step the team took was to set project milestones and create a project work breakdown structure.

The project milestones would serve as a guide for the team to see upcoming deadlines to our major events and the work breakdown structure would serve to create an organized breakdown of weekly goals that would lead to the full completion of our prototype. To better organize ourselves, the team created a work breakdown structure for the Fall '17 and Spring '18. The Fall semesters goal was to create a lab prototype proving the theory of our design, with the Spring semester implementing the theory of our design. While having a planned-out schedule of weekly goals, in engineering we know that nothing ever goes as planned. To prevent problems from occurring or even to mitigate them, the team also performed risk assessment on the work breakdown structure to foresee future problem and mitigate any damage that could potentially happen. Despite the potential risks we thought we could face, our biggest problem was one that was not accounted for. The problem we faced was that an electromagnetic magnetic brake issue. This problem took the team two weeks to find and was quickly resolved by removing the brakes. After plotting out the risk, the next item that will go over is the design overview.

In the design overview section, we detail the design philosophy of our project the ThoughtChair which is to accomplish simple mobility for those who suffer from immobility. In this section we explain how the combination of our hardware and software accomplish the feat of giving mobility to those who may have quadriplegia. We also explain how the obstacle avoidance; battery safety and rearview awareness features were completed. The next section of this document explores the ThoughtChair prototype's status.

The deployable prototype section summarizes the status of the deployable prototype at the end of the project due date which is May 2018. Here we detail the device test results and how the prototype performs. He we also detail where and to what extent the ThoughtChair prototype meets the targeted design criteria. After this, the last section, Deployable Prototype Marketability Forecast, details the effort still needed to refine the deployable prototype to achieve a marketable device. This section will discuss what changes in hardware and software would be needed to be addressed to release the prototype to manufacturing.

While our deployable prototype was able to function as we wanted to, we found that the user must undergo extensive training to perform the mobile commands. An hour of training a day, constantly, was required for Anthony to master the movement commands. This is not a perfect solution for the potential consumer. The consumer must be strong willed and minded and be willing to undergo the training as if it were a form of rehab.

II. SOCIETAL PROBLEM

The main goal of this project was to try to develop a possible and effective solution to a societal problem. After evaluating several problems in society and solutions to those problems such as backup batteries for electric cars, controlled environment for farming, and a home automated system for those who suffer from disabilities. In the end, the team decided to build a solution for those who suffer from immobility for various reasons. Once reason was due to the lack of options. We believed complete immobility was an overlooked problem in the US after researching current solutions. After researching current affordable solutions in the market, we were only able to find two current solutions. Those solutions are manual wheelchairs that are used with the assistance of a caregiver or a family member, and the sip and puff system that operates by the users input which is done by blowing into a tube. During our research, we found that these two options were not the best solutions for immobility. Manual wheelchairs require another person to help the individual suffering from quadriplegia move which does not give the individual the independents they may desire. Since the sip-and-puffs systems require a straw, they also need to be cleaned multiple times a day by the user. A common complaint is the buildup of saliva from using the straw which is undesirable from the user [2].

Another reason we chose to tackle immobility was because life has been known to become more challenging for people living with disabilities, however, for those living with quadriplegia it has been even more difficult. In Sanket Sameer Bagewadi's article, he states that "While the needs of many individuals with disabilities can be satisfied with traditional wheelchairs, a segment of the disabled community (like quadriplegics) finds it extremely difficult or impossible to use wheelchairs independently" [1]. The third reason the team decided to come up with a solution to immobility, was due to the number of people with quadriplegia and the outlook. In 2013, there was an estimated 300,000 people who suffer from complete quadriplegia [3]. As for the future, it is estimated that there are around 7,000 people who become immobile in the US due to an SPI alone [3]. We were not able to find a concrete number for the other people who are born or become quadriplegic from a medical condition, but we were able to find that on average, about 8,000 people become quadriplegic due to cerebral palsy. This equates to 15,000 individuals at the very least who become quadriplegic each year. With the problem the team wanted to solve clearly set, the team decided to develop an Electroencephalogram (EEG) controlled wheelchair as part of our senior design project. Once the project objective was established, the next step was to design the EEG controlled Wheelchair.

III. DESIGN IDEA CONTRACT

The design idea contract was formulated early in the project and its purpose for the team was to clearly lay out what we would call the project goals or project features along with the design of the solution to our societal problem. These features are the promises we made to our project advisor and ourselves, to be completed by the end of the project on May 11th. We used the features to guide the completion of the project and the process which we took to complete the project.

Our societal problem was the lack of mobility more specific would be basic movement such as those who suffer from quadriplegia. Our goal is to bring basic mobility back to those who have lost it or those who were born without it. Our design idea to accomplish this goal was to create a thought-controlled wheelchair in which the user could regain basic movement without external assistance. The design idea was broken down into four features which covered all the important aspect and functions of the wheelchair. The features for this design are as follows:

- EEG Sensor Controlled Wheelchair Movement
- Hardware obstacle avoidance
- Battery Use and Safety
- Rear view mirror for blind spot detection

Each of these features cover an important function of the wheelchair and are placed in order of importance to the project.

A. EEG SENSOR CONTROLLED WHEELCHAIR

Using an EEG (electroencephalogram) sensor in our case it was the Emotiv Epoc 14+_channel EEG Headnet the wheelchair will be able to move through one's thoughts. The Emotiv comes with two key programs, Emotiv Xavier and EmoKey, that were integrated into our design which allows the wheelchair to move by thought. The Emotive Xavier is the interface on the computer with the Headnet itself and is what takes all the readings. It has the training programs and everything one would need on taking and displaying the signals. EmoKey converts the signal into an ASCII symbol which could then be sent out onto other programs such as Arduino IDE. When working together we are able isolate a thought and convert it into a signal that can be used to make the wheelchair move. The feature is as follows:

TABLE 1
EEG FEATURE

EEG Sensor Controlled Wheelchair Movement	This feature will be completed when the user's thoughts are a moving the wheelchair forward, and are able to make the chair pivot 10 degrees slowly left and right The wheelchair must hit these specific requirements, to meet the criteria: ● Be able to respond to mental activity within 3 seconds if not moving. ● The wheelchair must be able to use changes in mental activity and convert it into electronic commands, understood by the microcontroller ● Be able to complete a minimum of 4 commands, without errors, bugs, or issues ● Complete commands with a delay less than 4 seconds (number can change according to situation)

Table 1 shows the sub features of our EEG feature [4]

FIGURE 1: Emotiv EPOC EEG 14+ Headnet [4]

B. HARDWARE OBSTACLE AVOIDANCE

Using four IR (Infrared) sensors we were able to get a basic use of obstacle avoidance. Two different IR sensors were used, the SHARP GP2Y0A710K0F which can measure a distance from 3 feet to 15 feet and the SHARP GP2Y0A02YK which can measure a distance from 20 centimeters to 5 feet. Two 15 feet IR sensors were place in the front of the wheelchair towards the edges and two 5 feet IR sensors were placed on each side of the wheelchair. All the sensors were programed on Arduino IDE onto an Arduino Mega 2560. The two front sensors when triggered at five feet will stop the wheelchair and reverse it for a second. Below 10 feet the wheelchairs speed will be slowed down so as not to hit an upcoming obstacle. The side sensors are set to stop during a turn if the user is turning onto a wall. The feature is as follows:

TABLE 2
OBSTACLE AVOIDANCE

Hardware Obstacle Avoidance	Obstacles will be able to be detected within 5 yards and the chair will have a response time of less than 1 second. The chair will then stop in less than 2 seconds once the response has been received.

Table 2 shows the sub features of our Obstacle Avoidance feature [4]

FIGURE 2: IR-Sensor Mounted on wheelchair [4]

C. BATTERY USE AND SAFETY

Using both a temperature, DS18B20 Digital Temperature Sensor, sensor and a FSR (Force Sensitive Resistor) sensor we can monitor the battery. The two things we want to check from the battery is the temperature of the battery and whether the battery is expanding. The temperature sensor is taped alongside the battery and will shut off the motors when the temperature becomes higher than 120°F. The FSR sensor has a piece of wiring taped on the front and wrapped around the battery to check if the battery is expanding. If the battery expands for more than one centimeter then the wiring will tighten up and trigger the FSR sensor; this will shut off both motors. The feature is as follows:

TABLE 3
BATTERY USE AND SAFETY FEATURE

Battery Use and Safety	The wheelchair will shut off if the temperature of the battery goes higher than 120° or if the width of the battery expands more than 1 cm.

Table 3 shows the sub features of our Battery Safety feature [4]

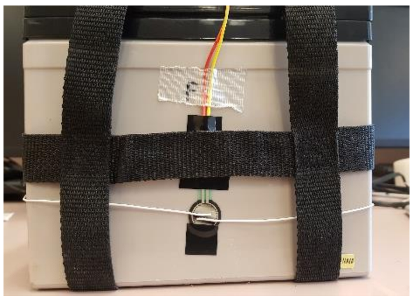

FIGURE 3: FSR Force Sensor on Battery [4]

FIGURE 4: Temperature Sensor on Battery [4]

D. REAR VIEW MIRROR FOR BLIND SPOT DETECTION

The wheelchair is equipped with two rear view mirrors to allow the user to have more awareness than what they would normally have. These mirrors run along the back of the chair and over to the user. They can be adjusted depending on the user and to any angle that the user would prefer. The feature is as follows:

TABLE 4
REAR VIEW FEATURE

“Rear view mirror”	Two Mirrors will be installed to allow 45 degrees each worth of vision. This feature will be completed when an individual in the wheelchair can view 45 degrees in blind spots when using the mirrors.

Table 4 shows sub features of our Rearview [4]

FIGURE 5: Rear View Mirrors Mounted on Wheelchair [4]

IV. FUNDING

After coming up with a design for the ThoughtChair and a detailing feature set, the next step was to generate a list of items that the team would need to complete the project. Along with identifying the items needed, the team needed to allocate the budget. The team decided to have an internal budget of $4,000, and at the same time try obtaining outside funding with the use of a project grant proposal. With the budget allocated, the items needed were then chosen. The list of items needed and used are found on the table below.

TABLE 5
PROJECT ITEMS

Item	Quantity
Jazzy Sport 1143 wheelchair	1
EMOTIV EPOC 14+-Channel EEG Headnet	1
Arduino Mega 2560 Microcontrollers	2
Sabertooth 2x60 Motor controller	1
Primary Wire, 12 AWG, 100ft Spool	3
Adafruit IR Distance Sensors	5
Plexiglass	5 square feet
12V 30A Jazzy Replacement Batteries	2
Temperature Sensors	2
FSR Sensors	2
Mirrors	2
¾ inch PVC Pipe	5 Yards

Table 5: All the items that we used for our product [4]

To obtain all these items, we created a grant proposal, so we could obtain outside funding. Fortunately, we were able to obtain an outside source of fund which covered our most expensive items. The rest of the items were purchased by internal funds the tables to the right show the items covered.

TABLE 6
EXTERNAL SOURCES

Item	Source	Price
EMOTIV EPOC 14+-Channel EEG Headnet	University Enterprise Inc.	$820.19
Jazzy Sport 1143 wheelchair	Ability Center of Sacramento	Donated

Table 6: The price of the external items in our product [4]

TABLE 7
INTERNAL SOURCES

Item	Price
Arduino Mega 2560 Microcontrollers	$80
Sabertooth 2x60 Motor controller	$190
Primary Wire, 12 AWG, 100ft Spool	$75
Adafruit IR Distance Sensors	$125
Plexiglass	$50
12V 30A Jazzy Replacement Batteries	$100
Temperature Sensors	$20
FSR Sensors	$15
Mirrors	$20
¾ inch PVC Pipe	$2
Total	**$677**

Table 7: The price of the internal items in our product [4]

To summarize the total cost of our prototype, we spent only $677 on supplies using only internal funds. Our internal budget allocation was set at $4,000. The team was able to successfully obtain outside funding and help save internal funds with our newly acquired sponsors granting us our most expensive tools.

