The Autonomously Returning Chair
(The A.R.C)

Group 44

Tony Du	Electrical Engineer
Lyons Mugello Opina	Electrical Engineer
Daniel Nouh-Chaia	Electrical Engineer
Eric Le	Electrical Engineer

University of Central Florida
Department of Electrical and Computer Engineering

Table of Contents

List of Tables

List of Figures

1. EXECUTIVE SUMMARY

The average individual always concerns themselves with the “three C’s”, Convenience, Comfortability, Cleanliness. Due to this fact, technology is advancing to accommodate those three essential concerns. Therefore, advancement in an important device, the chair, was desperately needed. Our project aspires to develop a chair that will have the capability to return itself to a set location without anyone having to physically do it themselves. This task will be accomplished with the use of timers, sensors, LEDs, and motors. This paper is an explanation of group 44’s product, the purpose behind it, and the choices that were made to accomplish a working finished device. The paper covers the choices and reasons behind the hardware and software applications used to design the Autonomous Returning Chair (A.R.C.). Furthermore, the components that make up the A.R.C., and the research and discussions that led to their usage in the design will also be covered. The resources used in the development of this device will also be accurately documented.

1.1 INTRODUCTION

As technology advances so do the lifestyles of many individuals, technology is being used to provide a sense of comfortability for its user. Therefore, it is recognized that the chair is an essential comfort in daily life, for most people are seated throughout the majority of their days. Therefore, it is important to have a chair that can provide more practicality than the average chair. Oftentimes, it has been found that returning a chair back to the original position is neglected by individuals who believe that they are returning to the chair immediately or believe that it is simply unnecessary. This tendency can cause the workspace or living area to become messy or even result in a tripping hazard when navigating through said area. When this problem is scaled up to a room full of chairs, such as a conference room, cleaning or janitorial staff are left with the tedious task of returning each chair to their original positions. With the Autonomously Returning Chair, the A.R.C., neither the janitorial staff nor individuals with their own office space will have to perform this tedious manual labor. Resetting the position of each chair before cleaning will expedite any cleaning endeavors while also bringing a sense of convenience to the users.

2. PROJECT DESCRIPTION

In this current, modern age, the availability and pace at which new technology is created and offered to consumers leads to even more opportunities for innovation. These advancements have managed to grace every aspect of our everyday lives, resulting in even the most basic things that have been thought of and improved upon. Chairs have been established as a common commodity long ago. Over time, whether it be for comfort or for convenience, additional features have been added, refined, and modified in order to stay relevant as new standards were set and more demands were created. As engineering students, intrigued by how we could incorporate technology to further improve upon the modern chair, the concept of the A.R.C quickly came to mind.

2.1 MOTIVATION (PROJECT NARRATIVE)

It is recognized that the chair is an essential comfort in the lives of most people. There are many specifications to consider when searching for a chair to purchase. In this case, the general purpose of A.R.C. is to have a chair that is less of a burden than owning a regular chair. As stated previously, it is seen that oftentimes, returning a chair back to the original position is neglected due to the belief that it will be used again shortly or that it is simply unnecessary to do so. This careless habit can cause cluttering in the workspace or living area and it could even be a tripping hazard. When applying this problem to a larger scale, such as for a conference room, it can become a tedious task to fix the positions of every chair.

Thus, the goals we aspire to achieve are cleanliness for the workplace (or living space) environment and convenience in removing the labor of returning a chair. With the A.R.C., we can improve the organization of chairs within our working or living space and reduce the burden and hazards brought about by the disorganization of chairs. Ultimately, we would decrease the amount of housekeeping immensely for one of the most used objects in society without losing any of its functionality.

2.2 OBJECTIVES AND GOALS

Essentially, the main objective of this project is to have a self-housekeeping chair that will return to a set position for the user. However, there are many smaller goals we must achieve so that we may successfully realize our ambition.

2.2.1 CORE FEATURES

Out of all the features discussed within the group, it had been decided that the core features we focused on are pressure sense seating, two operating modes, infrared operations, and obstacle avoidance. We decided to focus on these features, for they signify the goal that we are trying to obtain, which is a self-returning chair. These features will not only make this device, but the group agreed that these features should be obtainable before our deadline.

2.2.1.1 SEATING ELEMENT

To start, we must create a product that will allow users to sit in comfortably. This base, that we address as the ‘seating element' from this point on, is to be used and will serve as the seat, the foundation, and the frame of the product. The seating element must allow for a stable foundation with four equidistant legs that are anchored in place. It must also have a comfortable and open or accessible seat that allows for balanced weight distribution as well as more degrees of freedom to mount various sensors, such as a pressure sensor, range finders, and a signal receiver. The pressure sensor on the seat is one of the main components that will initiate the starting phase of the autonomous mode. This feature, as well as the other core features of the A.R.C., is stated in Table 1. In addition to the sensors, the frame of the seating element will also serve as sturdy mounting locations for the wheels system and microcontroller units that we incorporated into our device.

2.2.1.2 OPERATING MODES

The largest objective of the A.R.C. is its ability to autonomously return to a set destination while also retaining its ability to act as a normal office chair. To realize this, we intend to have the chair operate in two modes: Standard Mode and Autonomous Mode. Whether the A.R.C. will be operating one mode or the other is determined with the pressure sensor discussed previously. The two operation modes is another core feature that is designated in Table 1.

In order to meet this objective, two different sets of wheels must be used depending on which mode the device is operating in. The two sets of wheels will be housed at the base of the chair: a set of regular caster wheels for smooth, standard rolling initiated by the user, and a set of Mecanum-wheels for motorized autonomous movement. A spring system will be implemented to ensure that only one set of wheels are in use at one given time.

Sitting on the chair would compress the springs, allowing the caster wheels to make full and firm contact on the ground to bear the weight of the user. While a user is seated in the chair, the A.R.C. will operate in Standard Mode. The caster wheels are engaged while the Mecanum-wheels are allowed to rest as the movement of the A.R.C. in this mode is done entirely by the user, There is no movement done by the device itself in this mode. In fact, most of the device remains offline, with the exception of having one of the microcontrollers periodically check the pressure sensor to determine if the user is still seated or not.

When a user leaves the seat, the springs will relax until both the Mecanum-wheels and the caster wheels are equal, sharing the weight of the empty chair and the device begins operating in autonomous mode. This configuration allows for the Mecanum-wheels to control the movement of the device while the caster wheels simply act as support. The Mecanum-wheels, driven by motors, will maneuver the A.R.C. to its set destination point in this mode.

2.2.1.3 WIRELESSNESS

The next core feature shown in Table 1 is to preserve the wirelessness of the device. Specifically, avoiding the need for the device to be connected to a power supply from a wall outlet. The purpose of this is to avoid limiting the range of the device, especially when used in a large space. In addition, this feature would avoid any potential issues that could surface, such as the cable prohibiting mobility due to the entanglement of power cables with the device. Utilizing the spacious base, rechargeable batteries can be stored on-board to power all of the sensors and motors necessary for autonomous mode. The rechargeable nature of the batteries allow users to charge the A.R.C. when not in use and disconnect the charging cable when they desire to use the device.

2.2.1.4 INFRARED NAVIGATION

To accomplish the main objective to autonomously return to a set position, we need to incorporate a signal communication system that will allow the A.R.C. to determine where its intended destination is. For our project, we planned to implement an infrared receiver on the chair and an infrared transmitter at the destination point. Using infrared allows the chair to determine where it is in relation to the transmitter, and provide directions for the Mecanum-wheels to navigate towards the destination. For this project, only one receiver and transmitter will be implemented. Using infrared for location tracking is a core feature stated in Table 1.

2.2.1.5 COMPUTER VISION

Computer vision is used widely in robotics for automation. During the A.R.C.'s automation mode, obstacle detection is necessary in order to prevent damage to both the surrounding environment and to the chair itself. Utilizing multiple ultrasonic sensors running on Python, the objective is to have a continuously operating chair that will have the capability to identify when there is an obstacle in the path, and avoid said obstacle, returning to its navigation to its destination after getting past it. Being that the group is fully electrical engineering, the coding aspect of this feature will take some more learning. This core feature, as well as all the previously mentioned features, are shown below in Table 1.

Core Features	
Pressure Sensing Seat	Detects presence of user and determines what mode for the device to operate in
Two Operating Modes	Standard mode using caster wheels Autonomous mode automatically returns the chair to the original position using motor driven Mecanum-wheels
Wireless Device	Will be able to move without any power cables that would restrict its mobility
Infrared Navigation	Infrared transmitter and receiver will allow the A.R.C. to determine where its destination is
Obstacle Avoidance	Computer vision using rangefinders to detect and avoid obstacles while heading towards destination

Table 1: Core Features

2.2.2 STRETCH GOALS

The main goal is to successfully create a working product that accomplishes the goals discussed above. That is by no means our only desire with this project, however. There is much to learn by working on this project and following the engineering process from the initial idea of the project until building the first working prototype.

Some minor goals we have as a group are to become proficient in the areas of weakness that we each identify. Whether that be improving on our coding capabilities through Python or C for the computer vision aspect of the project, becoming proficient with CAD software to 3D print specific components (which would also help in quickly prototyping for parts) or gaining experience with the design and realization of Printed Circuit Boards.

Upon our initial brainstorming session, we came up with many ideas for what we wanted our product to be capable of doing. After outlining the main features we wanted to incorporate, we did not want to simply discard some of the more interesting ideas. As such, these ideas became stretch goals that we would like to pursue after successfully creating the product.

2.2.2.1 STATUS LEDS

Throughout the process of the operation, we would like to integrate a status indicator composed of LEDs to give the user an understanding of what the chair is currently doing to the device. Different colors as well as patterns of flashing would be used in order to easily convey information about what the device is doing. Both the chair and the transmitter will have matching LED indicators so that the user could identify the problem from either ends of the system. While this idea is a stretch goal, we believe the practicality and ease of implementation this feature has is definitely within our capabilities and expect to be able to incorporate this feature with our final product.

We would want the LEDs to have a significance when it comes to flashing. In other words, when the A.R.C. and the transmitter are not in use, then the LEDs will be off. Now assume that the A.R.C. is out of the distance boundary between the transmitter and the receiver of the A.R.C, now the LED will flash every one second, for fifteen seconds, to signify that the transmitter and the A.R.C. are turning on. Once, fifteen seconds have passed, both the transmitter and the A.R.C. will activate and the LED will stay on and show a constant light till the A.R.C. returns within the distance boundary of the transmitter station, the constant light shows that the device is activated. Once, within the boundary, the LED will flash every one second, for fifteen seconds, to signify that the device is getting ready to turn off. Once the fifteen seconds have passed, then the LED will turn off to signify that the device is off.

2.2.2.2 MOBILE APPLICATION

Developing a mobile application is common practice for smart electronics in this day and age. It allows easy access for controls or information on an easily accessible device. A mobile app for the A.R.C. would provide data for when the chair is in-use. Some of the information the mobile app would display are the relative location of the device to the transmitters, the current battery charge of the device, and the current mode the A.R.C. is operating in. While it would take away from the principal feature of our product, remote control capabilities could be implemented into the app to provide the user with more control.

2.2.2.3 MULTIPLE DESTINATION POINTS

Having more than one transmitter dispersed to multiple locations around the home or office would allow one chair to be easily used anywhere within the area. With the press of a button on the transmitter, the chair would proceed to navigate towards it all while avoiding obstacles. This would allow for more freedom in the use of the A.R.C. as it would not be limited to a single room and would have a larger area of effect.

This design in and of itself would be quite an interesting design to use. The reason why this method would be interesting is because you will have to attach a receiver on the transmitter location and a transmitter on the A.R.C. in order to turn on the transmitter station to have the A.R.C. move towards the desired receiver. In other words, the transmitter station won't know to start sending out a transmission without first receiving an activation signal from the transmitter on the arc. This would also be interesting to do, for it would be quite a challenge to have the A.R.C. navigate through different rooms trying to find the transmission signal.

2.2.2.4 CUSTOM SETTINGS

In a classroom setting, an application for A.R.C. settings is to have a mode that instructs every A.R.C. in a specific room to relocate to a different transmitter so that the floor is clear of clears and prepared for cleaning. Scaling this concept up to a room full of A.R.C.s could marginally improve the housekeeping of each chair and result in saving a lot of time. Janitorial staff could easily clear half of the room of all the chairs by moving them to one side of the room. After cleaning the now vacated area, they can repeat the process for the other side of the room. This would result in not only an immense time save, but also in a lot of effort automated by the product rather than by the staff. Without this mode, it would be time consuming for somebody to manually remove each chair and return the chairs back after cleaning. Table 2, shown below, the various stretch goals discussed are stated and accompanied with a brief description.

Stretch Goals

Status LEDs	
Phone App	Displays seating status, relative location status, and battery status of chairs
Multiple Home Bases	Chair capable of self-navigating to many predetermined locations
A.R.C. Settings	Preset commands for recurring tasks

Table 2: Stretch Goals

2.3 REQUIREMENTS SPECIFICATIONS

The Autonomously Returning Chair has several requirements that need to be satisfied in order to guarantee feasibility, functionality, safety, accuracy, and other core traits. These requirements are listed and detailed in Table 3 below.

Specification	Requirement	Value
Weight	Must be lightweight for mobility	≤ 12 pounds
Weight Capacity	Must be capable of supporting a certain amount of weight	≤ 300 pounds
Velocity	The motors will move with a steady velocity	2 meters/second
Torque	Motors will generate a certain torque	1.3 Newton*meters
System Start Time	Time transmission signal search after prompt	1 second
Signal Transmission	The transmitter will transmit a signal up to a distance	≤ 6 feet
Signal Detection	Will be able to detect/receive signals from the transmitter	≤ 6 feet
Time to Find Signal	Time for receiver to find signal	≤ 3 seconds
Obstacle Distance	Sensors will detect obstacles within a certain range	4 inches
Obstacle Avoidance	Will navigate around obstacles in a timely manner	≤ 5 seconds
Voltage for Control System	Amount of voltage needed to power the control system	3.3 Volts
Voltage for Motor Controller	Amount of voltage needed to power the motor controller	5 Volts
Voltage for Motors	Amount of voltage needed to power all motors	12-24 Volts
Battery Life	Time before the A.R.C. requires charging	12 hours

Table 3: List of Part Specifications

2.4 HOUSE OF QUALITY

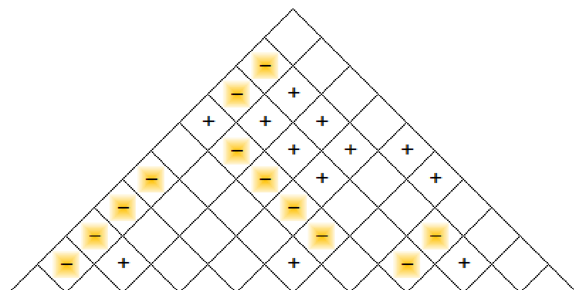
The house of quality shown below in Figure 1 categorizes the different aspects of performance and quality of life for our product. It also shows how the different components of our product correlate to each aspect of performance or quality of life, and between each component as well.

For this project, we are aiming to ensure the performance of our product, that is , the functionality, stability, and speed, are maximized while also maintaining a high standard for the quality of life it provides.

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Category	Weight	Column #	1	2	3	4	5	6	7	8	9	10
		Direction of Improvement	▼	▲	▲	▲	◇	◇	▲	▲	▲	◇
		Engineering Requirements / Customer Requirements (Explicit and Implicit)	Power Usage	Receiver Range	Transmission Range	Motor Functionality	Seat Detection	Load Support	Charging Capability	Location Tracking	Object Detection	Seating
Performance	7	Stability	▽	▽	▽	●	▽	●	▽	▽	○	●
	8	Autonomous	○	●	●	▽	●	▽	●	●	●	▽
	3	Speed	●	▽	▽	●	▽	▽	●	●	○	▽
	5	Weight Capacity	▽	▽	▽	●	▽	●	▽	▽	▽	○
	7	Functionality As A Chair	▽	▽	▽	○	●	●	▽	▽	▽	●
Quality of Life	6	Responsiveness	▽	●	●	●	○	▽	▽	●	●	▽
	6	Low Maintenance	○	●	●	●	●	▽	●	●	●	▽
	7	Affordability	▽	●	●	●	▽	●	▽	○	○	▽
	1	Comfortability	▽	▽	▽	▽	○	▽	▽	▽	▽	●
	4	Product Lifetime	●	▽	▽	●	▽	▽	●	▽	▽	○

Figure 1 - House of Quality

2.5 BLOCK DIAGRAMS

In this section, we visually map out the components for the hardware and the software sections of our project. Furthermore, we also show the division of labor and expand on what each member will be contributing to their sections.

2.5.1 HARDWARE BLOCK DIAGRAM

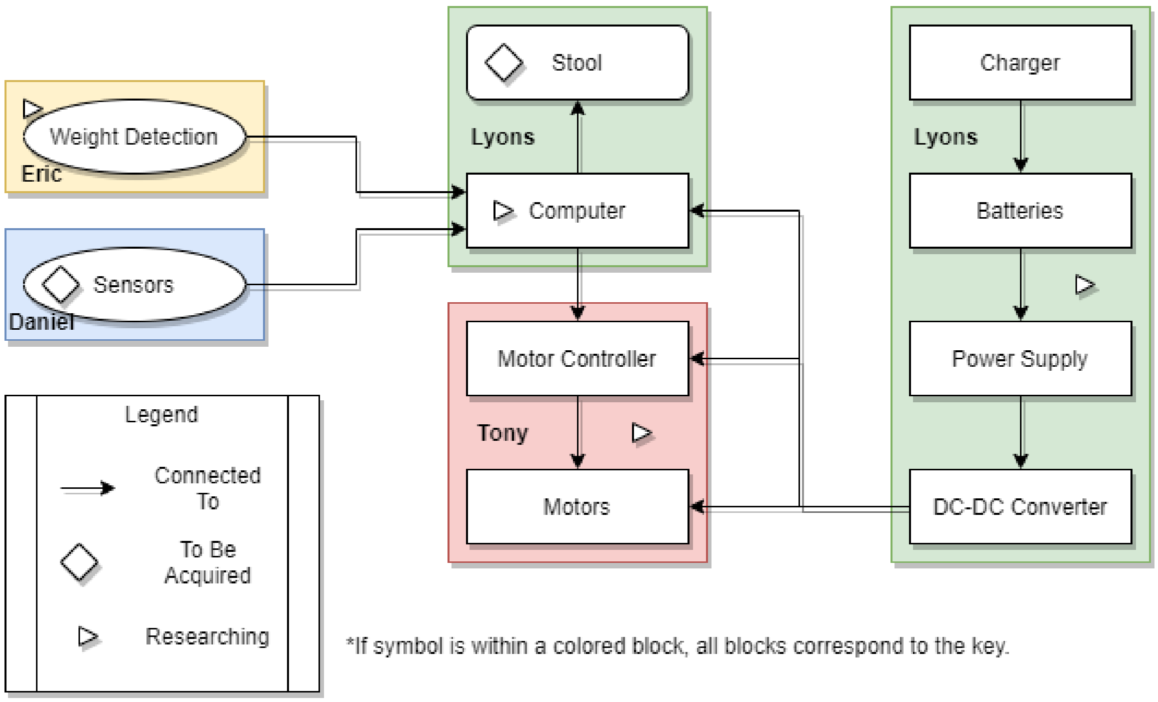


Figure 2 - Hardware Diagram with Assigned Members

The hardware diagram, as represented in Figure 2 above, organizes the different components required to construct the Autonomously Returning Chair. Each block is colored with embedded names that are responsible for ensuring the timely completion of the component. In general, members are not solely responsible for each block as all members will be involved with getting each component accomplished.

Notice there are arrows pointing to its corresponding block. Each block contains a prerequisite before going into the next block as represented. The main computer, assigned to team member Lyons, is responsible for connecting all of the hardware together which ultimately become the moving chair, or in our case, the stool. The importance of completing each block is essential to the team's success.

An example of how this block diagram should be read would be to understand that the right-hand portion containing the charger, batteries, power supply, and dc-dc converter is responsible for supplying power to all arrowed components. From there, a computer receives data points and information from the weight detection hardware, and the sensors. Processing the dataset the computer obtains, the computer will communicate a set of instructions to the motor controller that will then provide the motors instructions on how to move.
The following information lists each members' names and detailing their corresponding responsibilities from the block diagram in Figure 2.

Lyons
Electrical engineering student that will focus on handling driving power into all other embedded components and provide microcontroller, or computer, communication to all other components of the block diagram. The computer will connect all other peripherals such as the motor controller and motor assigned to team member Tony, the weight detector assigned to team member Eric, and the sensor array assigned to team member Daniel.

Driving power to the automatically parking chair is necessary to power every component from the microcontrollers to the sensor array to the motors themselves. Without power the devices will not function at all. Every component and peripheral will take varying levels of power, otherwise, voltage. Therefore, after running power into the system, a direct current to direct current (DC-DC) converter will be a necessary application to regulate variable voltages across the whole seating system. The power supply system is explained in further detail in section 3.2, Power Supply.

To explain the functionality, the computer will either be an Arduino, Raspberry Pi, or a combination of both devices. These choices are programmed in two different languages known as Python and C. Each language is unique to its corresponding microcontroller simply due to the architecture of that microcontroller. The modules are explained in much further detail on section 5.1, Microcontroller Unit.

These devices are necessary to connect all other peripherals which are the weight and vision sensors, as well as the motor controller that will be provided instructions on how to move the motors in a given scenario.

Tony

Electrical engineering student dedicated to handling the motor section of the autonomously parking chair. This member will focus on selecting a type of motor as well as a motor controller suitable for our seating system needs. Those needs are otherwise called requirements and constraints of our system. A requirement would be four individual motors that would be attached to a corresponding wheel of the chair, or stool. To drive those motors, a motor controller would receive instructions from the embedded computer based on peripheral sensor information. Some constraints to consider would be the amount of power required for both the controller and the motor, the weight the motor can withstand before structurally breaking, and the torque needed from each motor to push an unparked chair. These are all points to consider when selecting these components.