V. PROJECT MILESTONES

Throughout the past year there were a few accomplishments that were set apart from the rest of the project because without these accomplishments the project would not be where it is today. These are major project progress events that would mark how close we would come to making this project become a reality. The project milestones are as follows from the beginning of the project to the end:

TABLE 8
PROJECT MILESTONES WITH DETAIL

Project Milestone	Description
Design Idea Review Problem Statement Revision Check/Test Equipment	The problem statement defined what issue we were attempting to fix, and the design idea is the solution that we implemented. This being the foundation that our project was built on.
Device Test Plan Feature Test	During the design process a set of features were developed to judge the completion of the project. This is the plan that we developed to be able to test when the features were completed.
Market Review Feature Test	A market review judging other products on the market vs the product that we are constructing. It also covers how much we spent on this project and compares it to the price of other products on the market.
Midterm Progress Report Team Leader Switch Feature Test	At this point the team is tasked with having 99% of the construction on the project completed. We gave a demonstration of our project up to this point and we switched team leaders.
Individual Tech Tasks Final Feature Test	Each member of the group incorporated their own parts for the project. Everyone worked on their own features and the technical aspects of these features.
Feature Presentation	Each member of the team was required to present their involvement in the group. This included all the features that they worked on and what they did exactly on the feature.
Team Leader Final Report	The fourth and last team leader is required to submit a report detailing his time as team leader. This includes any issues the team might have had and what made him an effective leader for the last part of this project.
End of Project Documentation	All the work done the past year needs to be documented and shown in the end of project documentation. This covers everything done from the beginning of the project to the end of the project.
Deployable Prototype	A deployable or fully functional prototype is required at the end of the project. This prototype will have incorporated all the features promised at the beginning and be ready for use.

Table 8: Project milestones with details [4]

VI. WORK BREAKDOWN STRUCTURE

The work breakdown structure provides a measurable metrics. Milestones defines when we need to complete our task and sub task. while the work breakdown structure defines what exactly are those task, what are their deliverables, budgets and or resources required to complete the task, who is responsible for completing the task, how long would it approximately take the team member to complete said task, and lastly how much percent wise does this contribute to the overall scope of the project.

The Design Idea contract shapes the deliverables in each subtask in the work breakdown structure. Funding shapes the budget and resource portion, because some of the tasks require funding as a resource. For example, in our first subtask in the EEG sensor control breakdown we needed approximately 1800 dollars to obtain the sensor and complete that portion of the subtask.

In the table below, we break down the work for the EEG Sensor feature set. Starting with the sub task, brain activity gathering and testing. The deliverables with in that subtask are obtaining EEG sensor, understand the software OpenBCI, find the brainwave signal that will be used to send a command, turn on an LED so it shows that this can be integrated with a microcontroller, and program the four commands. This leads to the next two subtasks, response time, implementing commands to an LCD, and integrating it to a microcontroller that will be used in the wheelchair. The feature set was completed in approximately 134 hours and contributed to 50.56 percent of the total project.

In the fall our goal was to get a command from the EEG sensor and have it output to a microcontroller. The reason being was we weren’t going to work on the chair itself until Spring semester because The EEG sensor is the focal point of the project we had to ensure that it would work and send a signal to a microcontroller and have said microcontroller send an output signal to an LCD screen. We were successful in completing this goal.

In the Spring semester the goal was to have the EEG sensor send several signals to the microcontroller to carry that signal to the motor controller and that will cause the motors to move in the 4 moves that we stated it would perform, forward, left, right, and stop.

TABLE 9
EEG SENSOR CONTROL BREAKDOWN

Subtask	Activity/deliverables	Beginning and end dates. Fall 2017 - Spring 2018	Budget/resources needed	Person/persons responsible for task. Hours needed to complete	% of the project
1.1 Brain activity gathering and testing	1.1.1 Obtain EEG sensor with cap and microcontroller along with the software needed.	10/2-10/23	We will need $900 for EEG sensor with the electrode cap. Microcontroller included in the package. ● EMOTIV Control Panel	Anthony Total hours: 3	1.13205
	1.1.2 Learn and understand brain activity with software used which is OpenBCI.	10/24-11/6	EEG sensor, Microcontroller, EEG Sensor software program	Anthony and David Total hours: 20	7.547
	1.1.3 Find brainwave signal that will be able to be used as a command efficiently	11/6-11/20	EEG sensor, Microcontroller, EMOTIV Control Panel	Anthony and David Total hours: 10	3.7735
	1.1.4 Turn on LED with brain activity	11/13-11/20	EEG sensor, Microcontroller, OpenBCI program, resistors, breadboard, LED's, Arduino IDE	Anthony and David Total hours: 3	1.13205
	1.1.5 Find Forward, backward, pivot left, pivot right command signal ranges	11/21-11/28	EEG sensor, Microcontroller, EMOTIV Control Panel	Anthony and David Total hours: 12	4.5282
	1.1.6 Find stop command signal range	11/29-12/3	EEG sensor, Microcontroller, EMOTIV Control Panel	Anthony and David Total hours: 3	1.13205
1.2 Response time	1.2.1 Be able to respond within 4	11/13-11/20	EEG sensor, Microcontroller,	Anthony and David	0.7547

implementation	seconds to brain activity and turn on LED		EMOTIV Control Panel, resistors, breadboard, LED's, stopwatch	Total hours: 2	
	1.2.2 Be able to display desired direction: forwards, back, left, right, on LCD display within 4 seconds	11/21-12/3	EEG sensor, Microcontroller, EMOTIV Control Panel, resistors, breadboard, LCD display, stopwatch	Anthony and David Total hours: 6	2.2641
	1.2.3 Make response time for forward, back, pivot, and stop under 4 seconds on the wheelchair	1/26-4/13	Electric wheelchair, 2-way switch, EEG sensor, Microcontroller, stopwatch	David Total hours: 20	7.547
1.3 Implement commands with LCD display for base testing and learning.	1.3.1 Set forward, back, pivot right, and left command through using LCD display	11/21-11/28	EEG sensor, Microcontroller, EMOTIV Control Panel, resistors, breadboard, LCD display	David Total hours: 8	3.0188
	1.3.2 Set stop command through using LCD display	11/29-12/3	EEG sensor, Microcontroller, EMOTIV Control Panel, resistors, breadboard, LCD	David and Anthony Total Hours: 2	0.7547
1.4 Microcontroller and electric wheelchair integration	1.4.1 Make the electric wheel chair go forward using the EEG sensor and microcontroller	1/26 - 2/19	Electric wheelchair: $2000 2-way Switch: $15 EEG sensor, Microcontroller, electric wheelchair, 2-way switch, wires	Jesse and Anthony Total Hours: 20	7.547
	1.4.2 Make the electric wheel chair back approximately a foot	2/12-2/26	Electric wheelchair, 2-way switch, EEG sensor, Microcontroller, electric wheelchair, 2-way switch, wires	David and Jesse Total Hours: 5	1.88675
	1.4.3 Make the electric wheelchair pivot 10 degrees left or right	2/27-3/21	Electric wheelchair, 2-way switch, EEG sensor, Microcontroller,	Anthony and Jesse Total Hours:15	5.66025

			electric wheelchair, 2-way switch, wires, tools for measuring. degrees		
	1.4.4 Make the wheelchair stop slowly on command within 3 seconds	3/23-4/8	Electric wheelchair, 2-way switch, EEG sensor, Microcontroller, electric wheelchair, 2-way switch, wires, stopwatch	David and Jesse Total Hours: 5	1.88675
				Total Hours: 134	**Total percentage of project completion:** 50.56%

Table 9: Work breakdown of EEG Sensor feature [4]

The Next Feature is the hardware obstacle avoidance. In this next table below, the feature set is broken down to the following subtask. Obstacle Detection which is to detect an object at a certain rage and stop the wheelchair if the user is within 5 feet of colliding with an object. Response time it will detect an object in less than a second and be integrated into the chair, accounting for 23.01 percent of the overall project.

For the Fall semester our goal was to find a sensor that would detect and object at 15 feet and have a quick response time. The two sensors that we compared was the IR sensor and the Ultrasonic sensor. We tested both these sensors and found that the Ultrasonic sensor has a maximum reach of 8 feet while the IR sensor has a maximum reach of 15 feet. We then had the microcontroller read the results of the IR sensor and display it on an LCD at what feet did it detect and object. This was the goal for the fall semester because we didn’t have the chair now.

During the Spring semester the goal was to have the two sensors that were mounted in the front of the wheelchair detect an object at 10 feet and cause the wheelchair to slow the speed of the wheelchair. When it detects the object at 5 feet or below it would bring the chair to a complete stop. The two mounted on the side of the chair would stop the chair if it detects an object when the wheelchair is turning.

TABLE 10
HARDWARE OBSTACLE AVOIDANCE WORK BREAKDOWN

Subtask	Activity/deliverables		Budget/resources needed	Person/persons responsible for task. Hours needed to complete	% of the project
2.1 Obstacle Detection	2.1.1 Obtain Proximity Sensors and microcontroller	10/2--10/23	Proximity sensors: $100, Microcontroller: $100	Angel and David Total Hours: 10	3.7735
	2.1.2 Be able to detect an object or obstacle within 5 yards by lighting up an LED when within range	10/24-11/4	$20 Measurement tools Proximity Sensors, Microcontroller, breadboard, resistors, LED, measurement tools. Wires, Piezo speaker	Angel Total Hours: 12	4.5282
	2.1.3 Perform a stop command by turning off LED when object detected	11/4 - 11/10	Proximity Sensors, Microcontroller, breadboard, resistors, LED	Angel and Jesse Total Hours: 4	1.5094
	2.1.4 Mount proximity sensors to wheelchair and do object detection	1/29-2/19	Proximity Sensors, electric wheelchair, microcontroller	Angel Total Hours: 7	2.64145
	2.1.5 Make chair stop when detecting within 5 yards	2/20-3/19	Proximity Sensors, electric wheelchair, microcontroller	Angel Total Hours: 4	1.5094
2.2 Response Time	2.2.1 Be able to detect an object or obstacle less than a second	10/24-11/11	Proximity Sensors, Microcontroller, breadboard, resistors, LED, stopwatch	Angel Total Hours: 4	1.5094
	2.2.2 Be able to respond to detected object or obstacle within 2 seconds interval by lighting LED	11/11-11/20	Proximity Sensors, Microcontroller, breadboard, resistors, LED, stopwatch	Angel Total Hours: 4	1.5094
	2.2.3 Make an LED fade and turn off within 2	11/11-11/17	Proximity Sensors, Microcontroller,	Angel and Jesse Total Hours: 4	1.5094

	seconds		breadboard, resistors, LED		
	2.2.4 Detect an obstacle using the sensors mounted on the wheelchair within 2 seconds.	3/19-4/2	Proximity Sensors, electric wheelchair, microcontroller, stopwatch	Angel Total Hours: 2	0.7547
	2.2.5 Stop wheelchair in 2 seconds when detecting an object within 5 yards	4/2- 4/23	Proximity Sensors, electric wheelchair, microcontroller, stopwatch, measurement tools	Angel Total Hours: 10	3.7735
				Total Hours: 61	**Total percentage of project completion:** 23.01

Table 10: Work breakdown of Obstacle Avoidance feature [4]

The Review Mirror is the next in the work breakdown structure. This accounted for 5.8675 percent of the overall scope of the project. From obtaining the mirrors, designing and building the frame to mounting and testing the mirrors.

During the fall semester nothing was done because we didn't have the wheelchair. In the spring semester we went through two designs. The first one was to have the pvc pipes mounted on the side of the arm rest, glued on using cement glue. However, it did not look professional and it was covering where the laptop stand would eventually reside. So, we cut up more pvc pipes, mounting them on the back of the wheelchair and hanging the adjustable mirrors on pvc pipes. Because our goal was to give the user some rearview awareness when they are navigating the wheelchair.

TABLE 11
REAR VIEW MIRROR WORK BREAKDOWN

Subtask	Activity/deliverables	Beginning and end dates. Fall 2017 - Spring 2018	Budget/resources needed	Person/persons responsible for task. Hours needed to complete	% of the project
3.1 Obtain Parts	3.1.1 Obtaining mirrors, metal rods and tools.	1/22-1/26	$40 for the Mirrors and metal rods. screws, power drill, welding torch, Wheelchair.	Angel Total hours 6	6%
3.2 Designing Frame	3.2.1 Design the frame where the mirrors will be mounted.	1/27- 2/2	Paper and pencil	Angel Total hours 4	4%
3.3 Building and mounting the frame and mirrors	3.3.1 Mount the Frame and mirrors on the wheelchair.	2/3 - 2/5	Mirrors, Screws, power drill, welding torch, metal rods and wheelchair.	Angel Total hours 10	10%
3.4 Testing full range of viewing using the mirrors.	3.4.1 An object such as a mannequin will be moved in increments of 15 degrees to determine full range of vision. In hopes of reaching at least 45-degree view.	2/6-2/11	Protractor, ruler, measuring tape, chalk	Angel Total hours 5	5%
				Total Hours: 25	**Total percentage of project completion:** 5.8675%

Table 11: Work breakdown of Rearview Awareness feature [4]

The last part in the work breakdown structure is the battery safety feature set. With the following subtask. Obtaining the battery and mounting the battery. This feature set would take approximately 45 hours and account for approximately 21 percent.