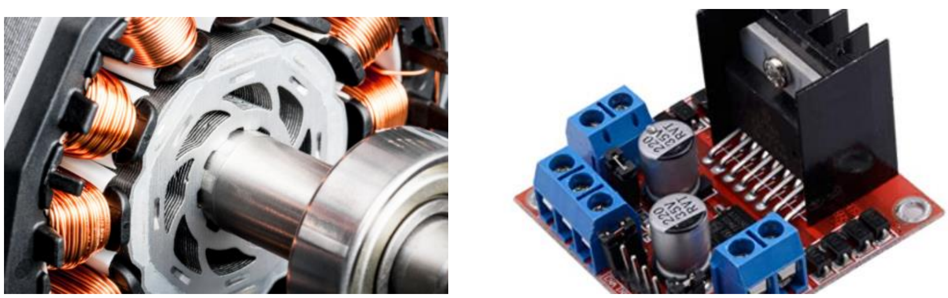


Figure 3 - Internal DC Brushless Motor and L298N Motor Driver

There are different motor designs such as a brushless or brushed motor, which is how a motor is internally constructed and essential to the quality of how the motor will rotate. Another specification to consider is the type of power drawn into its system whether the power be alternating current or direct current. For our case, a direct current (DC) brushless motor will be used for our motors. To note, no alternating current (AC) will run through our chair system, DC power will be our driving source of our project.

The motors alone can not operate as a standalone device, a controller is required to receive instructions from a computer to move in specific directions. The motor controller must follow certain standards as engineers are looking for. The controller, or motor driver, must control the speed at which the system will move around, as well as how each individual wheel will rotate to either turn, move forward, backwards, or diagonal.

An example of a motor controller along with the internal components of DC brushless motor are shown in Figure 3. Quality is everything in our project to ensure a properly functioning chair system, more detail is provided on motors and controllers in section 5.2, Motor System.

Eric

Electrical engineering student with the primary focus of designing a pressure plate detection system to determine whether a user, or customer, is actively using the chair. On active use, the chair should not move whatsoever. This section of the project falls into the category of sensor arrays, which are the peripherals that gather ambient data from user detection to environmental surrounding information. In the case of this sensor, weight on the seating system will be detected to tell the computer whether the chair should be allowed to park at its home destination

There are many choices to select a type of sensor to detect whether an individual, or user, is occupying the chair. Some choices include contact detection in which the system will know if a foreign object has come into contact on to a sort of metal plate, an actuation system in which a mechanical component is actuated to tell the system that the is currently being used, or a weight sensor similar to weighing scale many individuals use to monitor their total weight. Below in Figure 4 - Different Sensor Types, is shown common sensors such as ones used in our mobile devices.

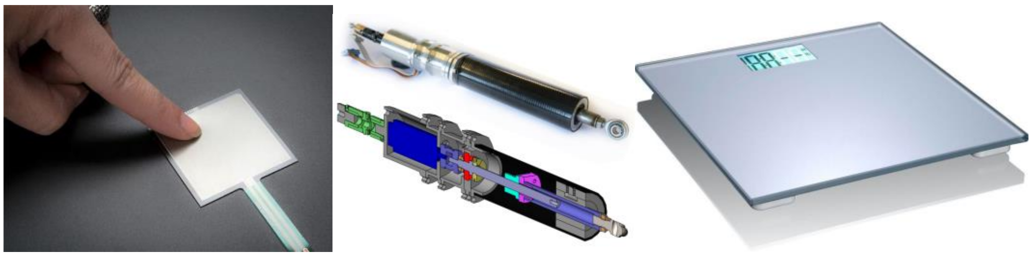


Figure 4 - Different Sensor Types

The main choice for weight detection would be a sort of pressure plate scale embedded to the underside of a selected chair. This is a sort of combination of both the contact pressure plate and the weighing scale. The weight detection is highly important to not only know when a user is occupying the chair system, but to also notify the user of excess weight that the seating system may not be able to handle when in use.

After gathering data from the weight sensors, an analog to digital converter would be required to translate and transfer captured data points into the microcontroller unit, or computer, for processing. The analog to digital converter, or ADC for short, takes analog data points from a peripheral sensor such as a pressure sensor in this case and converts the information to digital so that the computer will be able to accept and process data. Raw analog data is not easily processed when directly connected to the computer, this can be a sort of peripheral driver similar to the motor driver to move motors, but in this case accept sensor data. More detailed information on this component is covered in section 5.1, Microcontroller Unit.

<u>Daniel</u>

Electrical engineering student in sensor management to read and gather ambient environment information for object and location tracking, as well as object avoidance. This member will develop a sensor system that will deliver information to the computer when the computer requests data to create instructions for the motor controller when the system determines the user is away from the seating system. This particularly sensor array can be done in multiple ways such as line tracking using an infrared system, rangefinding using an ultrasonic range finder module, geolocation using a gps grid system, modern bluetooth for base detection, radio frequency signaling, bump detection with actuators, or simply a camera utilizing a library known as OpenCV, which is an imported and highly developed open-source library for computer vision. The decision to select either of these sensing types has not been made as of yet, due in part, of the many options and understanding what is most beneficial to our project. Figure 5 visualizes some options for ambient sensing for the chair to return to home base.

Figure 5 - Ambient Sensing Modules

When selecting the appropriate ambient sensor, there are multiple standards to contemplate after looking into and comprehending how each of the component's peripheral functions. In some cases, all sensor types may be considered for one system as a sort of feature, or stretch goal. For our case, as an initial design, simply one or two sensing modules will be ample to achieve our base goals and integrate the core features of our design. The main idea to consider is how each sensor's peripherals will capture ambient, environmental, information and relay information that will allow the computer to decide where the A.R.C. will go. Furthermore, it is crucial to narrow down which type of sensor will serve as the home base and broadcast the destination for where the seating system will park itself after an individual is no longer occupying the chair after a period of time.

Seeing the home base, whether it be through infrared signals or a specified image that the A.R.C. must recognize, is important for the chair's capability of always moving towards the same destination and parking at the same location every time. A viable option available to us to achieve this is through the use of a camera. The camera would be very efficient, as it can both pinpoint where the home base is located as well as identify any other objects that may be in the way during the pathfinding operation. This information is very important to the computer as it will process this information and generate an appropriate mapping instruction at the same time, the chair back to its home plate while implementing object avoidance. More information on this is covered in sections 5.3 and 5.4, as we discuss both the sensors used to return to home and for object avoidance.

2.5.2 SOFTWARE BLOCK DIAGRAM

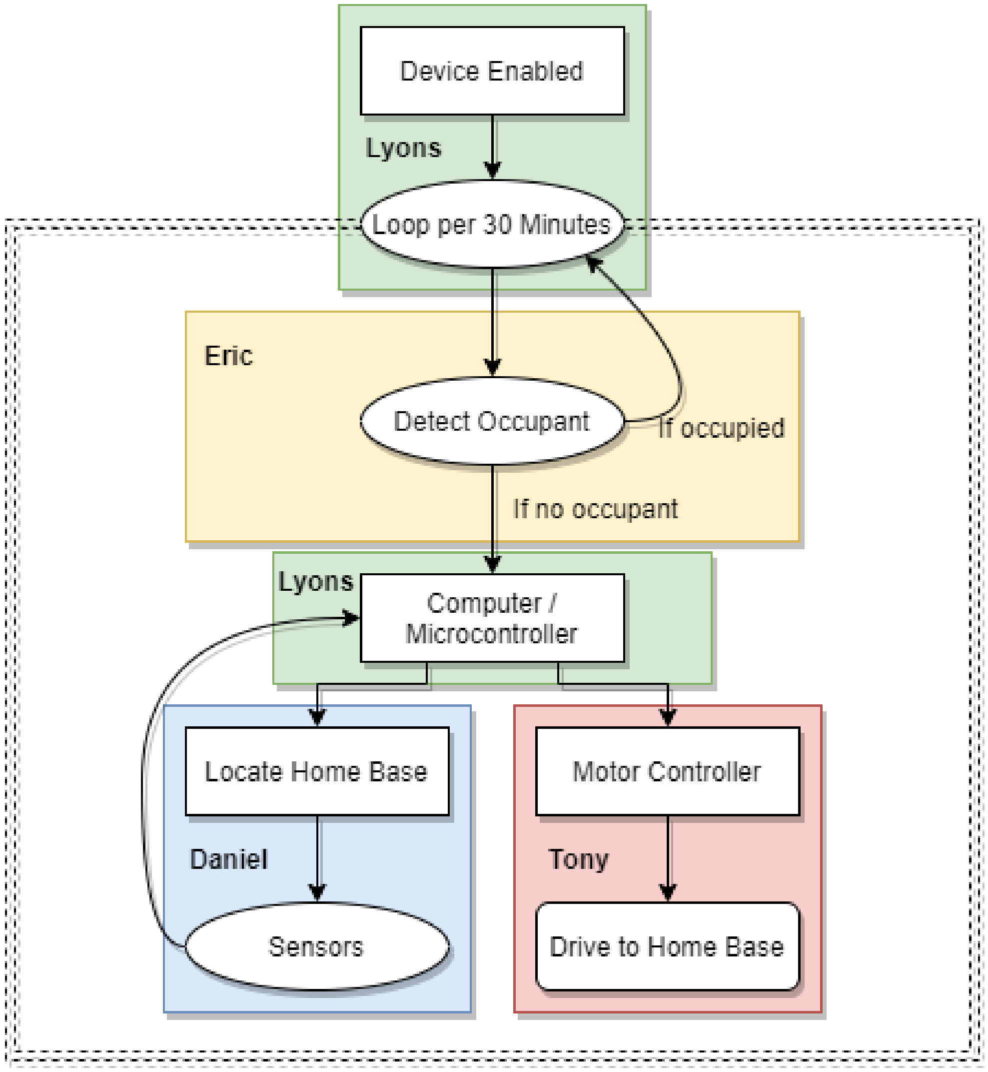


Figure 6 - Software Diagrams with Assigned Members

The software block is just as important as the hardware wherein specific code per module must be programmed. The structure of this software block diagram itemizes the order in which the programmed code will operate. To translate into detail, the seating system will be actively detecting when an individual is occupying the seating system, should a flag raise when no individual is occupied, the system will begin the instruction to move the chair into its corresponding home base. This instruction is to locate home base by gathering data from the sensor array designed by team member Daniel. From there, instructions are sent to the motor controller to drive the seating system into home base.

As shown, similarly to the hardware block diagram, the software blocks are colored to specify each team member responsible. Those items are explained further per member below.

<u>Lyons</u>

As an electrical engineering student, this team member Lyons is assigned to program the main computer, otherwise a microcontroller that will carry out specific functions of the seating system. The main code here would be to connect all other programmed code created by other team members which would be the sensor array program and the motor controller program. This member was assigned to this position as the member responsible, has a rich and greater understanding of programming in both the C and Python languages that will be used throughout the whole seating system.

Here are desired functions of the main microcontroller unit. These functions may exist in both the Raspberry Pi and Arduino microcontroller modules depending on peripheral type.

- Program a delay in which the system may or may not operate.
    - Determine whether a user is occupying the seat by gathering data from the pressure sensor designed by team member Eric.
- Import all necessary libraries to drive each programmed component.
    - Drivers for motors and controllers.
    - Math for computing some gathered data points.
    - Python to C to transfer vision data from language to language.
    - Sensor reading libraries for translating delivered data.
- Develop an access point for sensor information.
    - Weight Detection
    - Ambient Information
        - Images captured from vision sensors.
- Develop a set of instructions using different program definitions specifically to take the seating system back to home base when a user is no longer available.

This particular section of programming is the most important as it is the point in which all programmed definitions and files come together to follow a specific set of instructions. Without the main code, can otherwise be called as the scheduler, definitions of other programmed peripherals will not allow the chair to function as intended. Separating all other program definitions is necessary to keep the master code organized. With organization comes proper order when developing code as a team rather than an individual.

<u>Tony</u>

Team member Tony, an electrical engineering student, will focus on programming the functionality of the motor controller for the motors. As such, a motor itself is not programmed, a driver must be installed with a corresponding microcontroller to drive the peripheral motors. This particular section of the code must accept instruction calls from the main code within the microcontroller to command the motor system.

These are the desired functions of this motor controller program. Since this is an actuated section, meaning mechanical motions are involved, this program will be made in the language of C within an Arduino.

- Accept an instruction set to go home from the microcontroller scheduler code.
- Define a set of movements that the motor is capable of making.
  - Move Forward
  - Move Backward
  - Move Diagonally
  - Stopping and Braking
  - Capable of full degree range of motion.
- Failsafe functionality when detecting motor failure.
  - Motor is not operating, either shorted or not connected (opened).
  - Faulted in which an instruction is not suitable for specific movement.
    - Motors move in a way that the chair is not changing location at all.
  - Low power, or too much power, driven to the motor and/or controller.

An Arduino and the selected motor driver will be electronically connected to each other. A datasheet from the motor driver will accompany the programmer to properly send instructions to the driver. The driver, in it of itself, or standalone, cannot be programmed without the support of another microcontroller housing the imported libraries and programmed definitions.

To program this set of code, the C language will be used to create different definitions for each desired function. The main program at the microcontroller, which is the Raspberry Pi will be programmed in Python. An embedded translator functionality must be made in order to interchange commands from Python to C and vice versa. The main reason this section is programmed in the C language is due to the architecture existing within the Arduino. Extensive detail of the Arduino architecture is covered in section 5.1, Microcontroller Unit.

Eric

Supporting team member Eric, electrical engineering student, will be covering pressure sensing and weight detection program functionality. This section falls into the common category of sensor arrays since ambient, or environmental, data is captured and transferred to the main program at the microcontroller for processing.

Since the sensed data from this peripheral is variable numerical data, an analog to digital converter module is necessary to apply into the system. Analog data is not easily read on a directly connected microcontroller due to subjugated noise. Noise in which data may be skewed and cause full system failure. Converting to digital data points would reduce such noise as well as transfer more organized data to the main computer. The computer will then process the data by reporting whether the weight is at or below the maximum threshold, and whether a user is occupying the seat. Should the user no longer occupy the seat, the main computer will then process a set of instructions to begin sending the seating system to home.

The desired functions of this section of weight sensing is itemized below. This area of code will utilize the library of an analog to digital converter to microcontroller, which will be the Raspberry Pi. As such, the corresponding language is Python. No translation will be necessary from this module to the main microcontroller.

- Take pressure sensor data from a physically installed module.
- Convert gathered data in digital data using the ADC.
- Send digital data points to the microcontroller for processing.
  - Utilize an imported ADC library to correctly pin the ADC's I/O configuration.
  - Must use a formula to convert digital data to weight values.
  - Will include if a user is actively using the chair. (Simple Boolean Logic)
  - Report for excessive weight when above the threshold.
- Apply a failsafe function if the pressure sensor is malfunctioning.
  - Faulted module; short or open connection
  - Incorrect values input and output

The sensors at this level are the most important since this part of the software will ultimately determine the instruction set to bring the seating system back to its assigned home base. Without this sensor functionality, the system will be left hanging at no movement when the user is either occupying or not occupying the chair, or in another case, the chair may move and the user is still sitting on the chair.

<u>Daniel</u>

Team member, Daniel, electrical engineering student like another team member, Eric, focusing on pressure sensing will focus on taking another type of sensed data. This portion of sensing will take actual images of an ambient environment and send the image data to the microcontroller program for processing. Unlike pressure sensing, an analog to digital converter is not at all required since imaged data is taken. The input data will always be an image. Another case that may not be an image, would be the implementation of geolocation and bluetooth, which in this case is purely signals and a sort of radio frequency. The research in computer vision use will be covered in section 3.1, Computer Vision. The receiving and transmission of signals and images will be covered in section 5.3 and 5.4, Receiver and Transmitter.

The required code here would be rather extensive since the desired captured information requires image processing and signal processing. The main standards for this sort of sensing are itemized below. The language of this sensing array will be in Python since the data captured is directly sent to the microcontroller, which is the Raspberry Pi.

- Accept a command from the main code to capture ambient data.
- Define camera movement to locate the home base.
    - A pre-made movement protocol of the camera module to find the home base image or signal.
- Capture running images of the environment.
- Consistently send and receive information from the microcontroller at the time of home basing.
    - Device will only capture images.
    - Microcontroller must process each image until the correct home base location is found.
- Account for when the user decides to sit on the seating system.
    - Must stop the image gathering function
    - Works with the pressure sensor
- Translate signal and radio frequency data if opting to use a geolocation, bluetooth, or radio frequency generating module.
- Failsafe feature functionality

- Must report faulted points when the camera is not functional.
- Unable to communicate with the module.
- Only black, or blank images are captured and received.

This area of code will be extensive and less simpler than other peripheral components, full team involvement will be necessary to ensure full functionality of the seating system.

3. RESEARCH

The research section summarizes the research we conducted for each component of our project. We looked into possible options for each component we desired, compared them, and finalized our decision based on which option would best suit the needs of our project. Throughout this section, the focus is to concentrate on going into detail about not only why specific components are chosen, but the specifications of each component as well.

3.1 SIGNAL SYSTEM

There has been discussion on which type of signaling system to use for this project. In today's world, there are multiple options that can be used for signal transmission and reception. All these different signaling options will yield the same result, which is getting the Autonomously Returning Chair, or A.R.C., to return to a set location. The main methods that were discussed were the use of a Bluetooth application, the use of infrared sensors, the use of Radio Frequency Identification (RFID) chips, the use of Light detection and ranging (LIDAR) sensors, the use of ultrasonic sensors, and finally, the use of bump sensors. All six of these options had their advantages and disadvantages. Picking the right signal system is crucial to the success of this project since each system can do dramatically different tasks. In the end, we used a combination of sensors to accomplish specific tasks to assist the device to function properly.

3.1.1 BLUETOOTH APPLICATION

In the case of a Bluetooth application, there has been discussion on its use and functionality. The way the Bluetooth application would work is frankly quite simple. The Bluetooth application (transmitter) would be any electrical device such as a phone, tablet, computer, etc. that would be able to download the “BLYNK” app. This app is a common app used when programming with devices such as arduino or msp430. The purpose of this application would be to program set locations, in this case by the desk of the chair, and having it relay a signal after a certain amount of time to have the chair return to the desk. This process would work by having the Bluetooth transmitter (phone, tablet, etc.) send out a signal to a Bluetooth receiver, which would be connected to the chair, and have it return to the set location made on the app.

3.1.1.1 BENEFITS AND DRAWBACKS

The benefit for using this method would be that there would be a constant connection between the transmitter and the receiver. In other words, it would be nearly impossible to break the connection between the transmitter and the receiver. However, the drawbacks to using this method are debatable. There are two issues with using this method, the first being that at the current time we are unsure if we are able to set a location within a building. The second drawback is that there has to be a Bluetooth device running, in order to send out the signal to have the chair return. Bluetooth generally is not and will not be used as a range measuring device to navigate the A.R.C.. It does have the capability to measure the signal strength, called received signal strength indicator (RSSI), which can in turn, technically be used to measure distance. Distance is a factor on the strength of the signal, but this distance does not factor in obstacles such as walls and furniture. The second method that bluetooth can be used to measure distance is by using the time of flight of the bluetooth signal. Both methods are highly inaccurate since the signal is highly influenced by the conditions.

Figure 7 - Bluetooth Lynk App (Compatible with Arduino)

3.1.2 INFRARED SENSORS

In the case of using infrared sensors, there has also been great discussion on its functionality. The way the infrared sensors operate is pretty standard. An example of infrared transmission and reception can be found when using a television remote to operate your television, when pressing any button on the remote, an infrared signal is emitted and picked up by the infrared receiver on the television. Just as the aforementioned example, this technique would be employed on the project. There will be a home base located at the desired location, which will be connected to a power source, and will function as an infrared transmitter. To complete the signal, an infrared receiver shall be mounted to the front of the Autonomously Returning Chair (A.R.C.) to receive the signal that will be sent out by the transmitter to have the chair return after a certain amount of time. After much deliberation, this may be one of the types of sensors we are using due to the reliable accuracy it provides when it comes to receiving and transmitting signals.

3.1.2.1 BENEFITS AND DRAWBACKS

The benefit of using this method is that it will be a lot easier to perform, in terms of coding. Another benefit would be that the signal is strong and will reach the receiver regardless of the obstacles. However, there are still some drawbacks, when considering this method. Mainly, that there can only be one transmitter per device, secondly, the device would have to remain within the signal reach, and finally the transmitter has to be connected to a power source.

Figure 8 - Infrared LED (Transmitter)

Figure 9 - Phototransistor SEN0158 (Infrared Receiver)

3.1.3 RADIO FREQUENCY IDENTIFICATION (RFID)

In the case of using Radio Frequency Identification (RFID) chips, there has been little discussion, however, there is a great case that could be made for its functionality, and its practicality when applying it to the Autonomously Returning Chair (A.R.C.) project. The way Radio Frequency Identification (RFID) chips operate is quite interesting, an example of this application can be found when using key cards to enter restricted areas in some building, i.e. when a faculty member at UCF touches the black box (scanner) found next to all class room doors, with their designated (keycard) then the door can either be opened or locked. This process works, because RFID keycards are coded with a distinct signature, this signature can either be accepted by the scanner or denied (depending on its signature). The way we would implement this technology onto the A.R.C. is by creating an RFID grid mat, which will have several RFID chips inserted in it. After having completed the grid matt, we would place an RFID scanner on the bottom of the A.R.C. so it can scan each independent RFID signature until it reaches the RFID chip which has the home location signature.

3.1.3.1 BENEFITS AND DRAWBACKS

The benefit of using this method is that it will be very easy to perform. Once the grid mat is created all that would have to be done is give each of the RFID chips located in the grid mat a location signature that would let the A.R.C. know where it is located on the grid mat at all times, in the case it has no user and it wishes to return to home. This method will also help with object avoidance, for it will allow the A.R.C. to simply move to another location on the grid mat away from the object and guide it towards home. The only downside to using this method is that RFID chips have a maximum distance of 30cm. This issue is the reason for the design of a grid matt, which ultimately reduces practicality, for the A.R.C. would only be functional on or close to the grid mat.

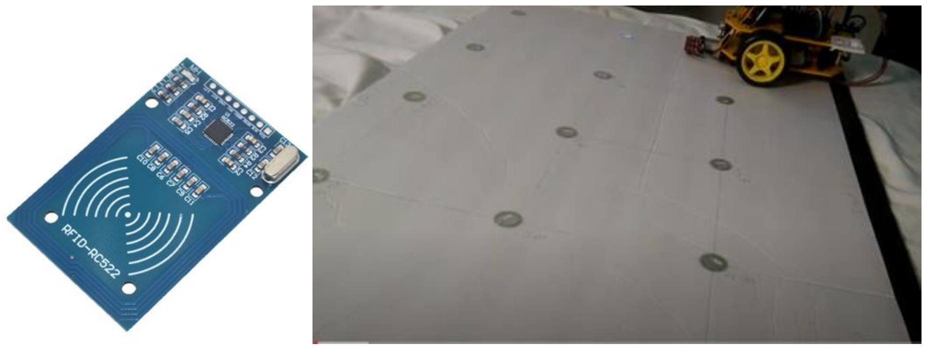


Figure 10 - RFID Sensor, and Grid Mat

After having discussed the different signals that can be used to return the device to the base, a new discussion had formed. What signaling device to use for object detection and avoidance. There are several good candidates, each having their own benefits and drawbacks. The main three that were up for discussion were Lidar sensors, Ultrasonic sensors, and bumper sensors. Each of these sensors would be able to perform the task of detecting an object. And each of these sensors are programmable to avoid/move around any given object

3.1.4 LIGHT DETECTION AND RANGING (LIDAR) SENSOR

In the case of using a Light Detection And Ranging(LIDAR) sensor, there has been a lot of discussion on its functionality/practicality for this given project. Lidar sensors are used to detect objects on 360 degree scale, from its location. The Lidar sensor emits a signal from a laser diode, which is then received by the photonic receiver. However, seeing how this method would only detect in one direction, the Lidar transmitter and receiver are therefore spun 360degrees at a high rate by an attached motor. This would provide a 360 view of objects near the device. This single device could be mounted to the Autonomously Returning Chair or A.R.C., and provide a 360 degree view of any objects that the A.R.C. might run into on its way to the desk.

3.1.4.1 BENEFITS AND DRAWBACKS

The benefit of using this method is that it will provide the best detection, for it provides a 360 degree view. Another benefit would be that there would only be one sensor to program when using the Lidar Sensors However, the drawbacks sadly outweigh the benefits. One of the major drawbacks for using this method would be location, where would the Lidar sensor be mounted in such a way that it would not detect any components of the chair. Another issue with using this sensor is that it is very code heavy, for a group of electrical engineers to perform.

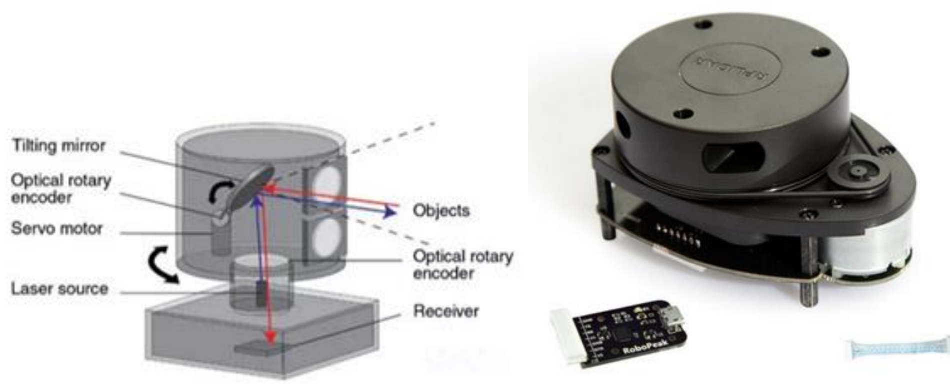


Figure 11 - Lidar Operation and Device Description

3.1.5 ULTRASONIC SENSOR

In the case of using Ultrasonic sensors, there has also been a great deal of discussion on its functionality/ practicality for this given project. Ultrasonic sensors are very familiar to every electrical engineer that has made it to senior design, for they were used in Junior design to create a range finder. Therefore, Electrical engineering students already know how Ultrasonic sensors can be used to measure distance between an object and a device. This knowledge was the main factor in considering this sensor for this project, for we'd be able to mount four different ultrasonic sensors on each point of the Autonomously Returning Chair or A.R.C., and program them to not only detect objects, but also to avoid them. In terms of practicality for the purpose of this project, it is likely that ultrasonic sensors will be used as one of the sensing methods for navigation and location tracking.

3.1.5.1 BENEFITS AND DRAWBACKS

The benefit of using this method is that it is a familiar sensor, and the coding required to make it work properly wouldn't necessarily be that difficult. Also, using this method would ensure that the Autonomously Returning Chair or A.R.C., actually manages to avoid objects in its way without running into them. The drawbacks of using these sensors, is that four different Ultrasonic sensors will have to be programmed. Another drawback is that they might not detect smaller objects such as cables.

Figure 12 - Ultrasonic Sensor

3.1.6 BUMP SENSOR

In the case of using Bumper sensors, there has also been a great deal of discussion on its functionality/ practicality for this given project. Bumper sensors are very familiar to most electrical engineering students at UCF. This is because most students have taken a class in which they created their own Roomba like device, which utilized bump sensors. The way a bump sensor operates, is given by the name, the bump sensor activates once it "bumps" into an object. The reason there has been such a great deal of discussion for the use of the sensors, is because they come with a certain low level of coding requirements. Most students can easily program a bump sensor to run into an object, turn and keep moving till they run into another object.

3.1.6.1 BENEFITS AND DRAWBACKS

The benefit of using this method is that it will be easier than the other listed sensors to program. Sadly, that is the only benefit. The drawbacks for using bump sensors start with simply the cleanliness of the design. When using bump sensors, the device will physically run into an object before turning to move around this. This can't be considered as object avoidance, for there is a collision that takes place prior.

Figure 13 - Bump Sensor

3.2 POWER SUPPLY

Design a power supply unit capable of converting an input direct current (DC) voltage to other direct current (DC) voltage values such 3.3 volts, 5 volts, and 12 volts. Each voltage case is dependent on the component requiring certain voltages. For example, some devices such as the microcontroller digital signal processor (DSP) may only require 3.3 volts to 5 volts such as to process low voltage signals. Devices requiring upwards of 12 volts and more, may involve physical devices such as the motors driving the wheels, or computer vision sensors to sense over extended distances.

The power supply is DC to DC since power is drawn, and used, from onboard rechargeable batteries such as a lithium-ion, or other compounded batteries such as alkaline. Batteries generally deliver direct current voltage from the batteries' terminals unlike alternating current (AC) that is drawn from an American standard socket, or mains voltage. For our case, the automatically parking chair is not wired, and will utilize wireless power by recharging embedded power banks. Some examples of direct current to direct current converters are imaged below.

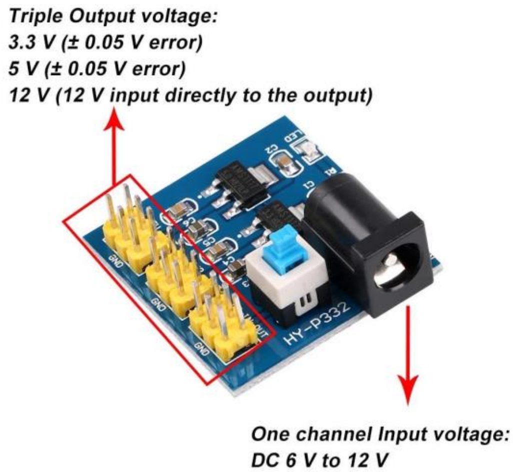


Figure 14 - Simple DC-DC Converter

The system does not require a complex converter such as an electric vehicle converter. An electronic circuit such as shown in Figure 14 will be able to regulate direct voltages from the power supply. Without alternating current running through our system, no sort of high voltage regulation is necessary. These variable voltage outputs will be able to supply power to different components of the seating system.

Energy for the seating system will originate from installed battery packs. Whichever battery we decide to use as a team, a direct current voltage will always be used. The next subsection 3.2.1, Battery Types, will cover different compound batteries.

3.2.1 BATTERY TYPES

The battery options available are limitless, therefore selecting the most appropriate battery is the most important for our energy needs. The right battery must be able to deliver the right amount of load, have a decent lifespan, and both environmentally and economically friendly. The most common battery types are Lithium Ion (Li-Ion), Lithium Polymer (LiPo), Lead Acid, Nickel Cadmium, or Alkaline. These five basic battery compounds are covered in detail for this subsection. Battery details are researched and placed in a hierarchy of which is most and least beneficial to our power goals.

<u>Lithium-Ion (Li-Ion)</u>

A lithium ion battery, or Li-Ion, is a highly efficient rechargeable battery type generally used in everyday electronics from mobile phones to modern electric vehicles. The main properties of a lithium ion battery is its efficiency, economy, and recyclability. The key quality being recyclability in which the battery, once reached its maximum life span, state of health, or otherwise depleted, can be recycled and used in another product.

The battery is commonly used today due to its availability and low costs. In the past, the battery compound was expensive and still undergoing development. The choice of the past were lead-acid batteries as they were far cheaper at the time. Now, lithium-ion batteries have become widely available as the human population progresses in technology.

The lithium ion battery is at the top of the project list of energy sources that will power the chair system. Many qualities of the battery have been named and can be easily sourced locally or online.The lifespan, power draw, and eco-friendly has drawn team members of the A.R.C. to use this battery product.

Figure 15 - Lithium-Ion Battery Energy Cell

Lithium Polymer (LiPo)

A variation of the lithium-ion battery in the form of a polymer. Much less effective, but nonetheless, rechargeable and recyclable. The battery utilizes a polymer structure rather than a liquid structure that the basic lithium-ion battery uses. The main factor of the lithium polymer battery is its' alternative compound and weight factor.

For the case of the A.R.C project, this polymer battery is next in line of the list of energy storage options. Although overall system weight is not a concern at this time, the polymer will remain an option due to its availability and extensive uses.

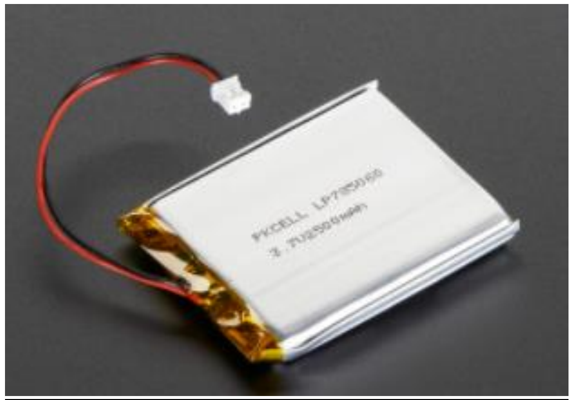


Figure 16 - Lithium Polymer Battery Cell

<u>Lead Acid</u>

The lead-acid battery is the first ever rechargeable battery that has been used for over a century. The battery is still used to this day, however, the properties and quality are lesser to that of the modern rechargeable battery such as the lithium-ion battery. This is mainly due to the low energy density of the battery compound.

Many rechargeable battery alternatives exist in modern society, the lead-acid battery sits as the lowest option of rechargeable batteries at this time for A.R.C.

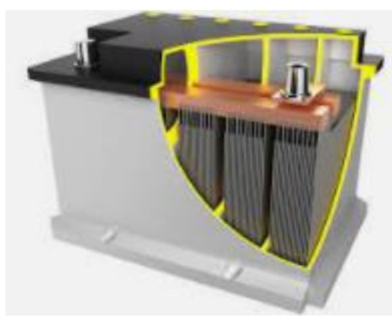


Figure 17 - Lead Acid Battery Cell

<u>Nickel Cadmium</u>

The nickel cadmium battery is another type of rechargeable battery that utilizes electrodes to store energy and has been around for over a century much like the lead-acid battery. The main compound of this battery is nickel oxide hydroxide and metallic cadmium electrodes. These batteries are not used in general products that many see everyday, but are used in portable power tools, emergency/back-up scenarios, and even some hobby remote control projects.

This battery compound is less effective than the lead-acid battery. Therefore, this battery option is one of the lesser choices for the A.R.C. Even though the battery may utilize its full capacity as a battery in low temperatures, the material is still expensive and self-discharges rather often.

Figure 18 - Nickel Cadmium Battery Cell

<u>Alkaline</u>

The alkaline battery is a zinc metal and manganese dioxide compound that is not generally rechargeable unless designed. If attempted to be recharged, the consequences may result in bodily harm due to rupturing and potential explosions. These batteries are mainly single use and have a higher energy density with a lengthy shelf life.

This battery has been classified as an option to the A.R.C. should team members decide to do replaceable batteries. The main constraint of this battery is the poor economy where the battery is not easily recyclable and must always be replaced.

Figure 19 - Alkaline Battery Types

3.2.2 Choice of Battery

After discussing the many battery choices and placing each battery into a hierarchy, the lithium-ion battery has been deemed as the choice battery. There are numerous benefits to the lithium-ion battery from its longevity, reusability, recyclability, and cost effectiveness. All of these factors are what we, as a team of engineers, look for in our modern projects. These are some questions we ask when selecting a battery type.

- What is the longest possible time our automatic chair can operate before the next charge cycle?
    - Consider energy density and charge time.

- How many times can we charge the battery?

- What are the standards of exchanging the battery upon reaching the battery's life?
    - Ease of replacing the battery from its former location in the automatic chair system.
    - Disposal process such as recycling to finding a site/location authorized to exchange batteries.

- How expensive would procuring a battery of the highest quality be?
    - Calculate for economic worth.
    - Cost per unit of charge (USD per mAh)

All questions are subsequently answered.The following lists itemize each benefit of the lithium-ion battery based on our reason for selecting the battery compound.

Longevity

The lithium-ion battery has a relatively lengthy battery state of charge and state of health due to the compound's numerous properties. With those features ranging from highest rated energy density, no memory effect, and very low self-discharge. The following list discusses each feature in detail.

- High Energy Density - Amount of energy stored in a specified volume. Can be in the form of energy per unit volume.

- No Memory Effect - Does not lose potential volume of charge when being recharged at a relatively higher state of health.

- Low to None Self-Discharge - A form of discharging when the battery is not in use. Occurs due to the battery being idle in a system with metal contact. Even though a system may not be completely disabled, the battery may still exhibit a loss of charge with small current running through its terminals. The lithium-ion battery compound disallows this occurrence.

Reusability

Building up from the previous property of Lithium-Ion Batteries, this battery can be consistently recharged for a great period of time before requiring a replacement. In this day and age, we use numerous handheld technologies that operate on a rechargeable battery. As engineers, a factor that influenced our decision was the general use of handhelds with implemented lithium-ion batteries such as our cellular devices, handheld video game consoles, and even electric vehicles.

The design of each technology using these batteries follows a sort of scalability from total energy cells to device size. With a phone having a single cell, while an electric vehicle having numerous cells. From our observations, we found that in both devices in either size, the technology can last a whole day before needing to be recharged for the following day's use. With this knowledge, the lithium-ion battery has become the optimal choice for our build.

Recyclability

Considering the materials on Earth and how resources will always deteriorate, have a limited life span, and will inevitably be depleted, the lithium-ion battery must also have a maximum life span. While its capability of being constantly recharged increases the lifespan of the battery by a significant amount, a great period of time will result in the battery reaching a completely depleted state of health.

The key factor of this property is that the battery has been deemed as fully recyclable, which means it can be dismantled and be implemented into another battery. This process includes the removal of anodes and cathodes from an electrode and simply reconditioning or refurbishing it.

As engineers seeking to better society, we value the environment and strive to incorporate eco-friendliness into our design. As such, the materials and resources we use must be evaluated for their eco-friendliness. Many batteries such as the lead-acid, alkaline, and other non-rechargeable batteries are not designed to be recycled. Upon depleted state of health and state of charge, these non-rechargeable batteries must be disposed of in a proper environment and do not provide any contribution to the creation of new batteries.

Selecting Lithium-Ion batteries will not only prove to have multiple charge benefits, but also benefit our earth by providing a sustainable alternative.

Cost Effectiveness

Throughout this section, numerous qualities were taken into account. From having the benefit of longevity, through the variety of physical properties of the battery, to its eco-friendliness of reuse and recyclability. These alone make passing up this battery compound and design in favor of other batteries would prove detrimental to our goals.

Many factors were considered, such as determining whether purchasing a large quantity of batteries that were not rechargeable for a very inexpensive price, or purchasing a smaller set of batteries that could be recharged numerous times. With careful determination, batteries that are rechargeable have more benefit in which numerous charging of the same set of batteries would be more cost effective than buying a fixed amount of single use batteries. This line of thinking will be implemented in the future when considering the costs of other components.

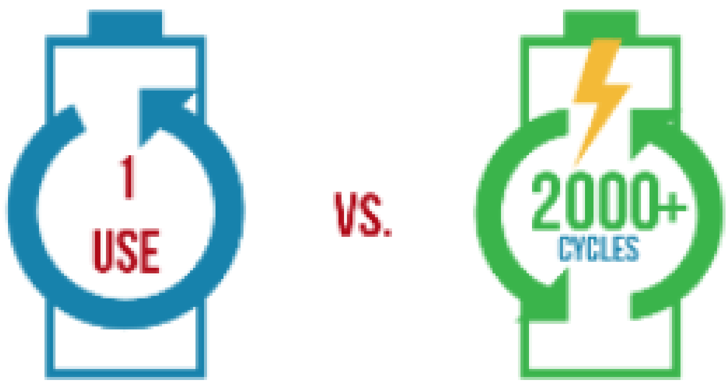


Figure 20 - Rechargeable vs Non-Rechargeable

With lithium-ion batteries, the longevity and recyclability is already shown. Buying a single set would last a very long period of time and save the user a great sum of money. Considering the modern economy, lithium-ion batteries are inexpensive and easily obtainable considering the amount in circulation and worldwide availability.

As a final note regarding batteries, as society progresses, improvements are always being made. Batteries are no exception to this trend. A new design of batteries has been floating around in modern news reports, with such designs being solid state batteries. Such a design does not require liquid compounds, and can have energy density much larger than that of lithium-ion. This battery design will be taken into consideration as a possible stretch goal for our energy storage system once more research has been done and the solid state batteries become available for commercial use.

3.3 COMPUTER VISION

This section details the resource and functionality of computer vision where it's main benefit for our autonomously parking chair is to locate it's main parking location as well as avoid any sort of obstruction. Covered topics are the language used, programmed functions, and explanation of each function.

Python

The main language used for computer vision will be in Python. Many of the instructions and data gathering will be done in Python. Other functions such as motor control will be done in C. The main benefit of the high level Python language is the ease and popular use. With Python, while regularly updated, users and developers have access to a wide range of importable libraries such as Computer Vision, otherwise OpenCV. Python can be easily programmed to relay instructions when the program is given a stream of data. The program will be nested into the Raspberry Pi computer with no need for an Arduino.

Figure 21 - Python & OpenCV

OpenCV

This library is directly imported from a public repository with multiple programmed definitions such as interpreting an image seen through a camera. Images can be transformed to capture specific data points such as corners, lines, and/or edges. For our case, this library will be used to locate a specific image and relay the information to the main instruction code for interpretation. With that image, the system should be instructed to calculate a path to that image. Using OpenCV and pretrained modules that are widely available for us to use, the computer vision aspect of the project used for object detection and avoidance would be simplified.

For other functional uses, OpenCV can take an image and detect obstructions. By capturing a fixed image of its path's surroundings, programmed code can be made to find image phenomena such as an obstruction in its path. From there, an object avoidance algorithm can be run to find a solution around the object. The programmed code does thousands of calculations as it compares images to quickly learn about the environment that it is in. Relaying this information to the arduino would control the wheels in a manner that allows for the system as a whole to think and react like an autonomous returning chair.

Functions of OpenCV

For the use of this library set, OpenCV will be used in the language of Python. Since the Arduino that the team has decided to use will be mainly to control moving parts of the automatic chair system as well as analog data reading, no use of OpenCV in the C language will be required.

Covering what functions will be used in computer vision, the following list itemizes some how some functions will be implemented into our project. Upon use of these OpenCV library features, the system should be able to develop instructions for the movement of the chair.

1. Scale Invariant Feature Transform (SIFT)
    - **1.1.** A popular feature of computer vision in which a program is run by detecting specific features of an image taken.
    - **1.2.** Will be used on an onboard camera gathering video footage to determine environment data.
    - **1.3.** Used for path finding and object avoidance.

2. Edge Detection
    - **2.1.** With an embedded collection of files, this library feature determines edges of a 2-dimensional image.
    - **2.2.** Useful for object avoidance in particular.

3. Feature Matching
    - **3.1.** Establishes comparison of two similar images.
    - **3.2.** Useful in machine learning where the system can learn proper pathing and optimize a set of instructions with repetition.

4. Stereo Vision
   4.1. A method of using dual cameras to take two 2-dimensional images to create a 3-dimensional image.
   4.2. Useful for determining distances and scaling objects.

5. Image Gathering (Filtering, Rotation, Translation)
   5.1. Simply takes an image from a camera gathering video footage and converts the image to specific needs such as grayscaling for use with other library functions such as feature matching.
   5.2. Will be used to find a specific image.
      5.2.1. Specified image is meant to determine where the chair system will park.