During the fall semester we were mostly doing research on potential wheelchair. Because as stated earlier we didn’t get the wheelchair until spring semester, 2018.

In the spring semester, the goal was to achieve battery safety. The reason for battery safety is because we are working with 24 volts that are powering two DC motors we had to take safety into consideration, we don’t want the user’s life to be in danger. To achieve this goal, we purchased a force sensor and a temperature sensor. The temperature sensor would monitor the temperature of the battery and alert the motor controller to shut down the motors when it detects that the temperature of the batter is 120 degrees Fahrenheit or above. The force sensor detects if the battery expands. We knew that those would be the best methods because we did our research on the batteries in the wheelchair, such as reading the safety datasheet.

TABLE 12
BATTERY SAFETY

Subtask	Activity/deliverables	Beginning and end dates. Fall 2017 - Spring 2018	Budget/resources needed, Risk Assessment	Person/persons responsible for task. Hours needed to complete	% of the project
4.1 Obtaining battery and testing	4.1.1 Obtain battery and sensors needed.	10/02 - 10/16	We will need $250 for batteries and sensors. A microcontroller to control sensors and relay values.	Jesse Total Hours: 3	1.6%
	4.1.2 Test battery full capacity and review specs	10/17 - 10/23	Multimeter, charger, specs sheet, lab space	Jesse and Angel Total Hours: 4	2.2%
	4.1.3 Program sensors to respond to battery	10/24 - 11/07	Microcontroller, sensors, blow dryer, Lab space	Jesse and Angel Total Hours: 10	5.6%
	4.1.4 Stop all non-basic functions if the temperature rises above 120° or if the battery expands more than 1 cm	11/08 - 11/22	Microcontroller, computer, sensors, blow dryer, lab space	Jesse and Angel Total Hours: 10	5.6%
4.2 Mount Battery	4.2.1 Construct a casing for battery	11/01 - 11/08	Drill, metal plates	Jesse and Angel Total Hours: 8	4.4%
	4.2.2 Install battery and sensors to casing	11/09 - 11/16	Drill, mounting screws	Jesse Total Hours: 5	2.8%
	4.2.3 Mount and test	01/29 - 02/05	Drill, mounting screws, blow dryer, wheelchair	Jesse and Angel Total Hours: 5	2.8%
				Total Hours: 45	**Total percentage of project completion:** 21%

Table 12: Work breakdown of Battery Safety feature [4]

In the table below, it shows the number of hours spent throughout the two semesters. The table shows how much hours everyone spent on the project throughout the two semesters. How many hours total the team met up and a grand total of hours spent on this project. Which is an addition of all team member hours and team meets up.

TABLE 13
HOURS WORKED

Total Team Meet up Hours	42
Individual total hours	
David Gomez	263
Anthony E.	263
Angel Figueroa	226
Jesse Polio	308.5
Grand total hours	1102.5

Table 13: Total Hours worked [4]

The work breakdown structure made sure when we are working on a task that we know what exactly we are doing. So, that we can achieve success in developing our deployable prototype, that address our problem statement.

VII. RISK ASSESSMENT

When in the process of decision making it is important to analyze the risk. A risk assessment is an excellent tool to use when analyzing risk.

The way we handle a subtask depends on our resources, design idea contract, and budget/resources. Risk Assessment provides an optimal decision making. Risk Assessment is a systematic process of evaluating potential risk that may be involved in the project activity or undertaking.

		Severity of Risk			
		Often	Likely	Ocassional	Unlikely
Occurrence	Extreme	Very High Risk	Very High Risk	High Risk	Medium Risk
	Critical	Very High Risk	High Risk	Medium Risk	Medium Risk
	Moderate	High Risk	Medium Risk	Medium Risk	Low Risk
	Minor	Medium Risk	Low Risk	Low Risk	Low Risk

FIGURE 6: Severity of Risk [4]

The Risk assessment process is structured by major key components. Preemptive Mitigation, oversight mitigation, and decisional Mitigation. An example of preemptive mitigation was the extensive research to make correct decision on headset. Oversight Mitigation was the document benefits and consequences of choice. Lastly, an example of Decisional Mitigation was that “quality comes at a cost” - Noriaki Kano, Tokyo University of Science.

The three main features that we needed to use Risk Assessment were the EEG sensor, Obstacle Avoidance, and Battery usage and safety.

When going about the Thought Control Feature set. We had to consider the sensor, we didn’t want to purchase the wrong sensor. Software selection, we needed a software that would work for what we need. We didn’t want the sensor to detect the wrong signal, so we had to make sure that the sensor didn’t have a lot of noise. The sensor had to also be compatible with the Microcontroller that we are going to use. Lastly, Command signals errors had to also be considered.

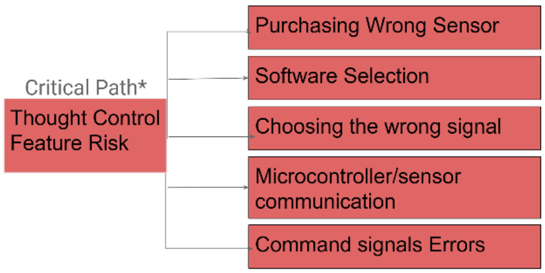

FIGURE 7: Thought-Controlled Risks [4]

The image below shows the reasoning in which why we went a sensor that was quite expensive. Inexpensive sensors tend to have too much noise, which leads to a lot of random noise that would be detected. We would then lose a substantial amount of time and would not be able to hit our metrics leading to failure. Having an inexpensive sensor would make the risk too high so it was not worth the trouble.

We could have saved money by building our own EEG sensor. However, there are lots of issues when going down that path. Safety being the biggest issues of all. A faulty EEG sensor can cause brain issues such as intense headaches. It would take too much time to build one and it would be ineffective because we would be acceptable to so many noise. The sensor that we purchased has low noise and it's been proven to be safe to use.

The biggest issue we had in working our prototype was the motors. For several long weeks we had problems with the motors and the motor controllers. When didn't want to buy a wheelchair because that would set us back $1,500 plus tax so we managed to obtain a donated wheelchair, however this did give us issues because electric wheelchair had motors that were outdated and no longer sold and had to fish around eBay to find motor brushes and a spare motor for it. We first purchased the sabertooth 2x25 motor controller. What happened was the motor controller would overheat, so we decided to purchase the 2x60 version and it was able to handle the current. We did make sure we spent more money one wires ones that were thicker, because if we had bought one that was not as thick we'd have a fire issue because the wires would not handle the amount current that is being moved. However, even with those changes we were still having an issue with our wheelchair. It wasn't until we decided to open the motors and see if there was anything wrong with the two motors. As it turned out there was magnetic brakes that were causing the motors to draw a lot of currents causing the motors to not work properly and heat up at times. So, once we removed the magnetic breaks it finally worked properly.

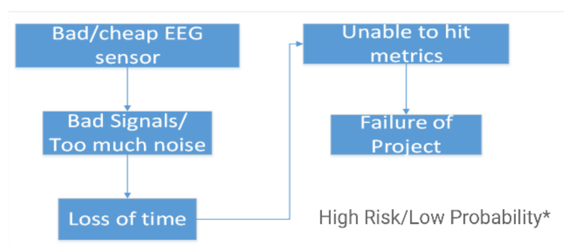

FIGURE 8: EEG Choice Risks [4]

FIGURE 9: Emotiv EPOC 14+ Headnet [4]

When it came to the motors we ran into the biggest issues that halted our progress for a few weeks. We went through a list of possible solutions. After a few weeks we found that the mag

The next item in the Risk Assessment was the Hardware obstacle avoidance. In the image below is the critical section part of the hardware obstacle avoidance. The sensitivity of the signal, Signal Delay, Incorrect mounting, and integration with the microcontroller and EEG sensor all had to be taken in consideration in the Risk assessment when deciding.

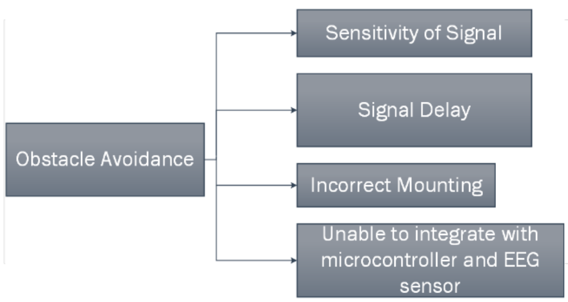

FIGURE 10: Obstacle Avoidance Risk [4]

We went with an IR sensor because it had a good response time, less noise, easily mountable, and was easy to integrate in the project itself

Originally we had placed 5 IR sensors rather than 4, with the 5th sensor being placed in the front center, but this was an issue because the user's legs would trigger it constantly and this was an issue for us, so we tested out taking it out and it worked better just the way we wanted.

Battery usage and safety was the third item on our Risk Assessment. When choosing a battery, we didn't want it to malfunction. The sensors may be obsolete and if mounted improperly it could cause issues, such as the motors that are moving the chair not spinning.

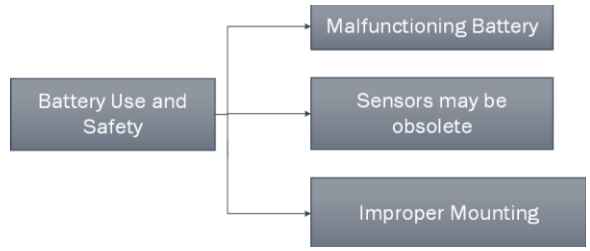

FIGURE 11: Battery Risks [4]

Purchasing the right materials was a critical section in this project, we made sure we did our research on what we would purchase so that we know that it was most optimal choice.

VIII. DESIGN DOCUMENTATION

The goal of this project is give an alternative option of movement to individuals who suffer from quadriplegia. By developing a wheelchair that is guided by the user's thought patterns.

The ThoughtChair takes the user's thought patterns and turns that pattern into an ascii key. That key is a signal that is sent into the master microcontroller. The master then relays a signal to the slave microcontroller. The slave relays a signal to the Sabertooth motor controller. The motor controller is responsible for controlling the motors causing the chair to move forward, left, right, stop, and reverse.

A. EEG SENSOR MOVEMENT

The EEG sensor that was used was from Emotiv. The sensor came in a form of a head net. The head net has nodes that were placed on the user's head and positioned at a certain position. The nodes allow the sensor to see the patterns of the user's thoughts. Through the software Emotive Xavier, the user can know how to position the Headnet. The user spends time training with the head net though the software in forms of brain exercises, so the system can learn the user's thought patterns. Two months' worth of training had to be done so that the sensor understood the user's thought patterns.

Through the software called Emotiv Xavier the thought patterns are then turn into an ascii key, which is a keyboard key. From there we have our input signal that will go into the master Arduino mega 2560. Through the training we have made out inputs. The "F" key was for our forward input. "S" key was for stop. "L" key was for left. "R" was for right. All these inputs would inform the Arduino which case to implement from the switch case statement. That signal is sent to the slave Arduino mega 2560, whose purpose is to send signal directly to the Sabertooth 2x60 Motor controller. The Sabertooth 2x60 motor controller sends a signal to the two DC motors that move the wheelchair.

When the signal "F" is sent the motors begin to spin clockwise causing the two wheels move forward. The signal "L" causes the right motor to be stationary while the other one spins so, that the wheelchair would pivot clockwise, "R" does a similar thing only the left motor is stationary so the wheelchair pivots counter clockwise. "S" signal cause the two motors to stop spinning causing the wheelchair to stop moving.

The risk assessment was the tool we used to ensure that when we were handling a task choose the right solution or way to address it, so that we may be succeed in building a deployable prototype that offers an alternative way of mobility to individuals who suffer from quadriplegia.

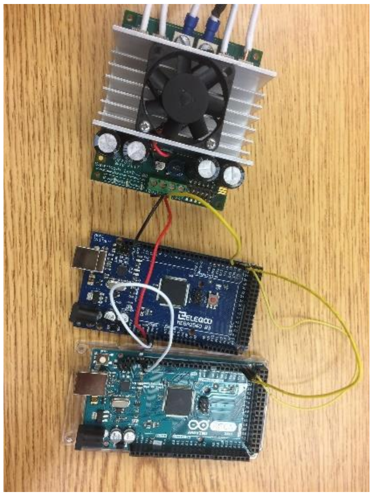

FIGURE 12: Hardware Connection [4]

B. HARDWARE OBSTACLE AVOIDANCE

The user may have the ability to move the chair only using his or her thoughts, but we took it further by implementing a hardware obstacle avoidance, so that the chair can avoid an object or obstacle to reduce the risk of collision. If a quadriplegic falls off the chair they won't survive very long, so that's where developed the idea to implement the hardware obstacle avoidance.

The materials that were used were 4 IR sensors positioned at strategic areas in the wheelchair. One at the left, one on the right side, one at the front left and one at the front right.

FIGURE 13: IR Sensor mounted on wheelchair [4]

The sensors mounted in the front of the wheelchair detect an object a range of ten feet causing the motors spin slower so that the wheelchair goes forward slowly. When the sensors detect an object at 5 feet or below the motors will stop spinning and begin the spinning counter clockwise causing the chair to go in reverse briefly, so the user can turn away.

The sensors mounted on the right side would trigger if it detects and object such as a way under one feet and it is turning. The same goes for the sensor mounted on the left side.

The IR sensor sends a beam of infrared light when it makes contacts with an object such as a wall it reflects sending. Intensity is the key when understanding how the IR sensor works. The higher the intensity the closer an object is position. Intensity depends on the number of photons that were reflected. If the sensors in the front detect an object at 5 feet or below the intensity is at 525 meaning it is picking up that many photos that were reflected. If they detect an object at ten feet the number lowers to 325, which means there are less photons that are being detected. The sensors do have a cutoff point below three feet it's not detecting anything. The reason being there is what's called noise.

C. *REAR VIEW AWARENESS*

With the IR sensors we addressed the issues of collision, but we took it further. When the user is navigating the chair, we wanted him to have some awareness and see if someone or something is behind him. This led to our Rear-View awareness design. Mounting mirrors on the wheelchair giving the user a 45-degree range of vision of rear view awareness. The mirror stands are mounted at a fixed position that is drilled onto the chair and glued together. The mirrors are adjustable, so they can me adjusted to the user's liking allowing for optimal rear-view awareness. The idea behind this design was to mimic that of a car's side mirrors. Side mirrors gives the driver some awareness, but it does reduce the user's blind spot.

D. *BATTERY SAFETY*

So far, we have covered the navigation using the EEG sensor. Obstacle avoidance to reduce the risk of collisions. Rear view awareness to give the user. The last part of the design ties in with the battery. Since we are working with two 12-volt battery we need to take safety into account.

When a battery expands its never a good sign. When a lithium battery expands it means it can be fatal. To address this issue and ensure the safety of the user we used a force sensor. This sensitive sensor is tied to the batteries. When the battery expands it will trigger it. That signal will send to the microcontrollers informing it to shut off immediately.

FIGURE 14: FSR force sensor on battery [4]

Heat of a battery is another issue that was addressed in the design on this prototype. When the battery hits to 120 degrees Fahrenheit or above the battery becomes fatal. A temperature sensor is tied to the battery as well so that it can detect the heat. When the temperature hits it will send a signal to the microcontroller, signaling it to shut off the motor.

FIGURE 15: Temperature Sensor on Battery [4]

Our design reflects our solution to the societal problem that we are addressing. From the EEG sensor that is the source of the user navigation and steering, Hardware obstacle avoidance to reduce the risk collision, rear view awareness to help the user make decisions when navigating, and battery safety to reduce the risk of harm to the user.

IX. DEPLOYABLE PROTOTYPE STATUS

Our deployable prototype has managed to become fully operational based on all the feature sets that were. The wheelchair can perform four movements through the implementation of an EEG sensor, Emotiv Epoc 14+_channel EEG Headnet, with collaboration of the software, Emotiv Xavier and EmoKey. These four movements are forward, left, right, and stop with reverse being implemented through obstacle avoidance. The wheelchair can respond to the signal and move in less than 3 seconds and complete its action in less than 4 seconds.

The wheelchair is equipped with four IR sensors, two SHARP GP2Y0A710K0F and two SHARP GP2Y0A02Y, to be used for obstacle avoidance while the wheelchair is moving. Using the two sensors in the front the chair can detect an obstacle that is 5 yards or 15 feet away from the chair. At 10 feet the chair will slow down is speed and at 5 feet the chair will stop and reverse for approximately one second. The response time of this action is one second to respond and stop within 2 seconds. The IR sensors on each side have a range of 5 feet and will stop the wheelchair during a turn if the chair gets too close to an obstacle.

The deployable prototype is also able to detect if the battery is faulty using a temperature sensor, DS18B20 Digital Temperature Sensor, and a FSR sensor. The temperature sensor is tapped along the side of the battery and is constantly measuring the temperature of the battery. If the temperature of the battery raises above 120°F, then the motors will be shut off. The FSR sensor has a wire glued to the front of the sensors and this wire is wrapped around the battery with only 1 centimeter of slack. If the battery expands for more than 1 centimeter then the motors will shut off. Since the wheelchair has two batteries in separate locations, there are two sets of each sensors to be able to cover both batteries.

The wheelchair is also equipped with two rear view mirrors for rear view awareness. These mirrors run along the back of the wheelchair and over the front to allow the user 45° of blind spot awareness on both sides. These mirrors are adjustable according to the user and do not obstruct and other vision that the user might need.

Aside from each of the promised features the deployable prototype is equipped with a table that swings up so that the user may have their laptop on the wheelchair. The deployable prototype is fully functional and able to allow the user to regain their basic movements without any external assistance.

FIGURE 16: Deployable Prototype [4]

X. DEPLOYABLE PROTOTYPE MARKETABILITY FORECAST

Even though the status of our ThoughtChair is complete due to our achieved feature set, our prototype still needs more refined work on order to perfect it for user comfortability and safety based on our user research. There are several issues that our prototype has that must be resolved. Those issues can be resolved by making changes regarding hardware and software and using different material for the physical aspects of the wheelchair such as the desk and hardware case.

Our prototype can be improved before hitting the market by making hardware changes. Currently the prototype is made up of two Arduino Mega, which are handling all the sensors. To reduce the amount of space and possibly increase efficiency, the use of an integrated circuit would be having the potential to further better our product and potentially lower the price of the final product. Another hardware changes we would make would be to add encoders. The encoders would be used to evenly distribute voltage to both motors while the voltage of the batteries drop. Currently, the ThoughtChair prototype drives slightly to more to the right when moving forward, but with encoders, this problem would be easily resolved.

Before releasing the ThoughtChair to manufacturing, we would also make software modifications. The modifications we would make would be to include an indoor and outdoor operation option. To achieve this, we would have to have two sets of code which would run depending on the option selected. The indoor option would limit the speed of the wheelchair to avoid possible collisions as well as decreased distance of obstacle detection given. The outdoor option would give the wheelchair and the user the option to have an increased speed. The obstacle avoidance feature would also change for the user to operate the wheelchair within a crowd. With these changes, the wheelchair would be ready for manufacturing.

With the final product ready to be manufactured, it is estimated that the potential market can initially generate between $750,000,000 to $1,500,000,000. These numbers are generated through multiplying the number of individuals with complete quadriplegia in the US, 300,000 times the cost of our product which would be $5,000. With at least 15,000 people becoming quadriplegic each year, $37,500,000 can be generated yearly [1].

XI. CONCLUSION

Over the course of nine months, August 2017 to May 2018, we successfully developed an EEG sensor-controlled wheelchair prototype to bring attention, help solve the issue of immobility, and improve the quality of life for those who suffer from quadriplegia. Many factors went into producing the ThoughtChair. The team followed the life cycle detailed by our senior design class. In this paper we discussed the work we did over the course of our two-semester senior design to complete the ThoughtChair. In this paper we detailed the societal problem we wanted to tackle, the design idea contract that would help solve the societal problem, the funding, the project milestones, the project work breakdown structure along with the risk assessment, the design overview, the final status of the deployable prototype, and the prototype marketability.

To better understand the problem of immobility, we conducted research to learn more about the problem and those affected. We found that those who are immobile suffer both physically and mentally. They are unable to move independently, and some individuals suffer from depression. We found those who suffer the most are those who became quadriplegic through a spinal cord injury because of the drastic change in their life. The next step was to research how many people suffer from quadriplegia. In 2013, there was an estimated 300,000 people who suffer from complete quadriplegia [3]. With the understanding of who and how many people are affected by immobility, we explored the current affordable solutions as our goal was to have an affordable solution. The wheelchairs in this market are made up of standard wheelchairs with body support that are manually driven by a caregiver or a family member, sip-and-puff chairs. The manual chairs offer not type of independence to the user while the sip-and-puff chairs offer basic movement through blowing into a tube. The sip-and-puff was found to have undesirable problems such as sanitation problems and self-conscious feelings while using the system out in public. With the problem and consumer clearly identified, the team then was ready to begin designing a solution.

In the Design Idea Contract section, we discussed what features would be included in the prototype to help provide a solution to the problem of immobility. The features were EEG sensor-controlled movement, obstacle avoidance, battery safety, and rear-view awareness. The EEG sensor would be the core feature for movement, using a combination device such as an EEG Headnet, microcontrollers, motor controller and an electric wheelchair. The obstacle avoidance feature would focus detecting obstacles and controlling the wheelchair for safety reasons as it was found that 15 minutes on the floor from a fall could be highly fatal for someone who is quadriplegic. The battery and safety feature would focus on battery life, battery temperature, and battery expansion. Lastly, the review awareness feature will give at least 90 degrees worth of rear view vision. With the main four features set, EEG sensor-controlled movement, obstacle avoidance, battery safety, and rear-view awareness, the item we discussed was the funding and budget allocation.

Funding and budget allocation was an important to the development of the project. The team being made up of college students, only have $4,000 of internal budget allocation. The items needed and mentioned in section IV totaled a cost of roughly $3,700. In efforts to reduce the amount of internal money spent, the team also developed a funding proposal which successfully was able to grant the team two outside sources of funds which greatly helped the team potentially save over $3,000. Our outside sources were UEI who donated $2,000 to cover the cost of our EEG Headnet, and our other sponsor the Ability Center of Sacramento was generous enough to offer us the Jazzy Sport 1143 electric wheelchair. With the most expensive items covered by our sponsors, the team only spent $667.

The next topics we covered was the project milestones and work breakdown structure. The project milestones served as a guide for the team to see upcoming deadlines to our major events and the work breakdown structure would serve to create an organized breakdown of weekly goals that would lead to the full completion of our prototype. The WBS was broken down by feature and sub feature. To prevent problems from occurring or even mitigating them, the team also performed risk assessment on the work breakdown structure to foresee future problem and mitigate any damage that could potentially happen. In total, we found that the total amount of hours worked as a team was 1102. David and Anthony both worked 263 hours, Angel worked 226 hours, and Jesse worked 308 hours between the start and end of the project.

In the following sections, design overview, creation laboratory prototype, and creation of deployable prototype, we discussed the design overview and went further into detail of what was done in the Fall of 2017 and the Spring of 2018. We detailed how the prototype would function and help the user gain mobility and improve quality of life. we explain how the combination of our hardware and software accomplish the feat of giving mobility to those who may have quadriplegia. We explained how the obstacle avoidance, battery safety and rearview awareness features were completed. Further detail will be provided in appendix B and C regarding the hardware and software. Following these sections, we discussed the status of our prototype.

The status of the prototype was considered complete. With these features completed, our deployable prototype has managed to become fully operational based on all the feature sets that were. The wheelchair can perform four movements in under 1 second after the command has been sent. These four movements are forward, left, right, and stop with reverse being implemented through obstacle avoidance. Using the two sensors in the front the chair can detect an obstacle that is 5 yards or 15 feet away from the chair. At 10 feet the chair will slow down is speed and at 5 feet the chair will stop and reverse for approximately one second. The response time of this action is one second to respond and stop within 2 seconds. The IR sensors on each side have a range of 5 feet and will stop the wheelchair during a turn if the chair gets too close to an obstacle. The deployable prototype is also able to detect if the battery is faulty using a temperature sensor and a FSR sensor. With these features complete, we had a product that was safe and effective enough to be used and help prove this solution can be used to solve immobility. Although we had finished our prototype according to our feature set, we knew we could have major improvements.