6. Hough Transform
   6.1. Transforms edge pixels to parameter space
   6.2. Voting occurs often to find the best edge
   6.3. The peaks that are found in the parameter space are used
   6.4. Provides accurate edge and shape detection

7. Visual Servoing
   7.1. This is the process in which the processed images from python is relayed to the motor controllers
   7.2. Using a feedback system, it will continuously adjust to reduce an image error until there is no error and the movement is complete

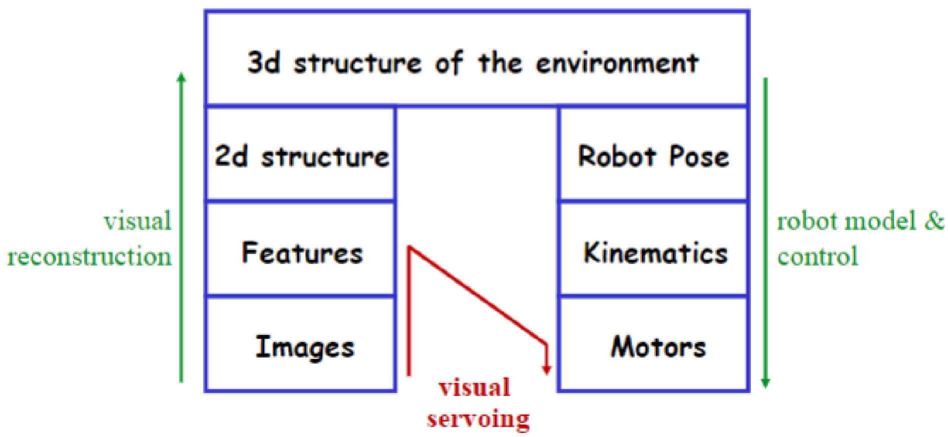


Figure 22 - Visual Servoing

3.4 MOVEMENT SYSTEM

The section refers to the motors and wheels that will be incorporated into the design of the project. This hardware is important as it dictates the capability of movement for the device, a fundamental aspect of whether or not the project will succeed.

3.4.1 MOTORS

The autonomous movement of our project is only meant to occur when the device is not in use. In other words, the motors will only be actively used when no one is seated in the chair. Thus, the motors must be capable of rotating the wheels with enough torque to move the weight of the chair and its components at a consistent speed that will not threaten to accidentally topple the chair over from moving too quickly. Of course this can also be prevented with proper motor placements and picking better center of mass of the chair.

There is a large diversity in motor choices that we took into consideration when deciding which one to incorporate into our design. We factored in the amount of power they would require, the torque they could generate, and how much accuracy we needed from the motors. For this project, we took into consideration two types of AC motors, synchronous and induction, three types of DC motors, brush, brushless, and stepper motors.

3.4.1.1 AC MOTORS

In AC motors, we find that the common trend is that they are not suitable for implementations in a system that require frequent starts and stops or variable speeds. This poses an issue to our project as our chair could require frequent starts as it makes its way to its destination if it must stop whenever it detects that there is an obstacle in the way. In regards to power, we would also have to introduce an AC source into our design separate from the power source for the other electrical components of our project.

3.4.1.1.1 AC SYNCHRONOUS MOTORS

The key feature of synchronous motors is that they rotate at the same rate as the frequency of the supply current. While this allows them to operate at a constant speed regardless of the load it is driving, it also means that in order to change the speed of these motors, you would have to alter your input source. This is due to the easy ability to control the factor in the AC synchronous motor. These motors are highly efficient especially at lower speeds at greater than 90%. In addition, they require excitation from an external source in order to start and possess a starting torque of zero.

3.4.1.1.2 AC INDUCTION MOTORS

In comparison, induction motors are simpler in construction, requiring less maintenance due to the absence of components such as brushes or commutators. Furthermore, induction motors have a robust composition, allowing them to operate in most environmental conditions. That being said, they are known to have difficulty with speed control and possess a low starting torque. On the other hand, a three phase induction motor has the capability of generating high starting torque, can maintain speed, and can overload reasonably.

3.4.1.2 DC MOTORS

In comparison to AC motors, DC motors provide high performance at low speeds and are simple to control. They are also widely used in similar projects due to their starting torque. The DC power source they require can be easily realized through batteries and incorporated with the rest of the project that will also use a DC power source.

3.4.1.2.1 DC BRUSH MOTORS

Brushed DC motors are the most inexpensive motor compared to all other motors discussed. This applies to both the motor itself and to their corresponding controller. However, they do require maintenance as the brushes in the motor will be worn down with use and generate noise electrically and acoustically. The electrical noise can result in complications with sensitive circuits.

3.4.1.2.2 DC BRUSHLESS MOTORS

Brushless DC motors, on the other hand, do not require as much maintenance due to the absence of brushes. They are also more efficient than their brushed counterparts, possess higher speed and acceleration capabilities, and generate much less noise. However, these benefits result in brushless DC motors being more expensive. Less heat is generated in brushless DC motors than DC brush motors. DC brushless motors also can output high power to size ratio.

3.4.1.2.3 DC STEPPER MOTORS

Stepper motors are a type of DC motor that is able to provide greater torque at low speeds while maintaining high precision. They are also known to have low efficiency, accuracy, and are very noisy. DC stepper motors require no feedback since the motor is the position transducer.

3.4.1.3 MOTOR SELECTION

For the scope of this project, a DC motor will be chosen, specifically Mecanum omni-wheels, due to the instantaneous torque they provide at start and the ease of incorporating a DC power source instead of an AC power source. Specifically, the DC brush motors will be used because the noise generated will not have a substantial effect on the operation of the other components.

3.4.2 WHEELS

The wheels used in the project are important in ensuring that the product can traverse the terrain smoothly and successfully support both the product and the user if necessary. However, the wheels needed for when a user is seated in the chair vastly differ from the ones that will be used when the chair returns to its destination point. Thus, we decided that instead of searching for a set of motors/wheels that are sturdy enough to support a person and flexible enough to handle movement engaged from a user as well as from the motors, our device will switch which wheels to use based on whether or not someone is seated in the chair.

3.4.2.1 CASTER WHEELS

When someone is seated in the chair, it should act like an office chair and allow the user to freely move the chair in any direction. The best wheels that suit this need are caster wheels, and are used in almost every office chair due to their freedom of movement and their unique design that gives them the capability to support the weight of most individuals. Attempting to use any other type of wheel to accomplish this goal would be unwise.

3.4.2.2 MOTOR WHEELS

In regards to the wheels that will be controlled by the motors, we need to be able to remotely turn the product, and move it in a straight line. In order to accomplish this with normal wheels, we would have to design and incorporate a turning system with an axle in place to allow for turns to be made.

In order to simplify this process, we elected to use Mecanum wheels that can not only turn in place without an axle, but also allow for lateral movement without changing orientation. These features will be essential in aligning the chair to return to its destination, and for avoiding any detected obstacles in the way without becoming disoriented. Since the stool is omni-directional, we figured that having the wheels be omni-directional would be the most fitting since it will be symmetrically facing in any direction. This means that there is no “front face” to the chair, allowing more degrees of freedom when designing, moving, and parking the A.R.C..

3.5 SEATING SYSTEM

The seating system is an integral part of the A.R.C. since it decides when the chair should and should not be in autonomous mode. While the chair is in-use, the pressure plate will become activated as well by the weight, and will detect that there is a user in the seat by collecting data on the contact of the plates. In this state, the chair is in regular mode, which is able to be used normally with no electronic interference. In other words, when the chair is in use, it should retain all regular functions of a regular desk chair. When the pressure plate is deactivated, meaning there is no user in the seat, the A.R.C. will activate after 30 seconds if it is not within range of the transmitter. Once all of the requirements are reached, the A.R.C. will activate its sensors to start the processes of returning to its set location in autonomous mode.

3.5.1 FORCE SENSITIVE RESISTOR

The force sensitive resistor sensor is one of the most basic forms of sensing for pressure/force. They are capable of being used to measure rate of change in force or the relative change in force, but for the purpose of this project, detecting touch will suffice. If needed, detecting a threshold may be implemented if there are issues with premature misfiring. When in-use, the resistance of the sensor reduces inversely proportional to the force or pressure that is compressing the sensor together. In Figure 23 - Force sensitive resistor build, it can be seen that when it is pressed together, the top and bottom substrate can bend into the spacer to come into contact with the active area. This would work effectively as a pressure plate for the seat of the A.R.C.

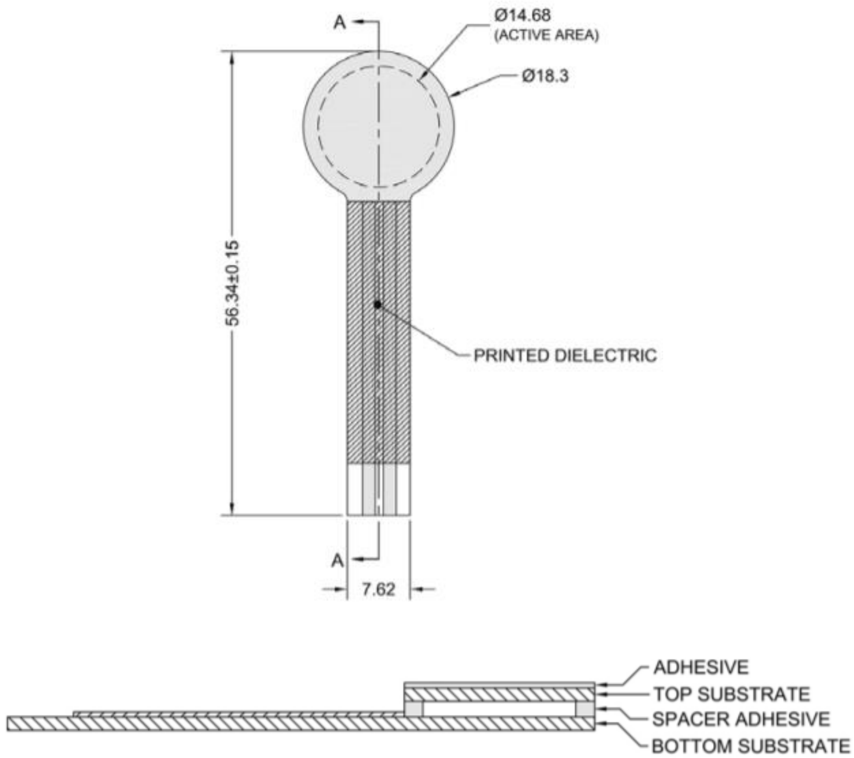


Figure 23 - Force Sensitive Resistor Build

3.5.1.1 BENEFITS AND DRAWBACKS

A benefit of the force sensitive resistor is that it is relatively low costing being that it is simple. Drawbacks are that the precise weight cannot be recorded with this device. For the purpose of the A.R.C., this is perfectly fine since a precise weight is not necessarily necessary to detect the basic data of a user using the seat. This allows the sensor to be used as a basic touch-sensitive application instead of a more accurate measuring application. Figure 24 - Force vs Resistance/Conductance shows the relationship between the force that is applied to the resistance, or the inverse, the conductance. This relationship is used to calibrate the sensor with a little number of samples since we know it is linear.

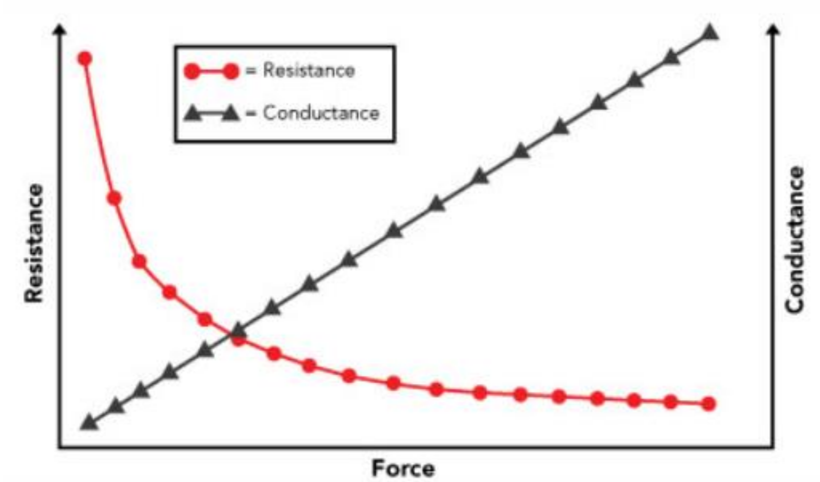


Figure 24 - Force vs Resistance/Conductance

3.5.2 LOAD CELLS

Load cells are another type of force sensing technology that is commonly used. They convert the compressive forces into measurable outputs such as weight. There are many types of load cell builds, to name a few: pneumatic, hydraulic, piezoelectric crystal, inductive, capacitive, magneto strictive, and strain gage. These options allow for flexibility for environmental conditions.

3.5.2.1 BENEFITS AND DRAWBACKS

Benefits of load cells are that they can accurately measure weight and that they are capable of adapting to many conditions depending on the build of the load cell.

Pneumatic load cells use pressurized air or gas that is regulated through chambers internally. A pressure gauge potentiometer is used to measure the applied force. Electrical signals can be generated by using the pressure that is needed to balance the pressure. The main advantage of this is that it has good accuracy, but the accuracy may be affected by high temperatures.

Hydraulic load cells are similar to pneumatic load cells except for the fact that it uses liquids. This, along with the pneumatic load cells can be used in cases when it could be hazardous to use an electric current. Hydraulic load cells have a limiting diaphragm that may impede with larger measurements.

Piezoelectric crystal load most closely resembles the force sensitive resistor in that they are both piezoelectric and deformities result in outputs. The difference is that this uses a crystal that uses a frequency response. Advantages of the piezoelectric crystal is that they are compact and rugged. Crystals are known to be sensitive to high temperatures.

Inductive load cells contain a ferromagnetic core that changes position depending on the force applied. Capacitive load cells use a capacitor and depending on the distance between the two plates, the force can be measured electrically and converted to an accurate reading. Magneto strictive load cells measure the magnetic permeability resulting in the change of magnetic state of the ferromagnetic when force is applied.

Strain gauge load cells measure force by compressing or elongating, which changes the length of the material inside. The change of length of the foil or wire changes the electrical resistance to measure the force being applied. The Wheatstone bridge is used to convert the change to measurements. Advantages of this is that it is cheap and has many uses. A disadvantage is that it relies on an amplifier to generate an output since very low voltages are involved in this.

3.6 TRANSMITTER

The transmitter is the device that we are creating to wirelessly transmit infrared signals to the chair. Like a beacon, this acts as the base that provides the A.R.C. reference of its current location to the destination. Using this in a feedback loop would allow the chair to home in onto the vicinity of the home base, thus successfully automatically returning the chair.

3.7 FLASHING LEDS

LEDs are great low-powered indicators that can provide a lot of information. The purpose of implementation of flashing LEDs is to determine whether the chair is currently idle or in-action. There could be more flashing patterns to indicate more states but those are currently the two most important states. The circuit design in Figure 25 - Flashing LED circuit is a circuit designed for a flashing LED. It uses a clock module as a timer to flash the LED at set speeds.

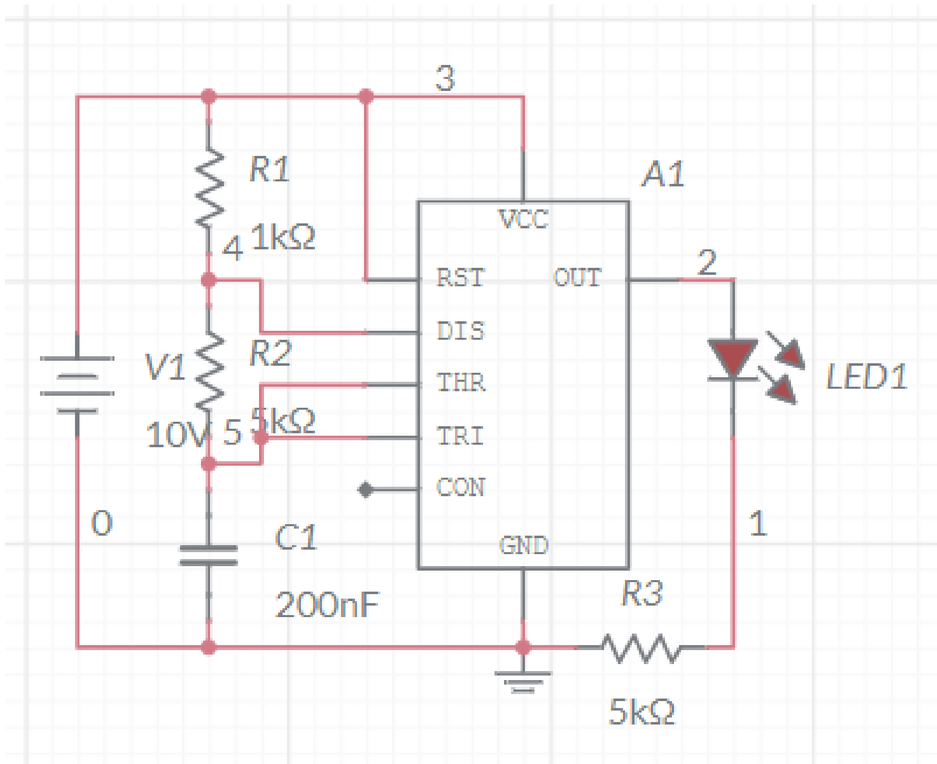


Figure 25 - Flashing LED circuit

4. STANDARDS AND CONSTRAINTS

In this portion, we discuss the various standards and constraints that surrounded the product we desired to produce and how it guided us through our design process.

4.1 DESIGN CONSTRAINTS

Throughout the culmination of our project, we encountered several design constraints that required a cognizant mind as we moved forward with the construction of our design. While we were expecting constraints in regards to health, safety, ethics, economics, manufacturability, and sustainability, we did not expect constraints from an environmental, social, and political perspective.

4.1.1 HEALTH AND SAFETY

The primary concern for our design was ensuring that it could act as a functioning office chair in addition to its autonomous returning feature. This aspect introduced the necessity of our design being capable of comfortably supporting the weight of a person while they are seated in the chair. This condition must not only be satisfied while the person is sitting still. The structural integrity of the design must also not be compromised if the user chooses to move around freely in the chair, both in the sense of moving their body in the chair and in moving the chair around the room while seated.

In addition, we must ensure that the chair provides proper comfort and support to a user. This includes providing back or lumbar support, arm support, and seat cushioning to facilitate long periods of time sitting down while protecting against possible health repercussions.

Furthermore, we must ensure that the signal transmission system we use does not interfere with the user. The signal must not cause discomfort to the user, such as with bright lights, loud noises, or any other distracting features.

4.1.2 ENVIRONMENTAL

The essential goal of the project is to improve the workplace environment's cleanliness. This goal is achieved by eliminating the chances of a chair being left out in the open and guaranteeing that the chair is put back in place. This promotes a better work environment that is organized and free of clutter.

The product must not interfere with people or objects that can be commonly found within the product's environment. Considering that the product is meant to primarily be utilized within an office environment, the objects that are primarily at risk are electronic devices such as computers and printers. The component of our product with the highest chance of affecting these electronic devices would be the signal transmitted from the target destination point of the A.R.C. Thus, we must ensure that the signals we transmit are not incredibly powerful or operate at frequencies that would cause any interference with nearby electrical devices or affect any person in the vicinity.

In addition, we have to take into consideration the effect our product will have in regards to pollution to our environment. The A.R.C. will operate entirely on electrical energy, so there is no concern of air pollution. However, our product will still generate heat and noise pollution. A single product will not generate enough heat or noise to have a substantial effect on its surroundings, however, a concentration of the A.R.C. in a small area, for example, in a conference room, could generate enough sound and heat to affect the small environment.

4.1.3 ECONOMICS

Due to economic constraints, the parts used in this project will be limited. Since we are financing the project ourselves, the project's budget should be as minimal as possible to avoid causing any financial trouble to any of the group members. Furthermore, we want the product to be affordable and thus we want the cost of creation to be kept minimal as well.

4.1.4 MANUFACTURABILITY AND SUSTAINABILITY

Manufacturability describes how easily a product can be constructed or produced. This entails the acquisition of materials, creation of the product, testing and delivering of the product. With this project, we hope to design a product that will, in the future, not require much manufacturing and mostly consist of pre-made components acquired from third-party manufacturers. The majority of the assembly should be a straightforward process of wiring, soldering, and other simple methods.

The electrical components of this project consist of controllers, motors, sensors, and other components that can easily be acquired from a wide variety of sources. The seating element of the product is also fairly standard. Most common office chairs or stools can be used as long as it satisfies safety standards and provides adequate support and comfort to the user.

In regards to sustainability, the largest factor from the mechanical side of the project would be the durability of the components. The product would have to be durable enough to support the weight of an average adult (as specified in the requirement specifications) multiple times throughout a day everyday. Furthermore, the wheels of the product, both for when there is a user seated and when there is no one seated, must be able to easily rotate in any direction if there is no obstacle in the way.

On the electronics side, the largest factor of sustainability would be the lifespan of the product. Specifically, how long the product can function properly before the power supply needs to be recharged. The motors, microcontroller, and sensors will be powered by a rechargeable battery system. To avoid unnecessary power usage, the sensors on the product itself will operate in low power mode, only using the minimal amount of power while someone is seated in the chair. It would only turn on all the sensors and motors of the device when notified that the user has left the seat and it needs to begin searching for the transmitter signal to navigate to its destination. The notification to search for a signal would be triggered when the product detects that no user is seated in the chair for an extended period of time. Ideally, while a user is seated, the product would only use power to check if the user is still seated or not.

4.1.5 SOCIAL AND POLITICAL

The goal of the project is to simply create a cleaner environment by returning a chair to its designated position when not in use. As such, it is unlikely for our product to have any lasting effect on society, however, the possible mindset the project could instill in others is worth discussing.

One of the project's primary goals is to promote a cleaner workplace within the workplace community, such as in an office building. This promotion of a tidier environment could lead to improvements in cleanliness from the same community and lead to more efforts taken to further facilitate this goal.

On the other hand, a device that tidies up after someone could end up having the opposite effect and instead culture laziness and messiness within the community, where individuals would behave under the assumption that something will clean up their mess for them. This would create an unhealthy mindset and negatively impact the community.

4.1.6 ETHICAL

As with any engineering project, all of our members must abide by certain ethical constraints. During both the research and the design phase, each individual member must remain honest when proposing ideas and designs. We acknowledge that the fundamental idea of our project has been realized multiple times in the past. Specifically, the autonomous chair designed by Nissan was the largest source of inspiration for our project.

We desire to maintain our integrity by utilizing an original design for our A.R.C. and avoid creating a product that would infringe on the intellectual property of others. Furthermore, we cited all authors, articles, research papers, and other sources that we reference in this document. The collection of references will be kept in the Appendix located at the end of this document.

4.2 STANDARDS

As stated previously, we must ensure that our project meets the standards set in place to ensure safety and comfort for the user. This section focuses on what the various standards that apply to our product are and the measures we took to abide by them.

4.2.1 OFFICE CHAIR

One of the main aspects of our project is that while someone is seated in the product, it becomes an office chair. Thus, the standards of safety and comfort outlined by the United States Department of Labor's Occupational Safety and Health Administration must be upheld.

The base of the chair should have five (or more) strong legs to provide adequate support and avoid the chair tipping over. Furthermore, the wheels should be caster wheels to allow the user easier to maneuver. The chair should have a backrest that is placed to fit the lower back and support a variety of seated postures. The seat of the chair should be at a height such that the user has feet support (contact with the ground or footrest) encouraging knee placements slightly higher than the seat of the chair. Finally, the armrests must be at the correct height to allow relaxed shoulders while supporting the lower arms and the right width to allow easy access/exit from the chair while keeping the arms close to the body.

The standards provided also discuss how the armrests, seat, and backrest should all be adjustable to allow the user to find the right setting for them (an alternative would be to have the chair made specifically to the user, but this is rare and inefficient for chairs designed to be used by a variety of people). Furthermore, these same components should be made of a soft, comfortable material and have rounded edges.

While we kept these standards in mind, our product is a prototype. We may not have followed every standard perfectly, however, we aimed to follow the principles behind these standards provided by the Occupational Safety and Health Administration to keep the A.R.C. safe for human use.

4.2.2 POWER SOURCE

The power source is an important subsystem of the A.R.C. as the source supplies regulated power to the whole A.R.C. system. Power is required to keep the computer and microcontrollers, as well as the peripherals and motors, active and functioning. The main safety standard here is to maintain, and regulate, certain voltage and power levels so the system does not overload. The voltage levels are itemized below.

- 3.3 Volts
  - Load voltage for small microcontroller devices such as the Arduino and Raspberry Pi processor.
- 5 Volts
  - For devices with higher load consumption such as a servo or sensor modules.
- 12 Volts
  - Voltage level to run the main motors to roll the chair.
  - To actuate automotive grade relays of the system.

Each of these voltage levels are the many load levels to maintain across the whole system. At the failure flag, the system should promptly shut down and light a fault LED that is detailed in the software section 4.2.4.

The following schematic design is a regulator circuit that is capable of stepping 5V to 3V. This system of regulation can be implemented within the computer housing.

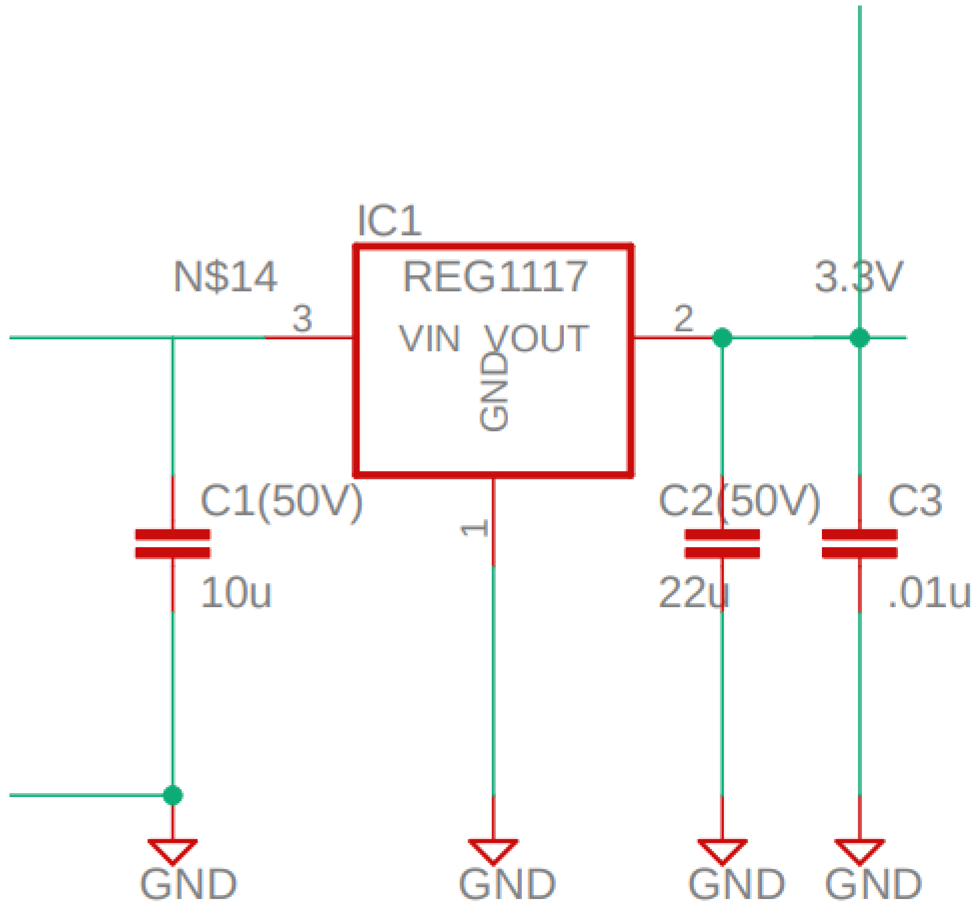


Figure 26 - Simple Voltage Regulator from 5V to 3.3V

As shown, the schematic represents a voltage regulator properly stepping DC voltages. The voltage regulator is a fairly inexpensive device and provides the specific need of producing the correct voltage requirements. The component contains 4-pins with a voltage input and output as well as dual ground pins. Note that EP is short for exposed pad, which is otherwise a ground pin. The exposed pad assists in mounting the microchip.

Notice that the design uses capacitors that smooth voltages from noise. This design implements filtering to ensure that voltage loads do not exceed the intended amount. Since the system does not use a single voltage level, but rather variable levels of load, noise may be generated throughout the system as voltages change. Capacitors ensure noise is reduced by smoothing direct current input and output.

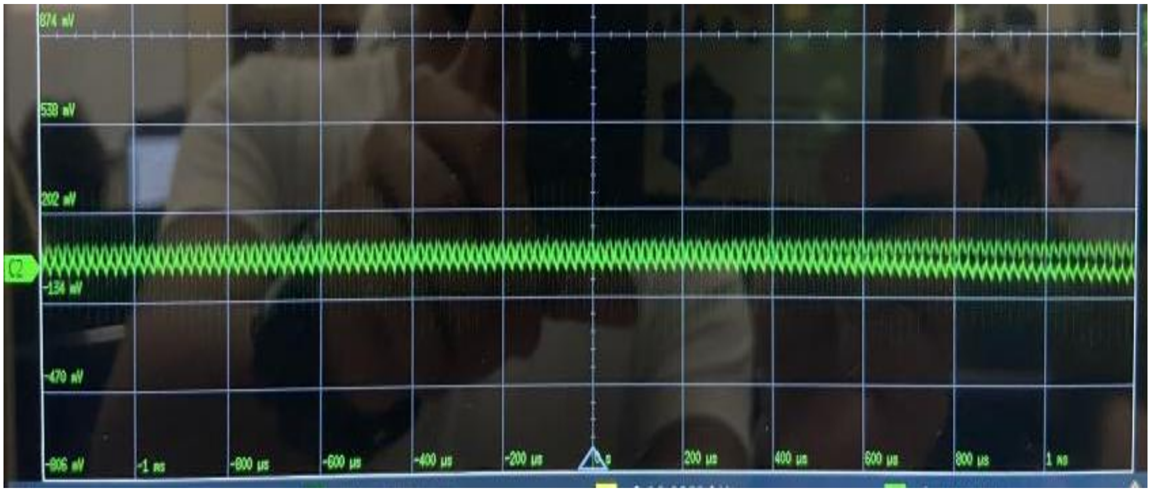


Figure 27 - Unfiltered Voltage Output

Figure 28 - Single Microchip with No Resistors or Capacitors

Using an oscilloscope, we tested what would happen if no sort of capacitors, and sometimes, resistors are implemented. The images above represent a noisy voltage output as well as a visual microchip that does not use resistors and capacitors to filter noise. An output should read a completely flat output. Jittering of loads, as seen, can result in undesired voltage loads. Considering this testing of the circuit shown, filtering is required to ensure reduced noise. A noisy system of voltage loads can disrupt instructions sent out by the controller and can result in a broken system if voltages exceed maximum range.

4.2.3 SIGNAL SYSTEM

The main signal system standard that the team is developing for the use of the signal system is material life extension and efficiency. What this means is that the team will do their best to ensure that the products use the minimal amount of energy during each of its activation cycles. This will benefit the design in the following ways:

- Minimize energy consumption
- Extend Infrared LED transmitter and receiver lifespan.
- Minimize potential heat soak, or short circuiting
- Increase product safety

This is mainly to extend the use of each of the materials used. An example of this would be with the infrared transmitter LED, instead of the transmitter LED being on 24/7 the team will be implementing an activation range via the use of an ultrasonic sensor that will be attached next to the infrared transmitter. The purpose of this is to ensure that the transmitter LED is only activated when the Autonomously Returning Chair (A.R.C.) is out of the set range, which in this case will be 2inches away from the transmitter, this will extend the lifespan of the transmitter LED.

Another example of minimal power consumption usage, and material lifespan extension would be for the phototransistor(infrared receiver) on the Autonomously Returning Chair (A.R.C.). The method the team will be using to accomplish this feat is a timer activated method to ensure this process. In other words, the Autonomously Returning Chair (A.R.C.) will only activate once the device its pressure plate is deactivated and the chair has remained on occupied for approximately 30 seconds. This method will ensure battery life extension, and phototransistor (infrared receiver) life expectancy.

After having taken these precautionary measures, the team believes that the Autonomously Returning Chair (A.R.C.) will be functioning on an efficient standard. These precautionary measures ensure that the device will be using the minimum required energy to operate, which will ensure product safety when installed, and will expand the life-expectancy of the device and its parts.

4.2.4 SOFTWARE

The main software standard is to develop a failsafe code ahead of the main instruction set. In terms of failsafe, that is to raise flags if the chair is faulted and notify the user promptly so that they may repair the issue themselves, or contact the proper technicians for repair. The faults and errors that may occur with the A.R.C are listed below.

- Power Failure
    - Battery is out of charge, or low power

    - The battery has depleted its state of health
- Hardware Failure
    - Shorted, or open, connection points within the system
    - Required peripherals not connected
    - A component has broken or not functioning properly
- Software Failure
    - Device is not programmed
    - Code program is hanging, stalling, or failing to respond

In the modern world of engineering, flagging the user at user level for any faults is the most important so that the user knows that there is a problem with their product, instead of guessing what may have happened when their product does not function as the user expected. Although these faults can be programmed in the software for much higher level errors such as component failures, some faults can be raised electronically through a hardware circuit where the device can light an LED when the system is not programmed, or if the device has a short or open. Installing a fixed hardware fault detection is the most important to ensure a full failsafe system.

At the user level of flagging for faults or errors, a single fault LED will be lit to a certain color by the software, or hardware, depending on where the fault may occur. If the LED is off, there is no fault/error, the A.R.C system is working properly. Depending on that LED color, the user can respond appropriately to the problem. The colors used are itemized below for the user to understand.

- Yellow - Power Failure
- Red - Hardware Failure
- Blue - Software Failure

Should the user contact a technician, the errors can be viewed in more detail and be promptly resolved. More detail means opening the system to reveal the electronic components responsible for making the A.R.C. function and using a third-party device to probe the problem. That third-party probe can be a multimeter, or a premade device that can detect the fault and name the error.

5. PROJECT HARDWARE DESIGN

The project hardware design on this project mainly consists of the mechanical components and the controllers that control the components. It will be necessary to use an MCU to control the movements of the Mecanum wheels and to process what movements to make from the cameras and sensors. This section will dive deeper into the specifications of hardware components as well as issues and reasonings.

5.1 MICROCONTROLLER UNIT

The microcontroller will be the computer that processes all logic surrounding the seating system. The two main devices used for the computer, or microcontroller unit, are the Raspberry Pi and Arduino. Each device is programmed in Python and C, respectively. The key takeaway from using either language and device is where the microcontroller will be implemented. In particular, device peripherals that are actuating such as the motors are programmed in C for movement, and other peripherals such as sensor and image processing are programmed in Python. Each microcontroller device is explained in detail below.

5.1.1 RASPBERRY PI

The Raspberry Pi is a small computer with a Linux architecture, both the central processing unit and random access memory is capable of committing functions and programs similar to a standard desktop personal computer. Any functions programmed onto the Raspberry Pi are generally written in the Python language. Peripherals programmed with this device are pressure sensors and image capturing. The main function of the Raspberry Pi is to collect and gather sensor data, then process a set of instructions to the onboard peripherals such as the Arduino connected to the mechanical objects such as the motors.

Figure 29 - Raspberry Pi Computer Module

This device, as shown in Figure 29, has unlimited modular potential with its expansive ports from universal serial buses to camera functionality to general purpose input/output ports to even an hdmi port for digital interfacing.

For the A.R.C. project, the Raspberry Pi computer will be used as the ‘brain’ of the chair system. The computer will carry out instructions as well as collect data for interpretation. Devices connected are the infrared sensors, camera module, and Arduino. Notice the motor controller is not connected as the Arduino is solely responsible for carrying out mechanical instructions to the controller the device receives from the Raspberry Pi.

We chose a Raspberry Pi because of the convenience of the usage of Python. Having access to Python’s computer vision libraries is essential to the implementation of the project since it is already so deeply established.

5.1.2 ARDUINO

Unlike the Raspberry Pi, the Arduino utilizes a single microcontroller utilizing a single imported code with a set of instructions programmed in the language of C. This language is very simple in which certain functions such as device actuation of motors such as by moving cameras or rotating motors. The main function of the Arduino is to receive instructions from the computer, or Raspberry Pi, and commit those instructions to its mechanical components such as the motors.

Figure 30 - Arduino Microcontroller Module

The Arduino, as imaged in Figure 30 - Arduino Microcontroller Module, has a limited amount of ports. Each port is responsible for relaying instructed outputs, as well as gathering voltage data points from the Arduino's embedded analog to digital converter (ADC). The device, as stated previously, does not function similarly to the Raspberry Pi. Notice in Figure 30 - Arduino Microcontroller Module, that there is a microcontroller on the circuit board of the Arduino. This microcontroller is not a processor with a specific architecture. The microcontroller is flashed with a set of instructions through its universal serial bus port. Once programmed, the microcontroller will only function in its intended functionality made by the programmer. This can otherwise be seen as a looped code, where code is continuously run until an interrupt flag is called, or power is removed.

Connected components of the Arduino are the weight sensors and motor controller. The weight sensor interprets weight by sending analog voltage to the Arduino's ADC port. At the port, the Arduino should be programmed to deliver the weight sensed data to the Raspberry PI for processing. In terms of carrying out instructions, the connected motor controller will be given instructions from the Arduino.

5.1.3 Pinouts

As seen with the microcontrollers in use, which are the Arduino and Raspberry Pi, there are pins with specific functions. The tables and images below represent the pins functionality for each microcontroller.

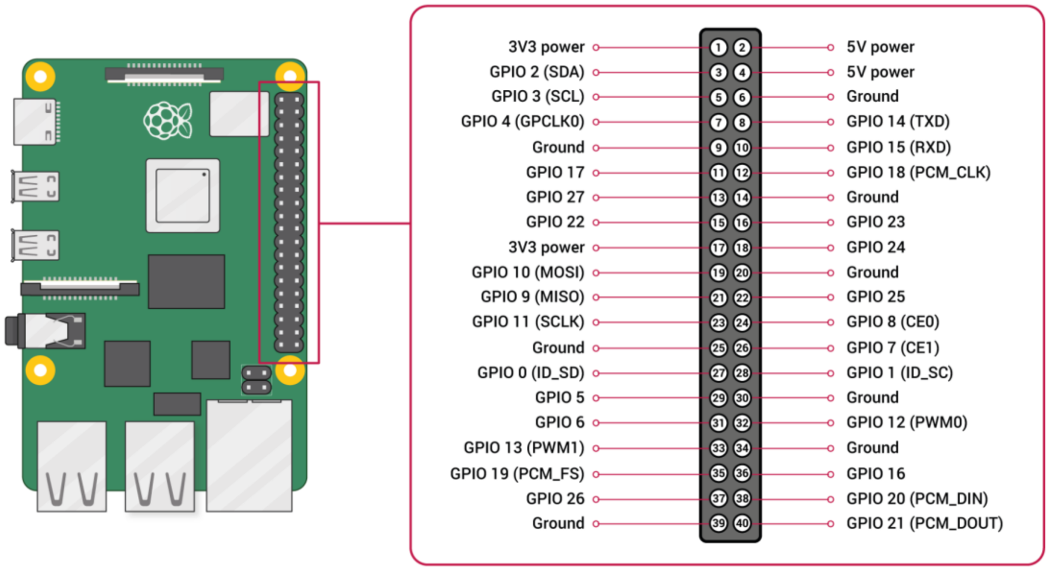


Figure 31 - Raspberry Pi Pinout Diagram

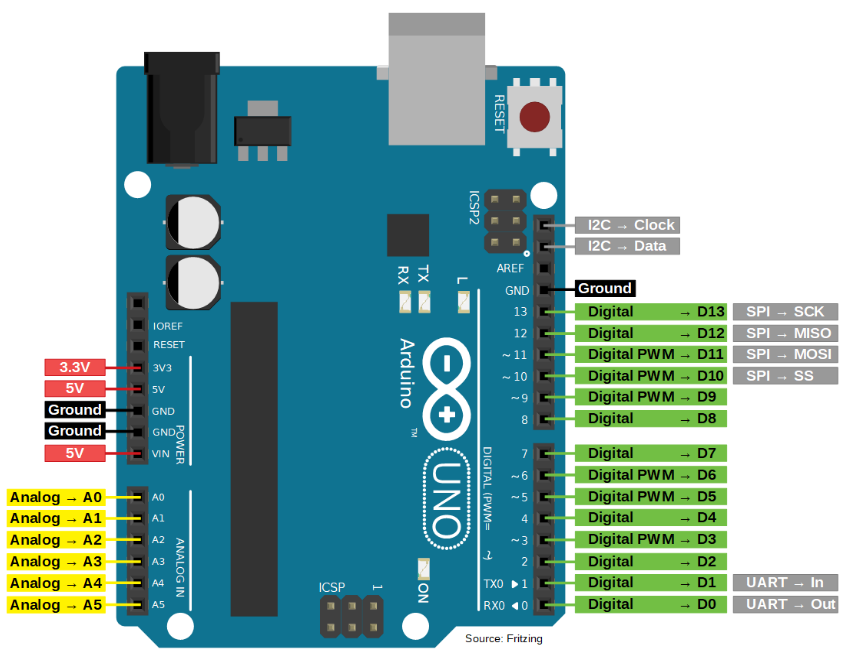


Figure 32 - Arduino Pinout Diagram

5.1.4 Microcontroller PCB Mount

This section outlines the initial design of the printed circuit board meant to mount all peripheral components such as the microcontrollers, which are the Raspberry Pi and Arduino. Other components include the power supply, converter, ultrasonic sensor, pressure plate sensor, and motor controller. Since the design is in the initial phase the shown schematic is populated with components that will be needed for the PCB Mount.

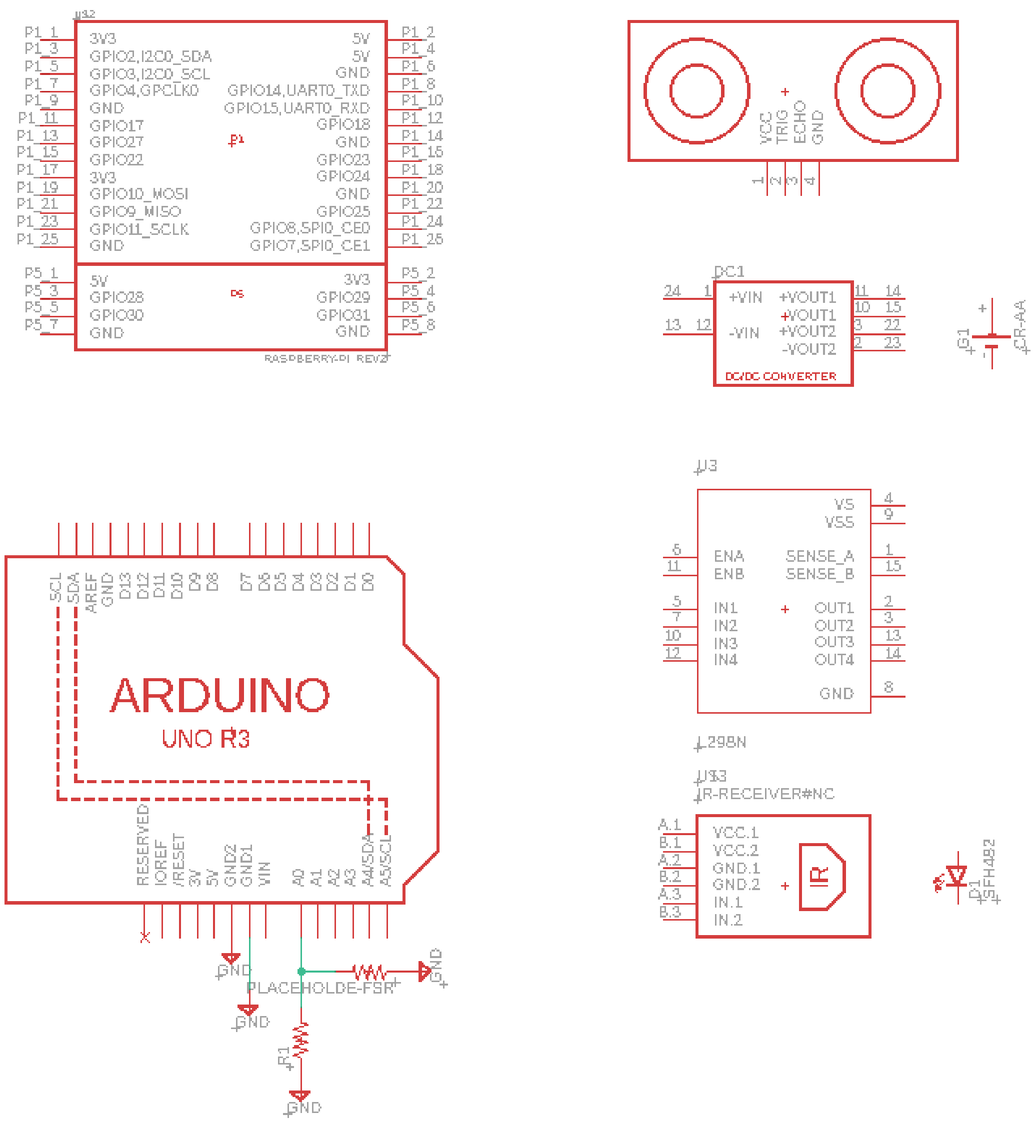


Figure 33 - Populated Schematic of Components

Wiring is not made at this time since the connections are subject to change based on our needs. The schematic simply represents all required components unconnected. To fully determine a working schematic a specific configuration made with a breadboard and loose wires will be used. The following figures are the breadboard for use and the specific wires.