In XII, we discussed the improvements that could be done to our prototype for it to be marketable. There are several issues that our prototype has that must be resolved. Those issues can be resolved by making changes regarding hardware and software. Currently the prototype is made up of two Arduino Mega', which are handling all the sensors. To reduce the amount of space and possibly increase efficiency, the use of an integrated circuit would be having the potential to further better our product and potentially lower the price of the final product. Another hardware changes we would make would be to add encoders to evenly distribute voltage to both motors while the voltage of the batteries drop. The software modifications we would make would be to include an indoor and outdoor operation option. To achieve this, we would have to have two sets of code which would run depending on the option selected. The indoor option would limit the speed of the wheelchair to avoid possible collisions as well as decreased distance of obstacle detection given. The outdoor option would give the wheelchair and the user the option to have an increased speed. The obstacle avoidance feature would also change for the user to operate the wheelchair within a crowd. With these changes, the wheelchair would be ready for manufacturing.

With the final product ready to be manufactured, we estimated that the potential market can initially generate between $750,000,000 to $1,500,000,000. These numbers are generated through multiplying the number of individuals with complete quadriplegia in the US, 300,000 times the cost of our product which would be $5,000. With at least 15,000 people becoming quadriplegic each year, $37,500,000 can be generated yearly [1].

Most importantly, what we have found while working on the Thougchair is that this product is not for the faint of heart. It is targeted for those who are willing to do extensive training as a form of rehabilitation in efforts for those individuals who desire a form of mobility. Constant training is required by the user which may be difficult for small children and the elderly.

Overall, we believe we were successful due the lifecycle we followed. We put in effort in choosing the correct project that had meaning along with a plan to help solve the societal issue. We designed the project well by choosing the right tools given the amount of time we had to work. The team worked extra hard on creating a funding proposal which ended up saving the team thousands of dollars. Another part of the life cycle that helped the team be successful was the laboratory prototype which helped the team prove it was possible to complete the project on time. The testing period we had was used effectively to tune and better the project. The market reviews we conducted opened our eyes as to how much money this product can provide and how low of a price it would cost for a person with immobility to be able to purchase this product compared to the alternative options in the market. Finally, what we were able to take away from this project was that smart thinking, hard work, good guidance, time, and effectively using our resources and creating opportunities for ourselves was needed to complete the ThoughtChair prototype. With the work and research done, we hope this project ultimately can help those suffering from immobility in any way, shape, or form.

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GLOSSARY

Electroencephalogram - a test or record of brain activity produced by electroencephalography

Feature - a distinctive attribute or aspect of something

Immobility - the state of not moving, motionless

Metrics - the use or study of poetic meters, prosody

Microcontroller - is a computer present in a single integrated circuit which is dedicated to performing one task and execute one specific application. It contains memory, programmable input/output peripherals as well a processor.

Quadriplegia - paralysis of all four limbs

Risk assessment - a systematic process of evaluating the potential risk that may be involved in a projected activity or undertaking

Sensor - a device that detects or measures a physical property and records, indicates, or otherwise responds to it.

APPENDIX A - USER MANUAL

Background

Immobility is a major societal problem that can vastly affect the quality of life for an individual and those around them. Immobility is when someone is unable to move. Immobility is an issue that affects many disabled people with different types of disabilities and Diseases. Due to the limited options and lack of independence, quadriplegics must rely on family, friends, or whomever is in charge to take them places. Our solution to the problem is a thought-controlled wheelchair, ThoughtChair, which would allow physically impaired individuals to move and allow them to roam freely. In this User Manual, we will be going over what ThoughtChair is and how to use it.

A. General Information

A Thought-controlled movement assisted wheelchair for movement impaired individuals.

1. System Overview

a. OS System: Windows 7+, MACOS
b. Software: Emotiv Xavier Control Panel, Emotiv EmoKey, Arduino
c. Hardware: Mini Jazzy Sport 2

2. Authorized Use

CSUS provides you with access to a variety of resources, including documentation and other product information (collectively the "Documentation"), download areas, communication forums, and other services (collectively "Services"), software, including developer tools and sample code (collectively "Software"), and Application Program Interface information ("APIs"). The Documentation, Services, Software, and APIs (including any updates, enhancements, new features, and/or the addition of any new Web properties to the Web Site), are subject to the following Terms of Use ("TOU"), unless we have provided those items to you under more specific terms, in which case, those more specific terms will apply to the relevant item.

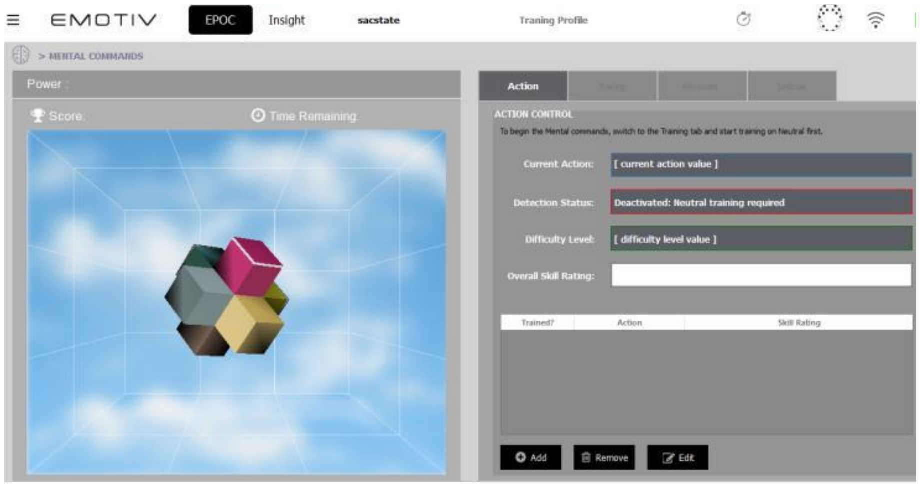
B. Getting Started

To start, make sure that you have all the software downloaded. The controllers will come preprogrammed, so they will not need any uploads. Make sure to read the Emotiv Xavier User Manual, Here [6], before you start. As well, use the user manual to learn how to set up, use and maintain the Headnet. This User manual will also teach you how to train the Headnet to perform any number of commands.

C. Start Up Emotiv Xavier Control Panel and EmoKey

The Emotiv Control Panel is the main program that the head net will use to convert signals into electrical commands. To review how to train commands, please go to the Emotiv User Manual Here [6].

1. Start up the Xavier Control Panel. Make sure that the Headnet is on and connected via Bluetooth receiver.

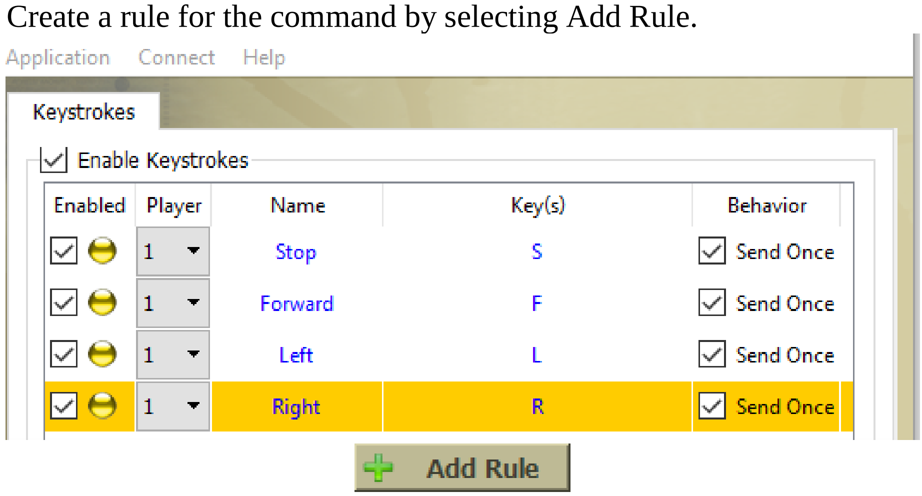


Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

2. Make sure the correct profile is set and the commands are as trained as you want. It does not matter what commands are trained, so long as you train at least 4 commands and can recognize them and isolate them as different directional commands.

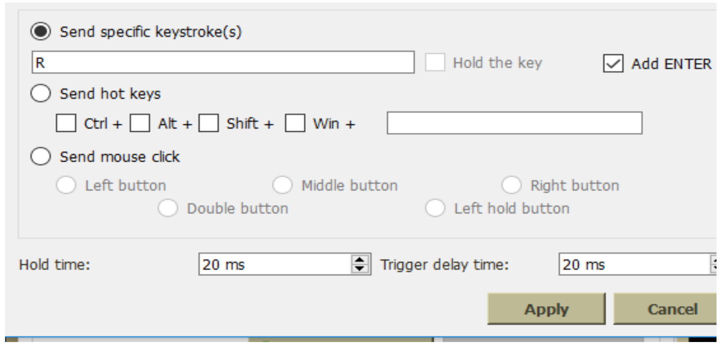
3. Start up the Emotiv EmoKey.

4. Create a rule for the command by selecting Add Rule.



Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

5. Set the direction using **ONLY** the first letter in capital. Make sure to add Enter before hitting Apply.

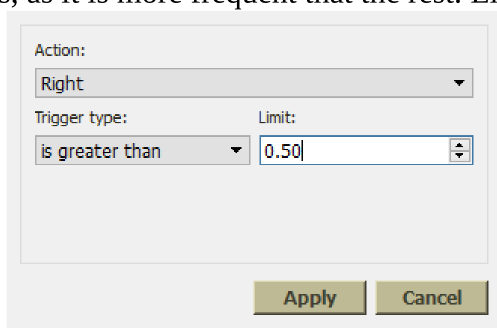


Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

6. Set the condition for the Rule by selecting the rule and selecting Add Condition.

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

7. Set the condition as one of the commands you trained. Though it varies and is completely up to the user, we recommend that Forward should use a higher limit than the other commands, as it is more frequent that the rest. Lick Apply when finished.

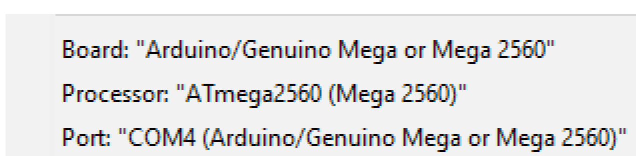


Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

8. Make sure that the Behavior is Set to only Send Once and the Target Application is the application in focus. When finished, you can disable keystrokes until you are ready to go.

D. Start Up Arduino

1. Startup Arduino.
2. The codes are preloaded into the controllers provided. So, plug the sub cable into the computer.
3. Make sure that the Board is set to Arduino Mega, the Processor is set to ATmega2560, and the Port is reading an Arduino Mega.