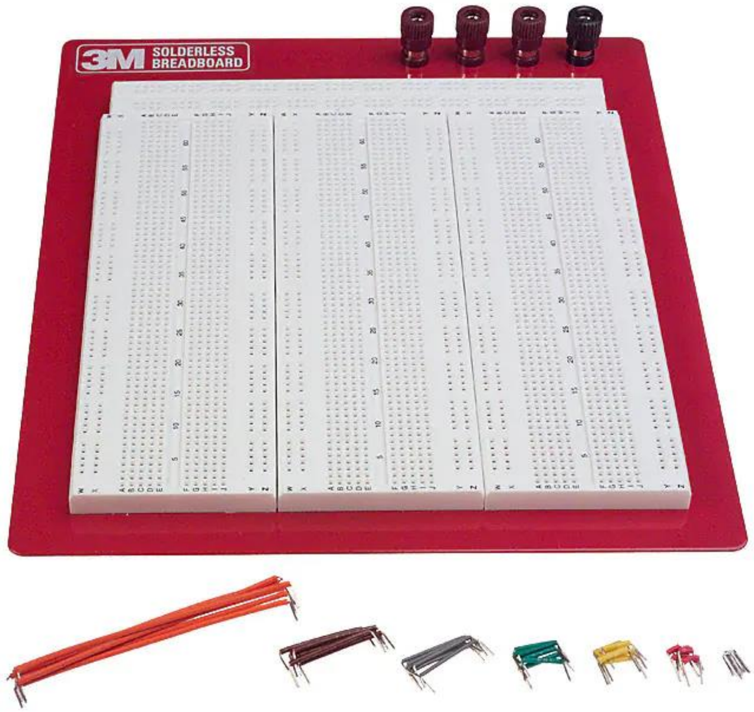


Figure 34 - Breadboard and Set of Wires

In order to design a proper printed circuit board, a rough test design must be made on a breadboard as shown above. Since this semester was solely based on planning, no parts were able to be procured at this time. The next document following the initial planning, the breadboard design will be itemized and shown in further detail. For now, the requirements and constraints for each component are made. The main function of a circuit board is to simply connect all peripheral components together. The components currently in line to be mounted are listed below with detailed explanation.

- Raspberry Pi
  - The main microcontroller processes all instructions received from the arduino and any connected sensors. This microcontroller must be mounted onto the printed circuit board to communicate with the rest of the Arduino and Sensor arrays.
- Arduino

    - The secondary controller that is configured to carry out mechanical functions as well as gather analog data. Programmed to send data to the Raspberry Pi. Mounted in conjunction with the motor controller, Raspberry Pi, and some analog sensors.
- Motor Controller
    - The controller relays instructions received from the Arduino to the connected motors. Must be connected onto the output edges of the PCB with only the Arduino.
- Sensors
    - Not limited to a single type of sensor. Sensors range from pressure sensing, infrared receiver/transceiver, ultrasonic sensor, and a camera. Designed to capture surroundings and digitally map a route to park the chair. Each sensor is different. Must be connected onto the PCB as an input and output for both the Arduino and Raspberry Pi.
- DC-DC Converter
    - There will be no alternating current running through the system as the chair will be running on a rechargeable battery unit. The converter is to regulate voltage levels across the system. This will be mounted on the input side of the PCB.
- Power Supply
    - The main source of energy. Must be completely isolated to prevent damaging of components with over-voltage. Will be connected to the converter to step voltages.

While this is an incomplete schematic, this list itemizes the printed circuit board we intend to implement into our design. As such, we do not limit our options as to how we can connect our circuits together. The next section covers another alternative to using a complex printed circuit board.

5.1.4 Microcontroller PCB Mount Alternative (Shields)

An alternative option to designing a printed circuit board to connect both the Raspberry Pi and Arduino would be to use shields. A shield in which the Arduino is directly mounted on top of the Raspberry Pi. This mounting procedure would provide a more compact approach to pairing the two main microcontrollers programmed in dual languages of C and Python. The design of the printed circuit board would be smaller since lesser connections are required. If at all, there would be no requirement of a printed circuit board, simply the process of cable management connecting peripherals would suffice.

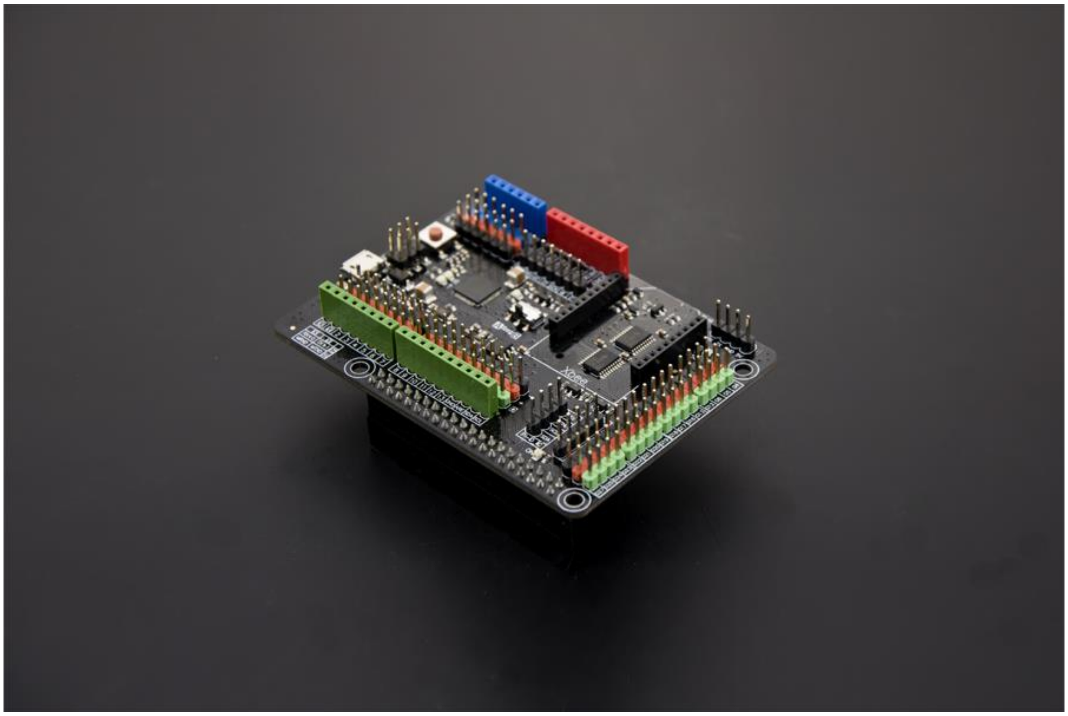


Figure 35 - Arduino Shield to Raspberry Pi

The shield as shown is a modified Arduino acting as an inter-integrated circuit, otherwise, an I2C for short. The idea of using I2Cs has been around for quite some time and is a staple in electronics that not only reduces the amount of wiring needed to connect components, but also saves space by being compact in design. With this method being in use often, costs are small. This specific shield can be used in the latest model of Raspberry Pi. While the Pi is a brain, the Arduino can be seen as the cerebellum. The “little brain” that carries out numerous functions to the system. In summary, the Arduino shield is practical, inexpensive, compact, and modular.

Both the Arduino and Raspberry Pi are completely necessary to create a robotic system. The two prominent components go hand in hand when building a robotic system in any form. These pre-built components are generally for initial designs. Once a proper design has been made, a circuit schematic can be designed with only the components needed. The Arduino and Raspberry Pi are rich in functionality, once a working system is made, the team can pinpoint what components we are using and locate other components that are unnecessary.

5.1.4.1 Pinout Diagram of the Arduino Shield

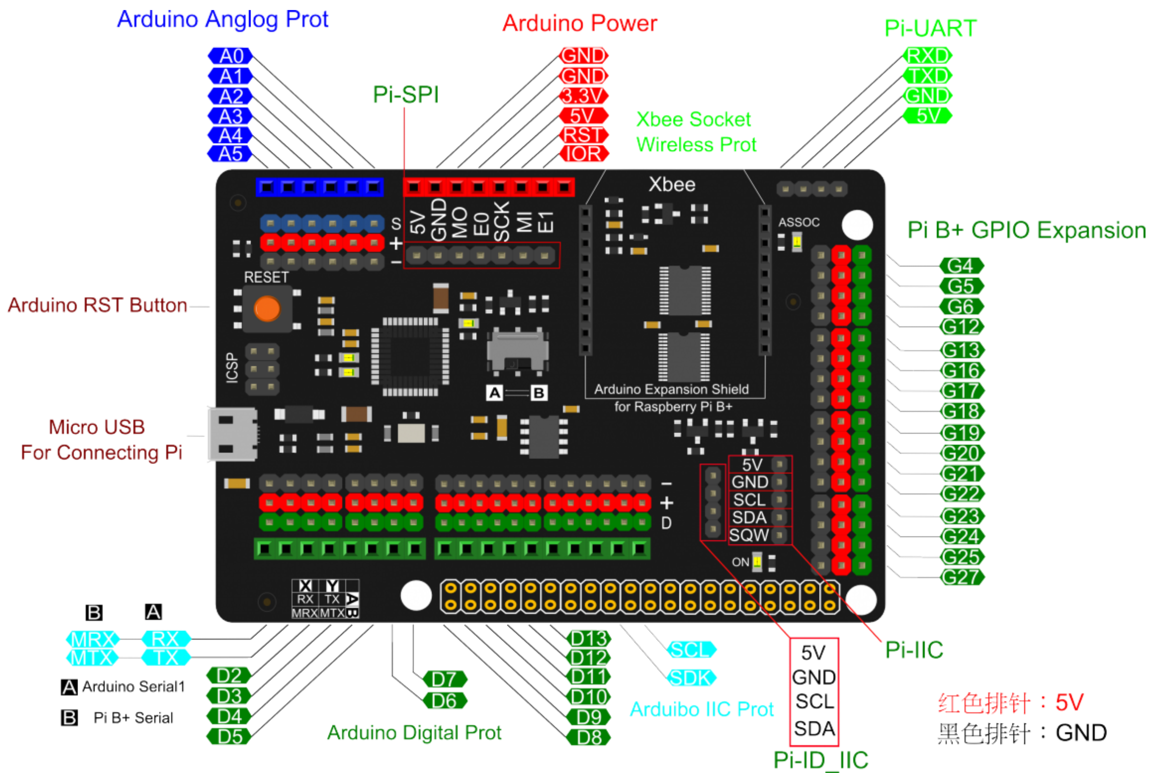


Figure 36 - Arduino Shield Pinout

The figure above are the pinouts of the Arduino shield alternative specified in the previous section. When designing our “brain”, or in engineering terms, the computer, the main peripherals are the sensors and the controller logic. The shield centralizes all connections to those peripherals with an analog to digital converter (ADC), GPIOs, and voltage outputs. What is also included are the SDA and SCL pins, which are the serial clock and serial data pins. These specific pins are responsible for receiving programs from a programmer as well as transmitting data out for testing purposes.

In summary, using shields is an alternative method to designing a printed circuit board. The space saved allows for more real estate in a system, as well as reducing the load weight that can contribute to power consumption. There is also the limitless ability to use shields, in which shields may be stacked onto each other to consolidate all functions to a compact array. For example, the motor controller and driver may also act as a shield for the Arduino. This would further reduce the need for a complex printed circuit board.

5.2 MOTOR SYSTEM

The motor system that was decided on by the group consists of a group of four 5-volt Brushless DC motors. These motors were chosen due to its low power requirement, instantaneous torque generation, and ease of implementation. These four motors will be attached to the base of the chair, split into groups of two for the front half and a rear half of the device. Each motor will be connected to their respective L298 Motor Driver, one for each half. The motor drivers will be able to control the motors based on instructions sent from the arduino controller. Each motor will also be connected to a Mecanum-wheel that they will rotate and control.

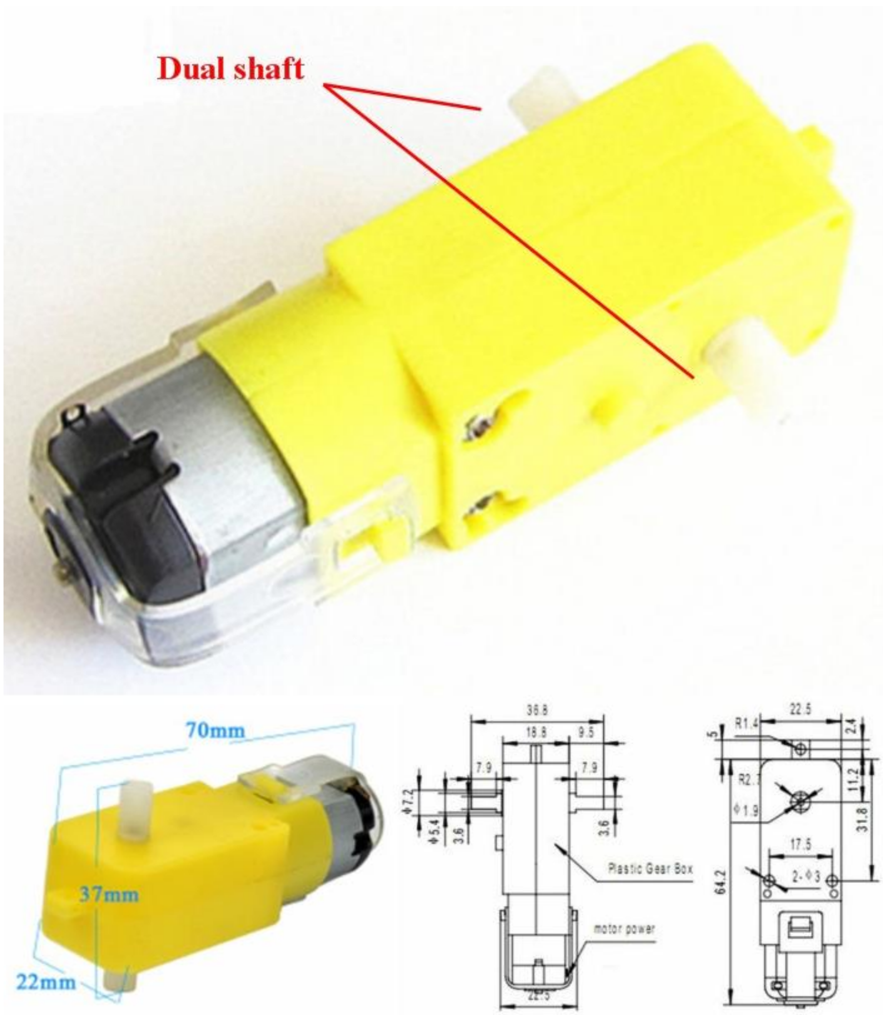


Figure 37 - 5 Volt Brushless DC Motors

Using Mecanum-wheels for the automated movement of the chair would allow for omni directional movement. This capability would allow for more fluid movements similar to a regular chair with caster wheels. The intention of using Mecanum wheels was to mimic the way a regular office chair moves. This is advantageous to us especially because of the specific orientation the chair needs to be in. This is also advantageous for the fact that it saves space due to removing the need to rotate the chair in order to make turns. The chair can take the shortest distance to the destination without the need to make difficult and taxing pivots or turns with the use of Mecanum wheels. They are within specs to withstand just the weight of the chair and components of roughly fifteen pounds. Pictured in Figure 38 - Mecanum omni-wheels, we can see that there are 45 degree rollers that span across the entire tread of the wheel which allows for lateral movements depending on the spin direction of each of the four motors. This will be covered in more detail below in section 5.6.2 Mecanum Wheels.

Figure 38 - Mecanum Omni-Wheels

5.3 SENSOR (DESTINATION SELECTION)

Ultimately after much deliberation, the team has decided on implementing Infrared Sensors as the transmission sensor for the A.R.C.'s home base. The reason the team chose this method is because out of the three options discussed, this seemed to have more characteristics of what the team is looking for in regards to destination selection. Having decided on a method, the team now has to proceed with ways of integrating the infrared sensors into the design.

After careful consideration, the team has decided that it would be best if the sensors are separated into two parts. The first part would be a transmission station positioned at the intended destination of the device (home). This part will function as the location for the Autonomously Returning Chair (A.R.C.) to return to. The second part would be the corresponding receiver that would be placed on the front of the Autonomously Returning Chair. This will serve as the means by which the

A.R.C. will be able to isolate and detect the transmission signal, and double as the guide for the device while it navigates home.

5.3.1 TRANSMITTER

The design of the transmitter (home base) will be as follows. The transmitter will be designed as a wireless box, which can be placed at any location inside a house. The transmitter (home) will not be able to be placed at any location that can cause obstructions and prevent its signal from reaching the A.R.C. In fact, the ideal location the team had in mind was to place the transmitter (home) station underneath a desk in the workplace, for that would be the location with the highest chance of having an open view with no interference that could cause a disconnection between the transmitter and receiver, or the ultrasonic sensor and the base of the A.R.C.

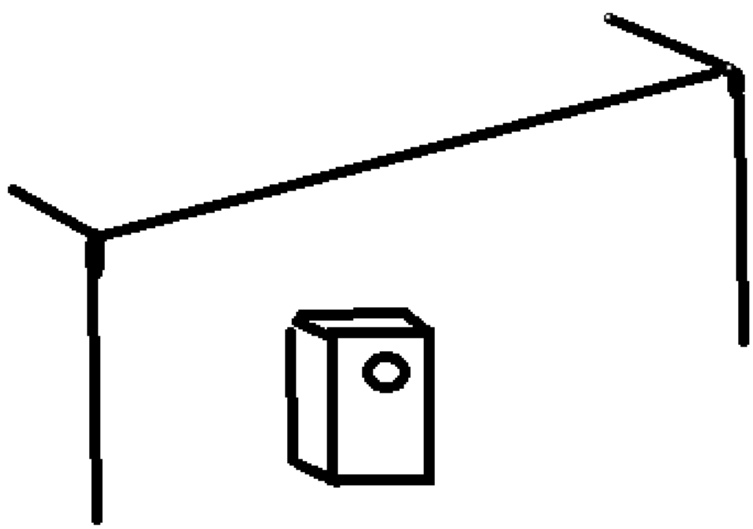


Figure 39 - Transmitter Under Desk

The operation of the transmitter (home) is as follows. The transmitter (home) will have a small incision in it's design, for the infrared led to project from. The transmission station (home) will be fitted with an ultrasonic sensor, which will be used as a range finder. In creating this range finder, the team will be able to program the activation of the infrared LED. I.e. if the Autonomously Returning Chair (A.R.C.) is within a given distance range then the Infrared LED would remain off, thus preserving its life span. However, if the Autonomously Returning Chair (A.R.C.) were to fall out of the set range, then the Infrared LED would project a constant beam of light, till the A.R.C returns within the required distance.

This set range is measured after the user has stood up from the chair for a certain amount of time, measured by the pressure plate. This means that the process begins with the reading from the pressure plate. There are two scenarios that could happen for this set range mechanism after the pressure plate has been raised. One, the chair is already pushed in so the code that reads the set range would skip the code that enables the autonomous mode. Two, the condition is met in which the chair is not within range of the transmitter, so autonomous mode is switched on and used to autonomously return to the transmitter, all while avoiding obstacles.

The purpose of setting a minimum range of activation is to create stricter parameters for when the A.R.C. will use autonomous mode. Having more parameters would give the design more control overall, thus reducing holes in the autonomous feature. It is necessary to think about all types of parameters when designing a project, especially when there are many moving parts that interact together.

5.3.2 RECEIVER

The design of the receiver mounted on the Autonomously Returning Chair (A.R.C.) will be outlined in this section. The base of the chair, which will be controlled by an Mecanum-wheeled robotic device, will have a phototransistor (infrared) receiver attached to the front of the device. The reason the team is attaching the phototransistor (infrared) receiver in the center front of the chair is simply to help the A.R.C. detect and navigate more efficiently, and more precisely.

The operation of the phototransistor (infrared) receiver is as follows. The phototransistor (infrared) receiver will remain in a turned off state for the majority of its use. The Autonomously Returning Chair (A.R.C.) will be programmed to return to its home base once the activation conditions have been met. Now that the activation conditions have been met (the chair has no user in it for a period longer than 2minutes) the phototransistor (infrared) receiver will be turned on. The phototransistor (infrared) receiver will be programmed to look for the transmitter beam, located at the home station. The phototransistor (infrared) receiver will cause the A.R.C. to move around till it finds the transmitter beam. Once the phototransistor (infrared) receiver detects the transmitter beam, then it will move towards the transmitter beam, till it reaches the appropriate distance of the range finder, to turn off the transmitter beam. Once the connection between the transmitter and the receiver has been broken, the phototransistor (infrared) receiver and the whole A.R.C. will turn off and await for the cycle to restart.

5.4 SENSORS (OBJECT DETECTION)

After much deliberation about which sensor to use for the object detection and avoidance feature on the Autonomously Returning Chair (A.R.C.), the team has decided to utilize the power of the ultrasonic sensor. The team has chosen this approach over the other options, because of its familiarity and practicality for object detection. Also, this method was chosen because the A.R.C. will be able to detect objects without bumping into them (referring to bump sensors), and it will be significantly easier than the implementation of lidar.

5.4.1 ULTRASONIC SENSOR DESIGN

The design of the ultrasonic sensor on the Autonomously Returning Chair (A.R.C.) will be as follows. The base of the Autonomously Returning Chair (A.R.C.) will be fitted with eight ultrasonic sensors, two in each corner, hence providing a 360º detection field around the device. The eight ultrasonic sensors are positioned at the red dots in Figure 40 - Position of Ultrasonic Sensors. The reason we chose this design is because it would provide us with the capability of coding the Autonomously Returning Chair (A.R.C.) to be able to maneuver around any object, or through any path, for it will have a constant 360º field of detection as it moves.

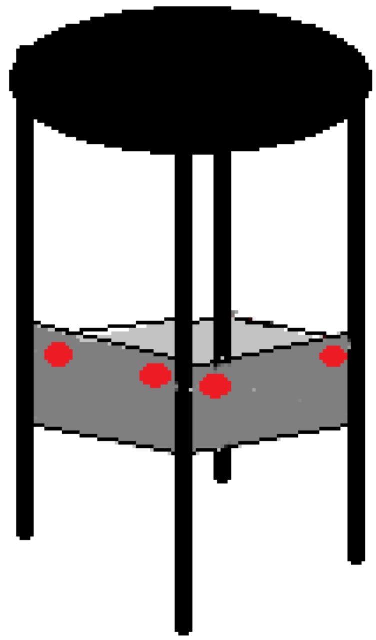


Figure 40 - Position of Ultrasonic Sensors

5.4.2 ULTRASONIC SENSOR OPERATION

The operation of the eight ultrasonic sensors will be as follows. As stated above there will be eight ultrasonic sensors, two in each corner, to provide a 360^o view around the device at all times. The reason the team is implementing two ultrasonic sensors in each corner is to ensure that there are two ultrasonic sensors pointing in the same direction at all times. The reason the team chose this design is simply to increase the efficiency and to give a chance to demonstrate the capability of the Mecanum wheels. I.e. say there is a small object in-front of the A.R.C. and it is only detected by one of the two ultrasonic sensors on the front of the device. Now the A.R.C. will have detected an object on one ultrasonic sensor, now the A.R.C. will use the remaining seven ultrasonic sensors to determine the best course of action. If the A.R.C. was not equipped with Mecanum-wheels, then it would simply turn x^o away from the object for “x” amount of time, then turn back. However, because the A.R.C. is equipped with Mecanum-directional wheels, it can simply use the remaining ultrasonic sensors to determine the most efficient approach for avoiding the object. In this case, it would move in a diagonal angle away from the object, and start to return to its natural course, when the object is detected by one of the side sensors.

In other words the ultrasonic sensors will be set up to detect more than one object at a time. Not only will they be able to detect more than one object, they will also be able to determine the size and importance of the object that they are detecting. The ultrasonic sensors relay the detection of an object to the raspberry pi, along with the location where they were detected from. The raspberry pi will be able to assess the location, and determine the importance based off this information. Importance will be relevant to the location or size of detection, in other words if an object is detected in any direction that is not interfering with the route to the home base, then it will be viewed as unimportant. This stays true except for when the object is detected by multiple ultrasonic sensors, for this usually means that the object is large and could prove to be a problem if not addressed.

5.5 USER DETECTION

The A.R.C. will determine what mode to be in based primarily on whether or not a user is seated in the chair. A pressure plate system will be the method for determining the presence of a seated user. The pressure plate that will be used is the FSR 402 Round Force Sensing Resistor. This pressure sensor was chosen because it is a simple, inexpensive, and reliable sensor that would fit well with the goals of the project. With an 18.28mm diameter sensor, is it small enough to not be bothersome to the user but it is still robust enough to detect a user in a seat. The range of force that the sensor is able to detect is 0.2N to 20N, which has a good threshold to detect a user. The sensor should work fine for the application of the A.R.C. as this is just used simply as a binary switch for the autonomous mode for the chair. Figure 41 - FSR 402 Round Force Sensing Resistor shows that there are two parts to the sensor. The left is the flexible substrate with a semiconductor film. The right is the flexible substrate with electrodes, which is also the active area. There is a spacer mounted on the lip of the flexible substrate with electrodes that leaves a gap between the two substrates to reset the measurement.

When someone is seated, the sensor is able to detect the user and the will flow. Otherwise, no current will flow and a “zero” signal will be sent. Essentially, the seat of the chair acts as a switch for a simple circuit. The pressure plate switch is used to not only start the timer, but to start measuring the distance of the chair and the home base to decide if it is necessary to turn on autonomous mode.

Based on the signal the Raspberry Pi reads during the periodic check, it will be able to interpret whether a user is seated in the chair or not and will either return to checking after the user’s custom set time interval or proceed to check the next conditions before navigating to the set destination.

The way that the FSR 402 is implemented is that it is embedded discretely into the chair where it is wedged between a sheet of plywood and a foam pad. The plywood is thinly blanketing the seat underneath the cushion. The purpose of this is to ensure that regardless of how the weight of the user is distributed onto the seat, the plywood always applies a gradient of force that will activate the sensor from anywhere. Two methods were implanted to allow for an even distribution of force across the active area of the force sensing resistor. The foam pad mentioned earlier provides support that allows the force sensing resistor to be pressed perpendicular to the plywood at any angle. Taped to the sensor's active area is a flat metal con that not only supports the flexible sensor, but it also slightly protrudes the active area allowing it to be compressed more easily and evenly.

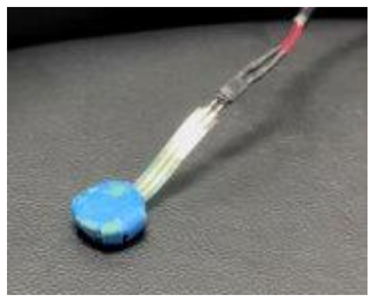


Figure 41 - FSR 402 Round Force Sensing Resistor

5.6 WHEEL SYSTEM

The wheel system will consist of eight wheels total, four Mecanum omni wheels and four caster wheels. This allows the chair to use the appropriate wheels for either the autonomous or the standard mode, respectively. The spring system and the Mecanum wheels will be further explained in these sections.

5.6.1 SPRING SYSTEM

The wheel system required much thought considering the mechanical challenges to be faced. The Mecanum wheels cannot bear the wear of a user while stationary, much less begin to be used properly afterwards. The load weight is around fifteen pounds which is just enough to support the weight of the chair. The initial thought was to have a ball support an even amount of weight as each of the Mecanum wheels but that solution would result with the same problems. Having an even amount of caster wheels split the weight along with the four Mecanum wheels would also be not enough, as the Mecanum wheels would still have to bear a portion of the weight of the user, more weight than they can handle. It was decided that using the caster wheels exclusively while the user was on the seat would be the most beneficial for more than one reason. Having none of the users' weight on the Mecanum wheels would allow for them to remain within load values. Using strictly caster wheels for manual movement also improves mobility since it allows for a better spin.

The design for this requires a system that would allow the Mecanum wheels to make full and exclusive contact with the ground when in autonomous mode. On the other hand, the caster wheels should make full and exclusive contact on the ground when in regular mode in order to bear the full load of the user. In order to do so, the design that will be used is a simple spring system that utilizes the compression forces of the spring. Each Mecanum wheel will have an accompanying caster wheel that is connected to create an enclosed system. When weight is applied to the seat, the spring becomes compressed and the caster wheels are exposed. The Mecanum wheels are applying the force of the compressed spring on the ground at a fraction of the force that the caster wheels are applying on the ground.

Figure 42 - Spring System shows a visual of how the caster and Mecanum wheels operate when weight is applied through sitting on the seat. When seated, only the springs' forces will be applied on the Mecanum wheels on the ground while the caster wheels become lowered through the same springs to support the full weight of the user. What is pictured is only one of the four legs that will be identical to one another. Part (5) is the caster wheel and part (4) is the Mecanum wheel. The parts labeled (1) and (3) on the picture are fastened together so that they are moved together. Part (2) will be able to slide within a shaft in order to accommodate for the compression of the spring, all while ensuring that the Mecanum wheel is free from contact of anything other than the floor. The space that houses the spring should be larger than the distance that (1), (3), and (5) needs to displace to make contact with the floor. The minimum spring force for each spring should be slightly greater than one fourth of the weight of the entire chair and the components. This is to ensure that the caster wheels are cleared from the ground when in autonomous mode. The final detail that is not shown is the lock that prevents (2) and (4) from sliding out of the shaft when the chair is lifted off the ground.

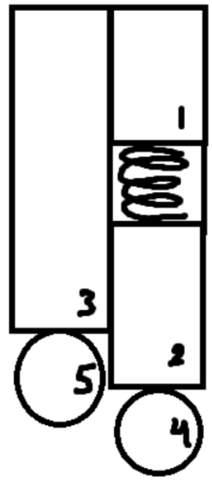


Figure 42 - Spring System

5.6.2 MECANUM WHEELS

The Mecanum wheels are different from regular motor wheels in that they are capable of moving in eight directions without changing orientation. The direction of spinning on each of the wheels will decide what the overall direction will be after all of the opposing forces have all been canceled out. In Figure 43 - Mecanum Wheel Direction, pictured are examples of how the force diagrams look in three specific examples. Wheel set 1 and wheel set 2 shows that when two adjacent wheels move in opposite directions, all of the forces generated will be canceled out completely. Driving sideways shows two examples where all of the diagonal and upward/downward facing forces are canceled out and leaving only the leftward facing forces. Driving forward also shows two examples where the forward forces are kept while all lateral forces are canceled. These combinations with four Mecanum wheels can generate eight directions of movement.

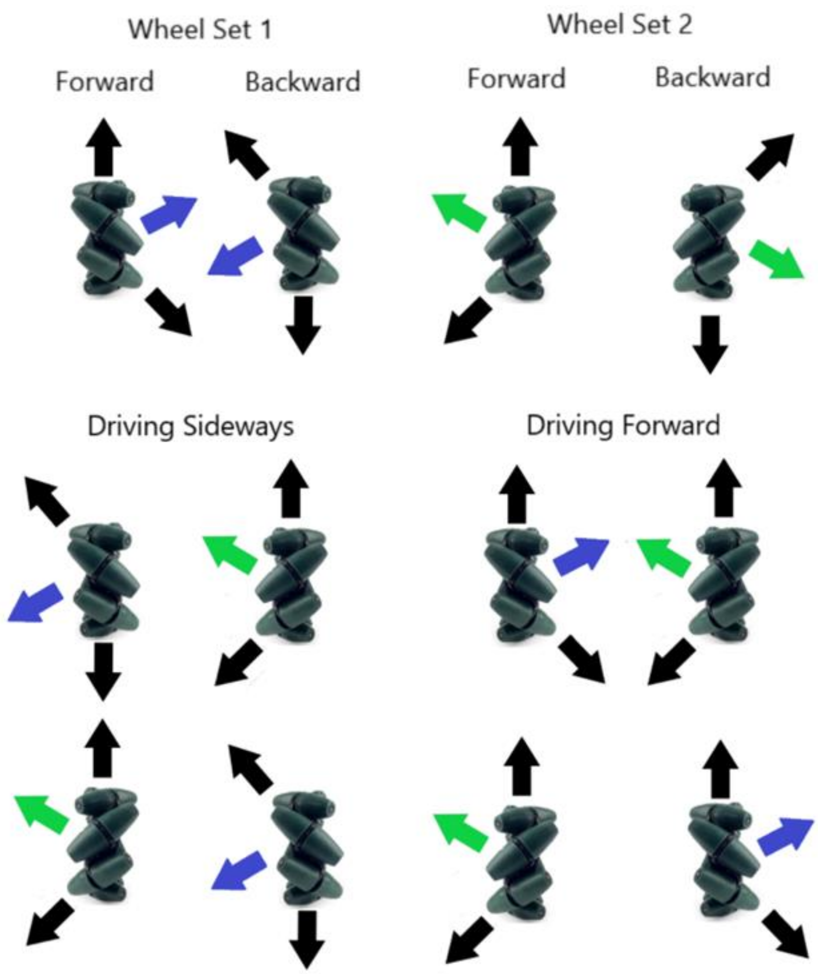


Figure 43 - Mecanum Wheel Direction

5.6.3 SPRINGLESS SYSTEM

An alternative option for the spring system would be to not use springs to allow independence for the two sets of wheels. A more simplified system would drastically reduce the likelihood of failures. Like the spring system, this springless system is also an automatic feature that does not require the user to manually adjust anything to isolate or engage the omni wheels. But we should not count out manual adjustment of the wheels. A manual pulley, which is a more intentionally controlled and rigid mechanical part may also be implemented so that users could have a more defined lift and planting of the wheels. Both ideas will be entertained below.

The underside of the base, pictured in gray in Figure 44 - Springless System with Lever will be where the omni wheels are mounted. The gray base has mounting rings to wrap around the four legs of the chair, but they will be loose fitting to allow for vertical movement. The purpose of the vertical movement of the gray base is to prevent the omni wheels from splitting the load of the chair with the caster wheels. If the gray base is fixed onto the chair and all 8 wheels are level, the weight would be evenly split between all of the wheels which is non ideal. Since the caster wheels are always in contact with the ground in this iteration of the system, the omni wheels underneath the gray base should have no problem maneuvering in autonomous mode while no user is detected on the seat since the casters will just freely roll along with the omni wheels.

The second iteration of this springless system involves a lever to raise and lower the gray base. The lever, pictured in brown in Figure 44 - Springless System with Lever will be attached to the side of the chair and will be free to rotate. Connected to it will be a shaft to translate the rotation from the lever into translational movement for the gray base through a rigid perpendicular arm.

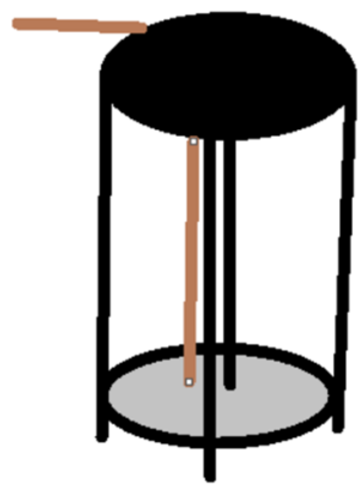


Figure 44 - Springless System with Lever

5.7 USER INTERFACE

An aspect of our design that we want to implement is a user interface. Specifically, we want to make sure that the user can easily identify what mode the A.R.C. is currently operating, whether it is in idle, moving towards its home base, and any other status in between. In addition, we also want to accommodate the user by providing them with the capability of being able to control certain aspects of the device.

5.7.1 POWER SWITCH

The Autonomously Returning Chair (A.R.C.) will be equipped with a power switch, which will be located underneath the seat of the A.R.C. The reason for having a power switch is two-fold: To start, an off switch is necessary in the unlikely event that the A.R.C. would malfunction and would need to be turned off immediately to prevent any damage or injuries. Furthermore, in the scenario where the chair would be inactive for an extended period of time, the user will be able to turn the device off for the purposes of conserving power consumption. Likewise, the off switch would also be convenient in the event that the A.R.C. ends up being transported far enough away from the transmitter station that it is incapable of receiving the signal needed to locate its destination. If left unattended, then the device will activate and actively attempt to search for a signal during its pursuit of returning to the transmitter station. Similar events can result in the chair being stuck in an infinite loop that results in the A.R.C. possibly becoming hazardous to its environment as well as consuming its battery life until it would run out of power. A simple fix would be to give the user the ability to turn off the device and prevent any of this from happening.

The transmitter station/ home base will also have a power switch. Due to the transmitter station being battery powered, and having its own design, the team thought it would be necessary to create a power switch for this device. The purpose of this power switch is solely to extend part life of the parts used in the transmitter station. The off switch is also very useful in the scenario described previously where the A.R.C. ends up a fair distance from the transmitter. Should the A.R.C. be taken out of range of the transmitter station, then the transmitter would activate. Although not dangerous, this would surely drain the battery and diminish the lifespan of the transmitter device.

5.7.2 STATUS LIGHT

It will be important for the user to be able to easily determine what mode the device is in. This information will be conveyed to the user through an LED light located on the back of the chair. The different colors of the light will be indicative of which state the device is currently in and will easily convey this information to the user at a glance. The design is outlined in Figure 25 - Flashing LED circuit.

If a solid white light is displayed, the A.R.C. is in an idle mode. This means that the last time it checked, the device determined that there was a user seated in the chair or that the A.R.C. is too close to the transmitter to warrant navigation. The chair would remain in this low power mode or idle state until it detects that all the conditions for navigation are fulfilled.

If the conditions have been fulfilled, the white light will begin blinking to indicate that the A.R.C. has begun scanning and searching for the transmission signal to locate the destination point. When the transmission signal has been located and the chair is aligned with the destination point, a solid green light will appear, indicating that the A.R.C. has started it’s navigation to said destination.

5.7.3 TIMER KNOB

The A.R.C. will be equipped with a timer knob as well. The timer knob will be located on the hand rest of the A.R.C. and will be accessible to the user. The purpose of this timer knob is for the user to be able to customize the wait time set for the device before it attempts to enter the autonomous mode. By allowing the user to set their own personal timer, the user gains the ability to tailor the device to their needs and tendencies. This privilege allows for more efficiency as the A.R.C. would, ideally, only activate when a significant amount of time has passed for their specific user. The timer knob is programmed to change the time interval between checks by five-seconds. The timer’s lowest setting is set to be 15 seconds and the user can dial it up fifteen-clicks up to the max time setting of one-minute and thirty seconds. While this may seem too short of a time frame in practice, we chose this in order to quickly run tests. The increments and range of the timer will be easily adjusted with changes to the code.

5.8 HARDWARE FLOWCHART

While briefly outlined in Section 2.5.1, a comprehensive flow chart of how the hardware of the A.R.C. will behave is shown below in Figure 45 - Hardware Flowchart. This flowchart is meant to clearly indicate the relationship between each component and the flow of information between them.

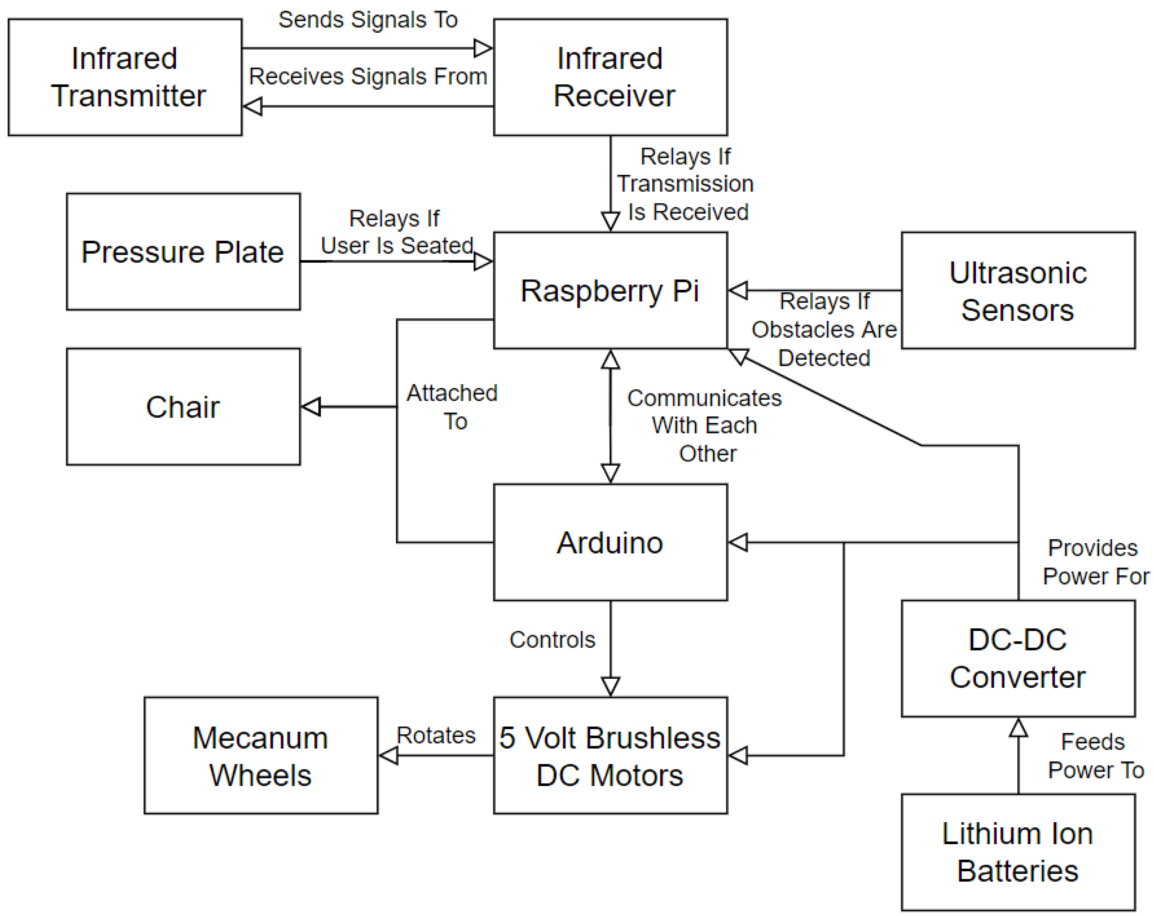


Figure 45 - Hardware Flowchart

6. PROJECT SOFTWARE DESIGN

In this section, we detail our approach to the software portion of this project. We specify the coding languages we used based on our microcontrollers and how the code will enable the features of our project. Furthermore, we breakdown which components of our project will correlate with which languages or microcontroller and how instructions will be communicated from one device to another.