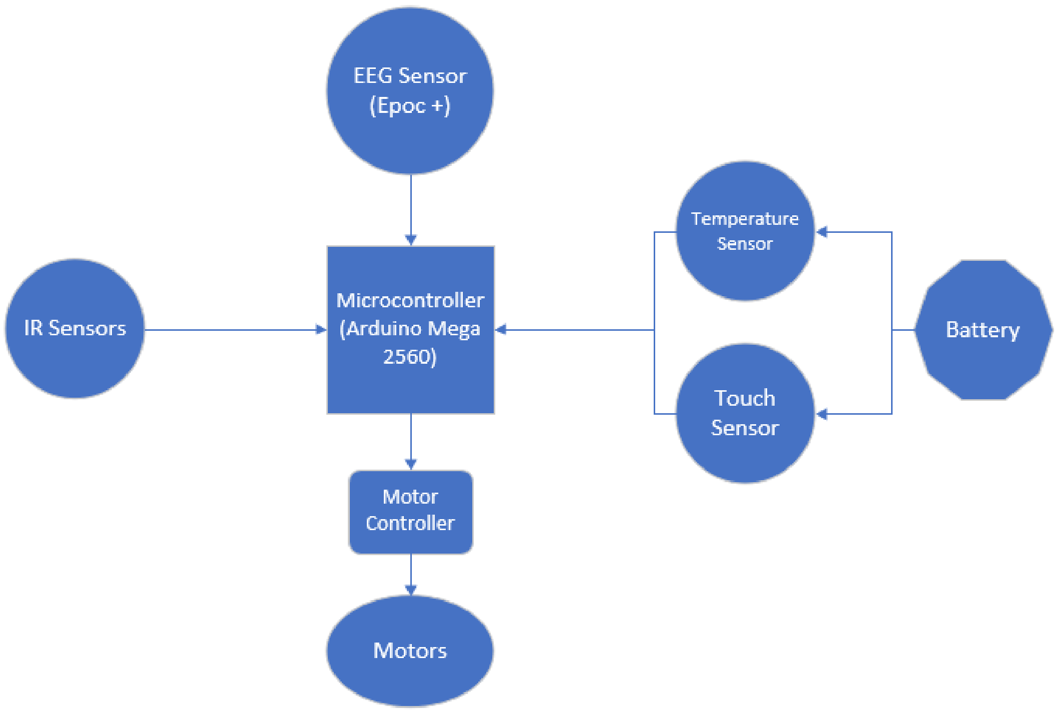


Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

4. Open the Serial Monitor.
5. When ready, enable keystrokes on Emotiv EmoKey.

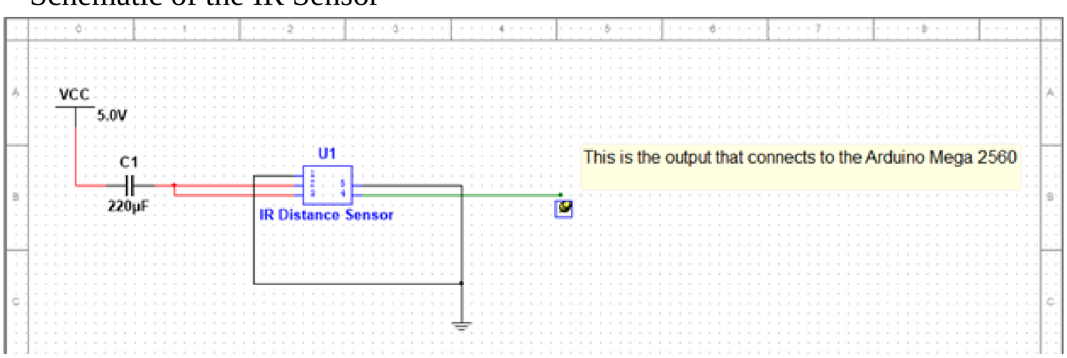
APPENDIX B – HARDWARE

Full Hardware Block Diagram



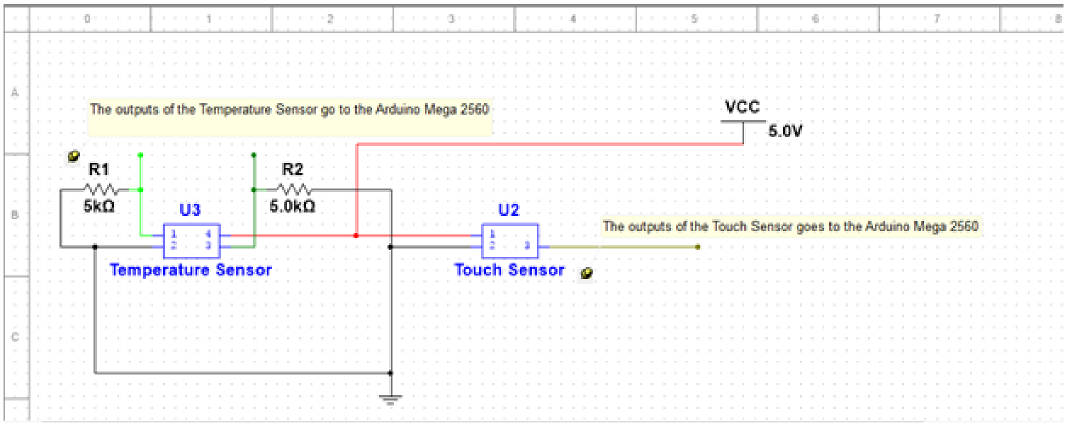
Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Schematic of the IR Sensor



Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Schematic of the Temperature and Touch Sensor



Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Features
EEG Response Time
Battery Temperature Test
Battery Pressure Test
EEG Distance Test

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

EEG Distance Test

Trial # 1	Distance	Command Received? Y or N
	0 ft	Y
	5 ft	Y
	10 ft	Y
	12ft	Y
	14ft	Y
	16ft	N
	18ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 2	Distance	Command Received? Y or N
	0 ft	Y
	5 ft	Y
	10 ft	Y
	12ft	Y
	14ft	Y
	16ft	N
	18ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 3	Distance	Command Received? Y or N
	0 ft	Y
	5 ft	Y
	10 ft	Y
	12ft	Y
	14ft	Y
	16ft	N
	18ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 4	Distance	Command Received? Y or N
	0 ft	Y
	5 ft	Y
	10 ft	Y
	12ft	Y
	14ft	Y
	16ft	N
	18ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 5	Distance	Command Received? Y or N
	0 ft	Y
	5 ft	Y
	10 ft	Y
	12ft	Y
	14ft	Y
	16ft	N
	18ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 6	Distance	Command Received? Y or N
	12 ft	Y
	13 ft	Y
	14 ft	Y
	14.5 ft	Y
	14.75 ft	Y
	15 ft	Y
	15.25 ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 7	Distance	Command Received? Y or N
	12 ft	Y
	13 ft	Y
	14 ft	Y
	14.5 ft	Y
	14.75 ft	Y
	15 ft	Y
	15.25 ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 8	Distance	Command Received? Y or N
	12 ft	Y
	13 ft	Y
	14 ft	Y
	14.5 ft	Y
	14.75 ft	Y
	15 ft	Y
	15.25 ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 9	Distance	Command Received? Y or N
	12 ft	Y
	13 ft	Y
	14 ft	Y
	14.5 ft	Y
	14.75 ft	Y
	15 ft	Y
	15.25 ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial # 10	Distance	Command Received? Y or N
	12 ft	Y
	13 ft	Y
	14 ft	Y
	14.5 ft	Y
	14.75 ft	Y
	15 ft	Y
	15.25 ft	N

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

EEG Response Time Test

Trial 1		
	Anthony to Laptop (s)	Laptop to Chair
1	4.577	.4s
2	3.2	.48s
3	13.793	.13s
4	3.234	.12s
5	5.536	.15s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 2		
	Anthony to Laptop (s)	Laptop to Chair
1	3.744	0.4s
2	3.234	.15s
3	3.458	.22s
4	3.423	.18s
5	2.593	.29s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 3		
	Anthony to Laptop (s)	Laptop to Chair
1	3.039	.36s
2	3.937	0.22s
3	5.088	0.18s
4	3.201	.13s
5	5.569	.17s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 4		
	Anthony to Laptop (s)	Laptop to Chair
1	3.104	.33s
2	5.344	0.15s
3	2.432	.26s
4	5.921	.21s
5	4.608	.19s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 5		
	Anthony to Laptop (s)	Laptop to Chair
1	4.9	.26s
2	13.825	.12s
3	3.232	.14s
4	2.722	.19s
5	2.668	.21s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 6		
	Anthony to Laptop (s)	Laptop to Chair
1	3.248	.35s
2	4.367	.26s
3	2.101	.18s
4	2.750	.15s
5	4.993	.31s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 7		
	Anthony to Laptop (s)	Laptop to Chair
1	5.372	.25s
2	5.093	.21s
3	6.913	.16s
4	4.492	.30s
5	6.485	.28s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Trial 8		
	Anthony to Laptop (s)	Laptop to Chair
1	5.306	.13s
2	2.349	.14s
3	5.058	.19s
4	2.701	.24s
5	2.722	.20s

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Battery Temperature Test Results

Trial #1		
Temperature	Object	Command Received? Y or N
97 degrees F	Heat Gun	Y
100 degrees F	Heat Gun	Y
120 degrees F	Heat Gun	Y
140 degrees F	Heat Gun	Y
160 degrees F	Heat Gun	Y
180 degrees F	Heat Gun	Y
200 degrees F	Heat Gun	Y
220 degrees F	Heat Gun	Y
240 degrees F	Heat Gun	N
250 degrees F	Heat Gun	N

Trial #2		
Temperature	Object	Command Received? Y or N
97 degrees F	Heat Gun	Y
100 degrees F	Heat Gun	Y
120 degrees F	Heat Gun	Y
140 degrees F	Heat Gun	Y
160 degrees F	Heat Gun	Y
180 degrees F	Heat Gun	Y
200 degrees F	Heat Gun	Y
220 degrees F	Heat Gun	Y
240 degrees F	Heat Gun	N
250 degrees F	Heat Gun	N

Battery Pressure Test Results

Trial #1	**1 Fl oz = 29.5 g**	**1 lb. = 453.5 g**
Weight	**Object**	**Command Received? Y or N**
0.28 lb.	33.8 Fl oz bottle	Y
0.55 lb.	33.8 Fl oz bottle	Y
0.83 lb.	33.8 Fl oz bottle	Y
1.10 lb.	33.8 Fl oz bottle	Y
1.38 lb.	33.8 Fl oz bottle	Y
1.65 lb.	33.8 Fl oz bottle	Y
1.93 lb.	33.8 Fl oz bottle	N
2.20 lb.	33.8 Fl oz bottle	N

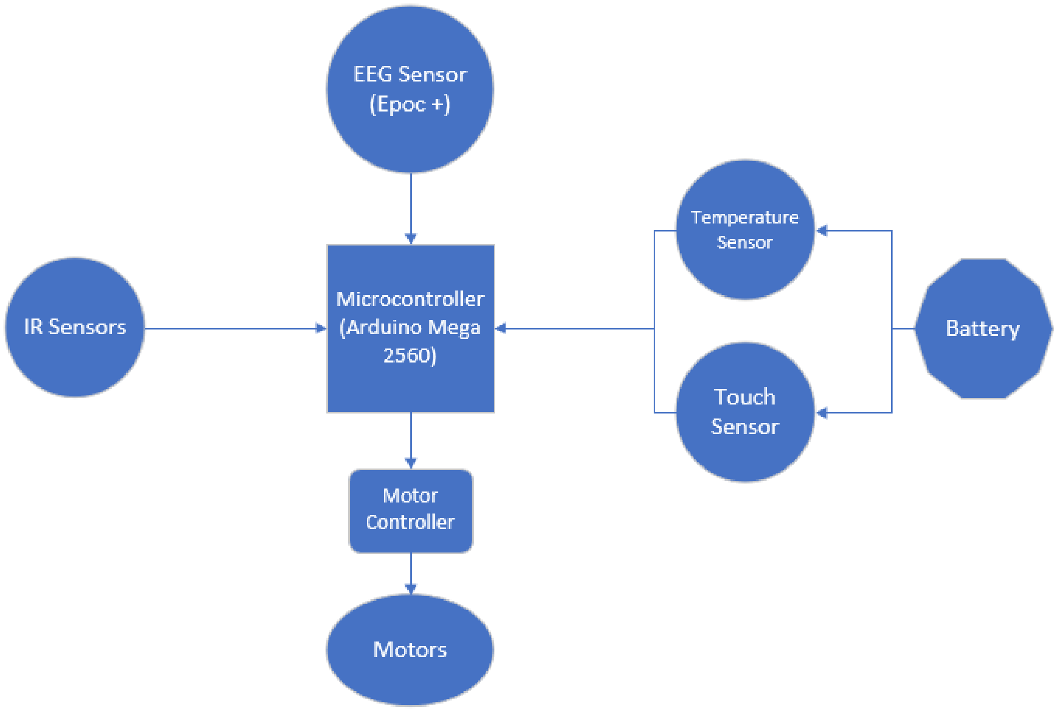
Trial #2	1 Fl oz = 29.5 g	1 lb. = 453.5 g
Weight	**Object**	**Command Received? Y or N**
0.28 lb.	33.8 Fl oz bottle	Y
0.55 lb.	33.8 Fl oz bottle	Y
0.83 lb.	33.8 Fl oz bottle	Y
1.10 lb.	33.8 Fl oz bottle	Y
1.38 lb.	33.8 Fl oz bottle	Y
1.65 lb.	33.8 Fl oz bottle	Y
1.93 lb.	33.8 Fl oz bottle	N

Trial #3	1 Fl oz = 29.5 g	1 lb. = 453.5 g
Weight	**Object**	**Command Received? Y or N**
0.28 lb.	33.8 Fl oz bottle	Y
0.55 lb.	33.8 Fl oz bottle	Y
0.83 lb.	33.8 Fl oz bottle	Y
1.10 lb.	33.8 Fl oz bottle	Y
1.38 lb.	33.8 Fl oz bottle	Y
1.65 lb.	33.8 Fl oz bottle	Y
1.93 lb.	33.8 Fl oz bottle	N
2.20 lb.	33.8 Fl oz bottle	N

Trial #4	**1 Fl oz = 29.5 g**	**1 lb. = 453.5 g**
Weight	**Object**	**Command Received? Y or N**
0.28 lb.	33.8 Fl oz bottle	Y
0.55 lb.	33.8 Fl oz bottle	Y
0.83 lb.	33.8 Fl oz bottle	Y
1.10 lb.	33.8 Fl oz bottle	Y
1.38 lb.	33.8 Fl oz bottle	Y
1.65 lb.	33.8 Fl oz bottle	Y
1.93 lb.	33.8 Fl oz bottle	Y
2.20 lb.	33.8 Fl oz bottle	N

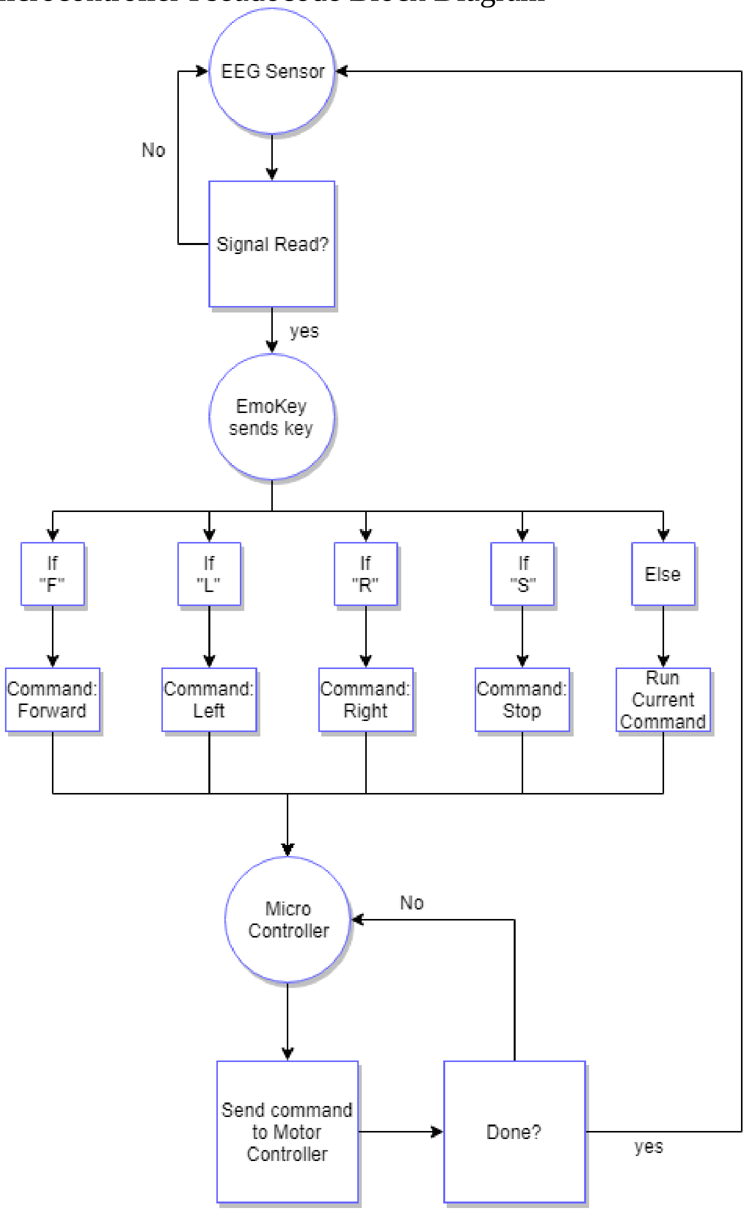
APPENDIX C - SOFTWARE

Full Software Pseudocode Block Diagram



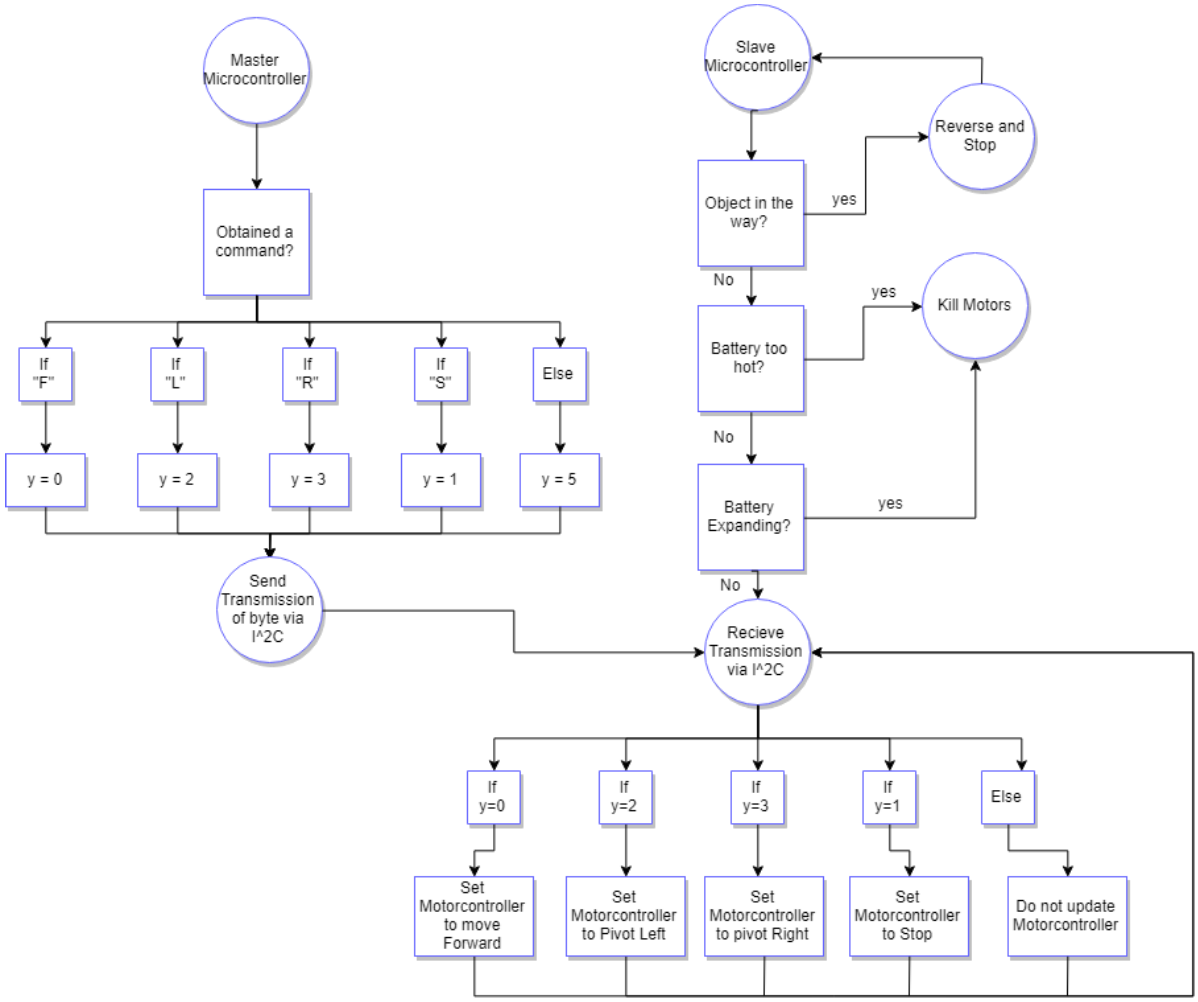
Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

EEG Sensor to Microcontroller Pseudocode Block Diagram



Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Microcontroller to Motor Controller Pseudocode Block Diagram



Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Software Test Plan

Features	Sub features	Date
Sensor to Software	Signal Measurement and Accuracy	3/25/2018
	Signal Reliability	3/25/2018
	Noise Reduction	3/25/2018
	Training software	12/08/2017
Software to Secondary Software	Signal Conversion	12/08/2017
	Signal Acquisition	12/08/2017
	Delay before next signal	4/9/2018
Secondary Software to Primary Microcontroller	Command Acquisition	12/08/2017
	Command Transmission	3/25/2018
Primary Microcontroller to Secondary Microcontroller	Command Reception	3/25/2018
Secondary Microcontroller to Motor Controller	Motor Commanding	3/25/2018
	Command Change	3/25/2018
Temperature Sensor	Motor Overriding	4/9/2018
Force Sensor	Motor Overriding	4/9/2018

Generated by David Gomez, Angel Figueroa, Jesse Polio, Anthony Egbujor [4]

Results of Software Testing

The results of our software testing were accurate and as we expected. Since this was mainly software testing, we were able to split up the software tests and do them according to what can be done outside the lab and what must be done inside the lab. Our tests ran from Last semester, all the way to this semester. This is, because some of the tests that needed to be completed were basically completed in the first semester, during the laboratory prototype. The ones that need the use of a wheelchair, however, were not completed until the middle to end of the second semester. Although we did not record the finding of our tests, as it was not asked for, we did get a specific understanding of what our results meant. With is new understanding, we made modifications to our project, in accordance to our results.

For our sensor to primary software, we tested the aspects of our EEG sensor to the Emotiv Control Panel. We measured the Accuracy, Reliability, Noise Reduction and Training Software. To measure the Accuracy and Reliability, we sent signals to the software consecutively to see how long it would take to send the signal that we need. So, we set a threshold of 75% power as a successful reading. After a total of 10 trials, we found that 9 out 10 trials were successful. The only trial that was not averagely successful was the first trial. For Noise reduction, we attempted to obtain signals while being told information. We found that when fully trained, the noise reduction will get rid of more than 90% of all noise. Lastly, for Training, we tested how long it takes to train the Headnet to function ability and how long it takes to fully master the Headnet. We found that it takes about 1 month to train the headset to be functional and two months to master the Headnet.

After, we tested the speed of the reception and convergence of the signal, and the transmission and reception of the command. We found what was expected. After 10 trials, every trial showed to be nearly instantaneous.

For most of the microcontroller and motor controller code was tested by making sure the correct commands are sent in from the correct signals.

Revisions after Software Testing

All the tests we ran went smoothly. Everything was accurate and had expected outcomes. Due to how we were getting the signals before, we found through tests that the motor controller messed with the commands being sent into our microcontroller. So, we decided to change from hard direct wiring to a I^2C Master-Slave model. This allows us to use more than one serial monitor to send the commands. So, thanks to our thorough testing, we were able to find a solution that made our project better for the long term.

APPENDIX E - VENDOR CONTACTS

We would like to thank all those who aided us in completing our project. Our special thanks go to:

- Kevin Horn, Manager of the Ability Center of Sacramento.
    - Generously donated the Jazzy 1143 electric wheelchair
    - Contact: Email khorn@abilitycenter.com

- University Enterprise Inc.
    - Granted us $2,000 to cover the cost of the EMOTIV EPOC 14+- Channel EEG Headnet
    - Contact: Phone: (916) 278-7565

- Arduino
    - Their Arduino Mega 2560 made our project possible
    - Contact: Email bizdev@arduino.cc

- Dimension Engineering
    - Their Sabertooth Motor Controller allowed us to successfully control the Jazzy's motors.
    - Contact: Phone (330) 634-1430

- Adafruit
    - Adafruit's infrared sensors, FSR sensors, and temperature sensor helped integrate the safety features

- EMOTIV
    - EMOTIV's EPOC 14+- Channel EEG Headnet, the EMOTIV Control Panel and the EMOTEKEY software allowed the team to accomplish the EEG Sensor Wheelchair Control feature
    - Contact: Phone (415) 525-3149

APPENDIX F - RESUMES

Anthony Okechukwu Egbujor

OBJECTIVE: To obtain an entry level position in a field or occupation relative to my major.

EDUCATION:
In progress: BS, Computer Engineering - CSU Sacramento - May 2018
Courses:
Computer Network and Internet Computer Architecture CMOS and VLSI
Advanced Logic Design Advanced Computer Organization Senior Design I & II*
Hardware Design Computer Software Engineering Operating Systems
Computer System Attacks & Countermeasures* Computer System Pragmatics*
*Spring 2018

PROJECT EXPERIENCE:
Security Implementation: OSSEC on Linux VM's
Installed and configured a security software, named OSSEC, on the Linux Virtual Machines for the San Francisco Department of Technology. OSSEC is an Open-Source Host-Based Intrusion Detection System. I created python installation and uninstallation scripts, as well as configuration scripts that would allow easy installation on the system, configure the software, and allow it to seamlessly monitor the Linux Machines.

WORK EXPERIENCE:
Cyber Security Intern San Francisco Department of Technology Jun 2017 – Aug 2017
Intern and work alongside DoT managers and technical experts to gain practical work experience through projects and task fulfillment for the cyber security division.
IT Support Assistant California Legislative Counsel Bureau Apr 2016 – Apr 2017 Follow analytical, hands-on, and technical functions to support the Legislative Counsel. Use tools and software created by the team to serve legislative. Lastly, assist assembly and senate members of the legislature in all hardware and software issues.
Software Application Assistant CSU Sacramento Nov 2014 – Mar 2016
Teach and assist students in software application usage and common features. Lead workshops to teach a class or large audience software applications.
Information Security Intern California ISO Jun 2014 – Aug 2014
Created procedures, reports and other documentation, Completed UAT Testing, and managed the “ServiceNow” Task Management System for California ISO’s Information Security Department.
KNOWLEDGE AND SKILLS:

Programming Languages: C++, Python, C#, Linux CLI, Verilog, VHDL, Java, SQL, Assembly, HTML
Operating Systems: Windows: XP to 365, MAC OSX, Unix, Linux
Software: Splunk, FireEye, Tennable, All Microsoft Office, Arduino, Photoshop, Dreamweaver, IBM
SPSS, Multisim, Matlab, Sketchup, EmotivPro, PuzzleBox
Tools: Arduino, Raspberry Pi, FPGA, Analog Discovery, Logic Analyzer, EEG

ACCOMPLISHMENTS AND ACTIVITIES:

- SPLUNK Certified User (Official Certification: June 2017 – June 2018)
- National Society of Black Engineers – President (Jun 2015 – May 2016)

David Jr Gomez

Objective: A position in Computer/System Engineering.

Qualifications Summary

- · *BS Computer Engineering*
  1.5 years if experience working with virtualization and 6 months with enterprise storage technologies
- 6 months experience working with MS Windows Server based operating systems administration and best practices
- 6 months experience using MS Active Directory with knowledge of DNS/DHCP and how they function
- Knowledge of MS SQL Databases: Basic DBM, Optimizing Database Performance, Data in Tables
- Knowledge of IT security best practices and principles
- Knowledge of mobile device management solutions
- 2 years of experience in customer service
- Excellent problem-solving skills; able to identify appropriate engineering solutions based on customer requirements and business needs.
- Excellent verbal, written, presentation and listening skills developed through experience in public speaking, working with technical teams, and providing customer service.

Computer: System Administration, Windows Server, Active Directory, Oracle VirtualBox, MySQL Workbench, Wireshark, secure programming, Operating systems programming, MS Office

Languages: MySQL, Java, JavaScript, C, HTML, Python, Verilog, Linux, VHDL, PHP

Bilingual: English/Spanish

Education & Specialized Training

BS Computer Engineering, CSU Sacramento • GPA 3.1 • Dean's List • May 2018

Related Courses:

Computer Networks and Internets - Computer Software Engineering - Systems Principles
Operating System Pragmatics - Advanced Computer Organization - Computer Architecture
Electronics - Advanced Logic Design - Hardware Design - Network Analysis - CMOS and VLSI

Intel Ultimate Engineering Experience: Developed team, leadership, technical, communication skills. (2013)

Related Experience

Software Analyst/Student Assistant ***Legislative Data Center***

8/2015 - 6/2017

Analyzed existing software and hardware, tracked bills, and requested quotes for new software and license renewal for the State Senate and Assembly. Helped a software management team to track computer hardware assets and existing software licenses. *Tools used: Flexnet, MS Access, Oracle database, MS Excel*

IT & System Support ***US Department of Agriculture***

7/2017 - Present

Maintain the USDA website for the Davis location, tier 1 system administration including Active Directory to add/remove users, creating groups, setting and resetting passwords, and setting security permissions. Help manage file server folders by creating and sharing folders and setting user permission. Tier 2 helpdesk and desktop support. Integrate scientific instruments to windows production environment. *Tools used: Windows Enterprise Domain; Windows Server 2012 & 2008, Active Directory, Server Manager, Service Desk*

Objective: A career position in Electrical Engineering involving control systems.

Qualifications Summary

- *BS EEE*
- *Computer Skills:* Matlab, PID Control, Arduino, C, C++, Python, Multisim, MS Office
- *Design:* Skilled at designing hardware and software using engineering concepts for projects.
- Able to troubleshoot and solve complex math and technical problems
- Experience programming robots using a variety of sensors and control systems
- Skilled at assessing team and assigning tasks based individual strengths
- Excellent team and leadership skills developed through previous experience as team leader on multiple technical projects. Able to motivate team to achieve best results - resolving problems and conflicts as they arise and deliver project deliverables on schedule and within budget
- Excellent communication skills; experience writing technical reports and delivering effective PowerPoint presentations.
- Able to adapt to and understand new technologies quickly
- *Bilingual:* English/Spanish

Education

BS Electrical and Electronics Engineering • CSU, Sacramento **•** Major GPA 3.1 • *Dean's Honor List* **•** *May 2018*

Related Courses:

Digital Control Systems
Intro to Feedback Systems
Robotics
Product Design Project 1&2
Intro to Microprocessors
Intro to Logic Design
Electronics 1&2
Network Analysis
Intro to C Programming
Intro to Circuit Analysis
Electro mechanic Conversion
Modern Communication System
Power System Analysis
Energy System Control + Optimization
Differential Equations
Engineering Economics

Projects & Experience

Co Team Leader* & *Team Member **Thought Controlled Wheelchair-** *Sr Design*
9/2017 - Present

With a team of four (*computer engineers and electrical engineers),* designing and constructing an electrical wheelchair that is controlled by an individual's thoughts. The wheelchair will be able to move by thought commands by use of an EEG head net. Infrared sensors are used for obstacle avoidance. A temperature sensor and force sensitive resistor force sensor used to manage battery. This year long project involves all aspects of project lifecycle: proposal concept, design, programming, construction, testing, tuning, documentation as well as weekly status updates, and delivery of a working prototype and a comprehensive final project report and a PowerPoint group presentation to industry representatives. *Technology used: Sabertooth 2x60 motor controller, Arduino IDE, Emotiv+, C, soldering iron, shrink wrap, breadboards, resistors, capacitors, wiring, hand tools.*

Co Team Leader & Team Member **Micromouse Design Project**

11/2017 – 12/2017

With a two member team designed and built a small robotic car that navigates through a maze without external assistance. Project components included a chassis, wheels, H-bridge, Arduino Nano, and DC motors. Personally, programmed all sensors such as IR sensors, encoders, and IMU to detect walls and turns. A technical report and documentation were delivered. *Technology used: Arduino IDE, C, soldering iron, breadboard, hand tools.*

Co Team Leader & Team Member **Robotic Car**

9/2017 – 12/ 2017

With a team of two, designed and built a robotic car that traverses a series of prescribed obstacles and tasks including line follow, car follow, narrow bridge crossing, and maze. Personally, programmed IR sensors, Ultrasonic PING sensors and encoders. A technical report and documentation were delivered. *Technology used: Arduino IDE, C, breadboard, soldering iron, hand tools*

Co Team Leader & Team Member **Security Gate**

1/2017 – 5/2017

With a team of four, designed and built a security gate system. The project used servo motors, a microcontroller and a series of RFID, PIR, and IR sensors. A technical report and documentation were delivered. *Technology used*: *Arduino IDE, C, breadboard, hand tools*

Lifeguard- Water Safety Instructor **San Fernando Regional Pool Facility**

5/2011 – 9/2013

Worked with a multi-function team of 15 to maintain a safe and healthy facility and rescued drowning swimmers of all ages and sizes. Maintain order during public and private pool hours with safety of the public as the highest priority. Taught multiple swimming classes for classes of all ages and up to 30 individuals daily. Explained complex concepts in easily understandable language in English and Spanish. Trained daily to maintain both the body in peak condition and rescue techniques/knowledge.

Locker Attendant **San Fernando Regional Pool Facility**

6/2011 – 7/2011

Maintained a safe, clean facility including pool, surrounding area, and restrooms. Operate the slide during public hours and for private parties while ensuring the safety of the patrons. Tested pool water PH and acid levels on an hourly basis. Work front desk taking payments, reciting pool rules, and maintaining front desk order and cleanliness.

Professional Activities

Member, **IEEE • Power Engineering Society • MESA Engineering Program • Society of Hispanic Professional Engineers**

Angel Javier Figueroa

OBJECTIVE: A position in Computer Engineering involving software development, network engineering

Summary of Qualifications
BS Computer Engineering
2+ years' experience
Computer: Java • C • C++ • Python • Verilog • Assembly • Cadence Virtuoso • Visual Studio • Autodesk Maya • Unreal Engine 4
MS Office • Windows OS • Mac OS • Linux Mint • Ubuntu
Tools:
Excellent Writing Skills developed through lab reports and technical project documentation
Exceptional problem solving and troubleshooting skills developed through
Strong team and leadership skills developed through professional activities, technical projects, and work experience
Highly organized, quick and innovative Thinker
worked 30 hours per week to finance education while carrying a full course load

Bilingual: English/Spanish

EDUCATION
BS, Computer Engineering • CSU, Sacramento • GPA 3.056 • Dean's Honor Roll • May 2018
Related Courses
Operating System Pragmatic Advance Computer Organization Data Structure + Algorithm
Computer Network+Internet Attack and Countermeasure Operating System Principles
Program Concept+Method Computer Interface

Related EXPERIENCE *worked 30 hours per week to finance education while carrying a full course load*
Co-Leader Brain-Controlled Wheelchair **Sr Design Project- CSUS** 8/2017-5/2018
Leading a four person team to create a thought-controlled wheelchair to aid individuals with quadriplegia. This one year project involved all aspects of the project management lifecycle including researching options, identifying
best option, project proposal, design specifications, documentation, prototyping, building, weekly status updates,
group presentation and a comprehensive final report. Personally, responsible for scheduling meetings, delegating responsibilities, coordinating deadlines with team members. Responsible for the integration for IR sensors that provide obstacle avoidance to ensure safety from collision. All documents were created in compliance with IEEE standards.
Tools: Arduino IDE, Arduino Mega 2560, Sabertooth, Infrared Sensors

Leader Remote Batch Rendering Service **Mesa Accelerator Program-MESA**
2/2018 - 7/2018
Leading a 2 person team to create a startup company that produces high quality films and images at low power consumption and low rates. A project that was designed and created in the first MESA Entrepreneur Accelerator program. This several months project involved identifying a target market, creating a business plan, weekly status updates, examine competition that are within the market, develop a 24 month step plan to implement your product into the market.
Tools: remote communication, google docs.

Text based RPG video game
February 2018 - Present
A current personal project developing a texted based rpg video game in C++. Harnessing my software development skills.

Anti-Cookie Monster Security System **Computer Interface course project** September 2016- December 2016
The purpose was to create a multi sensor security system that secures your cookies from thieves. This was a semester long project which I lead. organizing the team to meet up and assigning task. My portion was to develop a udp server, triggered by the motion sensor, so it can record the thief.
Tools:raspberry pi 2, webcam, small motor, motion sensor

Smart Wash **Start up Grind Sacramento**
November 2016
A project presented at Sacramento Startup grind in hopes of recycling the water from washing machine for next load of laundry. Giving me my first experience in the process of starting up a business in the tech field.
Tools: business plan, Arduino max 32, washing machine, pvc pipes.

PROFESSIONAL EXPERIENCE

Franchise Tax Board
September 2017 – Present Reimaging & repairing systems for the state ensuring they are at optimal quality. I help ensure that the systems workers are using meet the standard.

Engineering & Computer Science tutor
September 2016 – January 2018 Tutored individuals in the Computer Engineering field of study. I helped students achieve better knowledge and understanding of their respected field

Green Tech
March 2017– August 2017 Worked as a volunteer over the weekend tutoring the youth at various computer programming skills such as, C program and HTML, in hopes of inspiring them to seek a degree in the Computer field.

Legends IT
September 2016 – October 2016 Installing and maintaining P.O.S systems for the Golden 1 Center as well as to respond to and resolve IT issues at a quick pace

Susanville American Indian Summer Outreach Program
May 2016 Encouraging children of the American Indian reservation to pursue a degree in STEM. I inspired Native Americans that they can become engineers as well.

Cloak & Daggers January 2015 – September 2015

Assisted in development of a security software. The experience created a foundation of knowledge regarding encryption and work experience in C++.

PRISM Summer 2014
Facilitated Pre-Calculus class for incoming freshmen, preparing them for college level math courses.

Computers for Kids December 2013 – August 2014
Built computers for low income families with donated parts from the state government. This gave me my first experience in IT

ACCOMPLISHMENTS & ACTIVITIES _

Founding Member, American Indian Science Engineering Society
President, American Indian Science Engineering Society
Member, Math Engineering Science Achievement Engineering (MESA) Program
Competitor, MESA Entrepreneur Accelerator Program
Scholar Participant, National Action Council for Minorities in Engineering (NACME)
Hackathon Participant, Sacramento Startup Competition