6.1 SOFTWARE LANGUAGES

Software necessary for programming and controlling the A.R.C. will be created with C and Python. The Arduino microcontroller will be programmed with C while Python will be used for the Raspberry Pi microcontroller. As stated previously, the Raspberry Pi will gather information from the various sensors on our device and communicate with the Arduino in order to direct the A.R.C.'s movements as necessary.

6.2 SOFTWARE BEHAVIOR

This section outlines how the A.R.C. will behave during each phase of its automation. We go into more detail here for the process that was briefly outlined in the software block diagram shown in Figure 6 - Software Diagrams with Assigned Members from section 2.5.

6.2.1 USER DETECTION

The device begins in a low power mode, checking for a flag that indicates that no one is seated in the A.R.C. This allows the device to conserve power when there is no need for the other components to be used. The time interval between each check is predetermined by the user based on their custom value inputted by a knob located on the A.R.C.

The pressure plate detects whether or not a user is seated in the A.R.C. The code itself would be constantly idling in a loop, checking if there is a user seated in the A.R.C. While there is someone seated, there will be no instructions communicated to the rest of the device until the pressure plate detects that the user has left the chair. The chair would behave like a normal office chair with caster wheels that allow the user to freely wheel the chair around.

If the user were to leave their seat, the pressure plate would decompress. Should the microcontrollers detect this compression during the constant loop in the code, they would send a signal to the Raspberry Pi to begin using the infrared sensors to locate a destination.

6.2.2 SCANNING FOR DESTINATION

After receiving instructions to search for a destination, the receiver located on the chair will begin searching for a signal from the transmitter. The chair will send signals to the motors to rotate the chair until the receiver alerts the Raspberry Pi that it detects the transmitter signal. Once this occurs, the infrared system will also communicate how far away the receiver is from the transmitter.

Should the distance be greater than 4 feet, then a flag will be raised that the A.R.C. should begin moving towards the destination. The Raspberry Pi communicates with the Arduino to send instructions to the motors to stop rotating and begin its approach, having fulfilled the two conditions for automated chair movement: no user is detected in the seat and the A.R.C. is far enough away to warrant navigation to its destination.

The A.R.C. will begin its return to the transmitter station by looking for the transmitter signal projected from the transmitter station. The A.R.C. scans for the transmission signal, by performing a 360 degree turn, actively searching for the transmitter signal, if the transmitter signal is not found, then the A.R.C. will move ten inches forward and repeat this process till the signal is detected. Once the signal is detected, the raspberry pi will send a signal to the arduino to start accelerating towards the transmission signal.

6.2.3 NAVIGATION

At this point, the Arduino has sent a signal to the motor drivers to begin rotating the motors such that the wheels simply move the chair forward, towards the destination that it just aligned with. As the A.R.C. approaches the transmitter signal, it will still be actively scanning for objects that might need to be avoided on the way towards the transmitter signal. If an object or wall gets detected during the navigation towards the transmitter signal, then the A.R.C. will be primed to make adjustments to its route, to safely get to the transmitter station. Also, if the transmitter signal gets lost by the A.R.C. for any reason, the A.R.C. will revert back to the process used to find the signal, in other words it will make a 360 degree turn, searching for the signal, if the signal is not found than the A.R.C. will move ten inches forwards and repeat the process till the signal is found, and the A.R.C. is back on its route towards the destination.

Once the A.R.C. reaches its destination, and the ultrasonic sensor on the transmitter station detects that the A.R.C. is within a certain distance, it will stop sending out the transmitter signal, and when the A.R.C.'s ultrasonic sensors determine that they are within range of the transmitter they will notify the microcontrollers and they will command the motors to stop. With the A.R.C. arriving at the destination, the system will return to a sleep mode waiting until a user returns and takes a seat or for the chair to be brought far enough away to begin scanning again.

6.2.4 OBSTACLE AVOIDANCE

Located on the base of the A.R.C. is a set of ultrasonic sensors meant to help the device locate obstacles that could interfere with the A.R.C. 's navigation to its intended destination. If the ultrasonic sensors detect something within 2 feet of the A.R.C., whether it is a wall or an object left on the floor, it will send a message to the microcontrollers to begin obstacle avoidance procedures.

The A.R.C. is fitted with eight ultrasonic sensors mounted around its base. These eight ultrasonic sensors provide a constant 360 degree scanning around the A.R.C. as its stationary or as it moves. These eight sensors also help the raspberry pi decide the importance of an object that has been detected. If an object is detected in any direction that is not the direction of the transmitter signal, then the raspberry pi will determine that obstacle as non-important. An object is only considered important if it is detected by more than one ultrasonic sensor, or if it is in the direction of the IR transmitter signal.

Based on the information relayed by the ultrasonic sensors, the microcontroller will decide which direction the A.R.C. will attempt to navigate around the obstacle. The motors will then be directed to rotate the Mecanum wheels in such a way that would allow the A.R.C. to go around the obstacle and return to a position close to being in line with the original straight line it was travelling to reach its destination (The specific obstacle avoidance route is discussed more in section 8.6).

Once the obstacle has successfully been navigated, the program would return to the phase of the automation where it would scan for its destination and repeat the previously mentioned steps until its destination is reached.

6.3 SOFTWARE FLOWCHART

A more comprehensive flow chart of how the software of the A.R.C. will behave is shown below in Figure 46 - Software Flowchart.

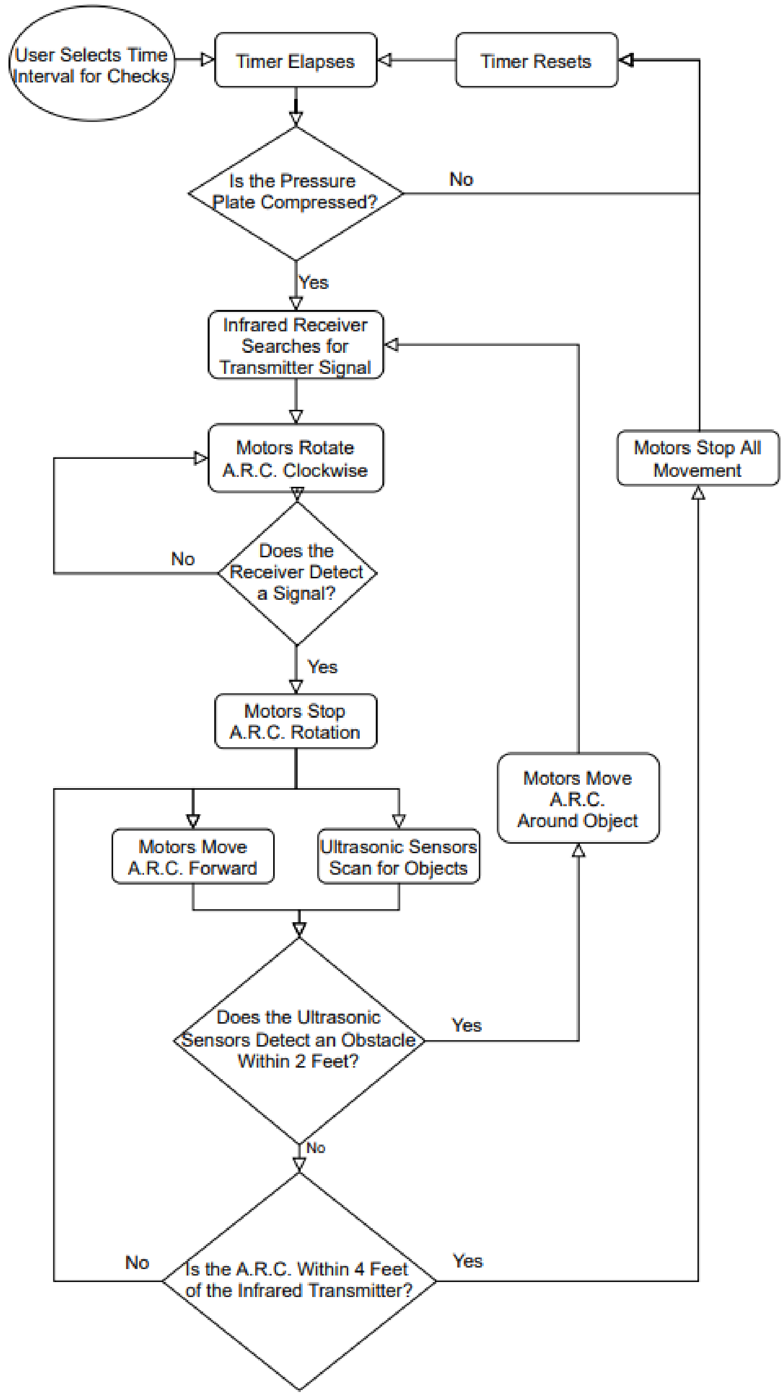


Figure 46 - Software Flowchart

7. PROTOTYPE TESTING PLAN

It was decided that prototype testing sessions were necessary for the success of the project. With many unknown components that were never used by the team, we slowly acquire parts to test as a group. These components could potentially be used directly for the final build in Senior Design 2 if deemed properly functional after testing.

7.1 MECANUM WHEEL TESTING

As a group, it was agreed upon that the omni-directional wheeled robot took priority for prototype testing. We planned on assembling and testing the basic functions performed by a prebuilt robot kit (Further discussed in Section 8). We would test how well the Mecanum wheels would work on different kinds of flooring as well as experiment with the Arduino (in C language) code to figure out how we would program a similar motor system for the A.R.C.

Based on these results, we would conclude how well the Mecanum wheels would fit the scope of the project. The most important flooring we would test would be carpet. While it is possible that the product can be used in a space where the floor is wood or tile, most office spaces would have the product operate on carpet. As such, how well the Mecanum wheels operate in carpet, how consistently it performs in carpet, and how easily we can adapt the motor strength through the code to suit the needs of the A.R.C. will determine if we continue to use the Mecanum wheels going forward.

7.2 MOTOR TESTING

For the motors that accompany the Mecanum wheels, we want to test the weight they can handle as well as their ability to rotate the Mecanum wheels at a constant speed even while handling a load with a weight detailed within the design specifications.

This would be tested by taking the prototype we acquire and running a basic movement pattern under normal conditions, being that the prototype has not been altered and there is no extra weight added. Then, we would run the basic movement pattern multiple times, each time increasing the weight added onto the prototype through small weights weighing 1 pound each.

7.3 INFRARED TESTING

Moving forward, we wish to test out the functionality of each part of the A.R.C. The team will be performing these tests in the prospective order of importance, starting out with the main function. This would entail the phase of returning to the home base location using infrared transmission and reception. We planned to test basic infrared transmission and reception as well as testing the limitations that there may be.

This includes testing the strength of the signal and its effective range, to make sure it would function at the distance we intend to have our device be capable of operating at. Furthermore, we also want to see how consistently the receiver would be able to locate the signal sent from the transmitter. Ideally, we would Using this testing session, decisions on how many receivers to use and at what locations they should be placed at can be found.

The infrared signaling will be tested as follows; firstly, we planned to make small scale prototypes and work our way up from there. To test the infrared reception capability, the team will be using the SEN0158 IR sensor, for it can pick up a signal at an impressive 3m range. We planned to use this IR sensor and a single WL-TIRW Led which would have connected to a breadboard, and which usually only has a transmission span of 10 centimeters. We planned to use these two as testers, to see how far the IR receiver can detect a signal, and to see if the signal can keep a constant connection.

Depending on the results, we would determine whether to increase the testing that was planned or change the type of sensor for this task. In other words, if the signal transmission and reception test did not yield satisfactory reception, we would increase the strength and distance of the transmission signal by using multiple WL-TIRW Leds as necessary to increase the transmission signal till it yields a long, sturdy, and satisfactory project. Once the transmitter projection is sturdier, we are confident that there won’t be any issues regarding detecting the signal and keeping that detection accurate all the way to the source.

7.4 COMPUTER VISION TESTING

Computer vision may be the weakest point in the group considering the lack of computer engineers. The team will proceed to utilizing object detection and avoidance by implementing ultrasonic sensors into the design. There will also be limitations to test since this requires complex algorithms to integrate properly into the system.

We tested how ultrasonic sensors detect when something enters its range and how accurate the distance readings they provided were. Furthermore, we wanted to test multiple layouts for the ultrasonic sensors to be able to use the information they provide to indicate when obstacles appear as the A.R.C. moves around. We also prototyped the code we used that directed the motors to move the A.R.C. to avoid obstacles based on the readings from the ultrasonic sensors. This testing process placed emphasis on how the movement system should respond according to the data that is being fed through the system by these ultrasonic sensors.

7.5 STRETCH GOAL CONSIDERATIONS

After having completed this second task, the team will attempt to try and achieve any of the stretch goals that were planned, to improve the prototype and to present the best possible version possible before the deadline. One of these stretch goal considerations is simply to have the A.R.C. respond to multiple IR transmitters (home bases), I.e- placing one transmitter in your office, one in your kitchen, and one in your living room, then when pressing 1,2 or 3 on the A.R.C., the A.R.C. will then travel to the desired transmitter. However, some of these features are going to require more funding and not just more time, that's why they have been made into stretch goals. Ideally the team would like for the A.R.C. to be created on a mass scale to accommodate a classroom for janitorial or teaching proposing. We would like to have an app that would allow the user to decide the orientation of the chairs through the app. For instance in an ideal situation the team would love to create a classroom of chairs that can move either out of the classroom on command, or to the walls of the classroom without running into each other, and after x- amount of time be able to return to their last known location within the classroom.

7.6 INFRARED PLAN

In the case of implementing the infrared transmission and reception on the prototype, the team will attempt to create an infrared transmission beam using an infrared led that can transmit from a set location, this will be called home base. After having successfully created the home base transmission, the team will proceed by mounting a phototransistor (Infrared receiver) to the front of the prototype. Once mounted and wired, the team will proceed to program the infrared receiver using Raspberry Pi, to detect the transmission signal, and once detected the prototype should advance towards the transmitter signal and stop once it has reached its location. In the prototype and finished product the infrared transmission signal will be terminated once the device reaches its destination, approximately two inches from the home base. The termination of the signal will be performed by an ultrasonic sensor attached to the home base, which will turn off the transmission signal once the prototype falls within the required range.

In using the prototype, we planned on mounting the SEN0158 IR positioning camera at the front of the prototype, and programming it to find the IR transmission signal. To create a prototype for the IR transmission, we created a transmitter using a circuit board. Wanting to ensure that this method worked, the prototype actively searched for the IR transmission signal in the following manner. Once turned on, the prototype will make a 360-degree rotation, actively looking for the IR transmission signal. If the signal is not found, the prototype will move forward ten inches and repeat the process till the transmission signal is found. Once we get our prototype to return to the IR transmission signal using its IR receiver, then we can proceed to focus on the efficiency of our design. After having determined the proper steps to making our prototype and transmitter station more efficient, we would have proceeded to scaling from prototype to actual A.R.C., and from breadboard to printed circuit board.

7.7 COMPUTER VISION PLAN

In the case of implementing the object detection and avoidance feature on the prototype, the team is planning to use this prototype to test the capability of detecting objects on a 360-degree scale around the prototype. This will be done by mounting eight ultrasonic sensors (two on each corner) of the prototype. The way the team intends to have these ultrasonic sensors operate is as follows; the team plans on programming the ultrasonic sensors, to detect an object that intervenes with the route of the prototype returning to its home base. The ultrasonic sensors will detect an object that is approximately half a foot from the prototype. Once the object is detected the prototype will be programmed to use the remaining ultrasonic sensors to detect objects surrounding it (such as walls, or other objects) and determine the best route to take to avoid the object. Seeing how the prototype is fitted with Mecanum-directional wheels, the team will either have the prototype move in a 90-degree motion (still facing in a forward direction), or have the prototype pass the object in a 45-degree motion. These features are possible due to the use of Mecanum-directional wheels. In the case of a 45-degree motion. Once the ultrasonic sensors on the side of the prototype detect the object, the object will return to its original route in the same manner used to avoid the object. In the case of a 90-degree motion; two inches after the object was last detected by the ultrasonic sensor on the side-rear of the prototype, the prototype will make a 90 degree shift back to its original route.

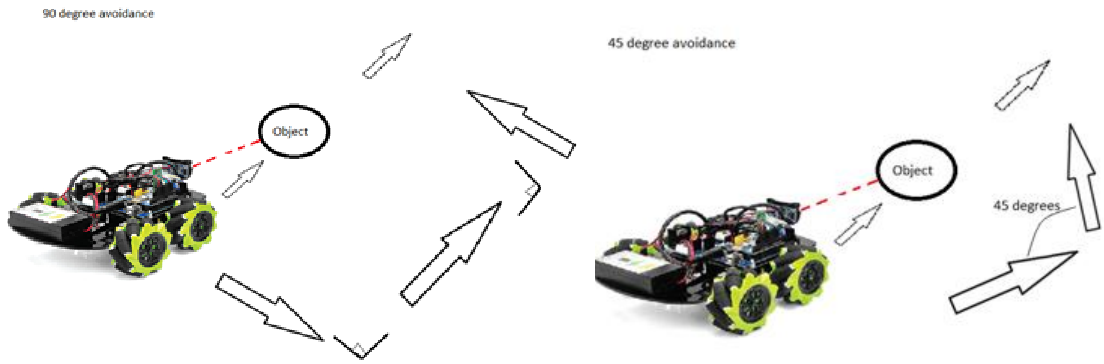


Figure 47 - Demonstration of 90 and 45 Degree Object Avoidance

7.8 FORCE SENSITIVE RESISTOR PLAN

In the case of testing the force sensitive resistor, the team would like to stress test multiple conditions for failure. Although it should work under the circumstances that is necessary for the project, it is still a small sensor that will be subjected to physical wear. We would also like to test the sensitivity of it due to the fact that it can detect as low as 0.2N of force. It might be necessary to maintain a perfect environment with no obstructions and/or covers that may give false readings. A possible solution could be to increase the threshold to the higher end of the load rating of around 20N of force. This covers all of the testing for the sensor.

Testing this sensor with the entire system is the other part of our test. Implementing this to work with the timing in the microcontrollers is the ultimate purpose of the force sensitive resistor. This is related to the software side of the testing conducted for this sensor.

7.9 SPRING SYSTEM PLAN

The spring system for the chair is a complicated mechanical aspect of the chair that is necessary to ensure that both sets of wheels can operate in their ideal conditions. The plan was to 3D print the moving parts with all of the respective locks and pins to hold the pieces in place. There are many points of stress and connections that need to be meticulously designed in order to ensure proper strength and usage. The spring housing can either be designed around the spring or the spring can be fixed to use the housing. The spacing in the spring housing is an important aspect to keep note of. To keep it light, the 3D printed parts could be used in the final design. This is not a main structural component that needs much strength since the max load would be the chair and electrical components, which is estimated to be under 15 pounds. The spring length for this design should be 1 to 2 inches. This would give enough clearance from the ground for the omni wheels to work while not being so tall that the user feels the chair fall to the ground with the compression of the springs under the load.

7.10 SPRINGLESS SYSTEM PLAN

In the springless system, there may be a possibility that the omni wheels do not have the initial friction force to overcome the weight of the A.R.C. on the caster wheels. The plan was to test on multiple surfaces such as tile, carpet, hardwood floor to ensure that it works on all indoor terrain. Adding more weight to the omni wheels might be a solution that should be considered but it ultimately will not solve the issue. Since the base is loose, it could just as easily ride up the legs of the chair since it would take the path with the least resistance. The very final option would be to implement a lever system that would lift and lower the base with the omni wheels. This removes the automatically changing wheel feature, but this guarantees complete independence of the two sets of wheels.

In the case that the Mecanum wheels don't have the traction to overcome the weight of the A.R.C. the team will change the wheel structure to ensure that the motors will have enough traction. In the springless system, the team hopes that they can set the motors to a neutral setting allowing for free range motion when a user is present. However, if the team is unable to realize this, we planned to implement a motorized feature which would have lifted up the motorized wheels of the A.R.C. when a user is present, or when the device is in off mode. This design will most likely consist of a 24-Volt motor attached to the bottom of the seating cushion and will be activated based on the detection of the pressure sensor used to detect a user.

8. PROTOTYPE RESULTS

In this section, we discuss the methodology and results of the prototyping and part testing that we were able to accomplish within the timeframe of senior design 1. This includes a discussion of how successful each component was in their respective test and our decision on whether or not to incorporate the part into our design going forward.

8.1 MECANUM WHEELS ROBOT KIT

To start, this prototype process began by purchasing a premade, functional omni-directional wheeled robot, operated by Arduino code. This robot is equipped with the same 5-volt Brushless DC motors and the Mecanum wheels we originally planned to use. It also came with additional peripherals, such as line following capabilities and ultrasonic sensors. This allowed us to test the features we incorporated into our project as well as alternate methodologies that the team chose to employ on the A.R.C. due to issues with our original design.

The fact that the robot runs on Arduino code also means that we can analyze the code already provided and use it as the basis for the code we would implement in our design, with necessary adjustments, if we chose to continue using mecanum wheels. In other words, the team of solely electrical engineers will be using this prototype to hone their coding capability using Arduino, to test out the ultrasonic sensor setup's ability to be used for object detection and avoidance, the motor's capabilities, and the Mecanum-wheeled robot's movement.

Furthermore, we could incorporate the infrared transmitter and receiver set up and test communication between the Raspberry Pi and the Arduino microcontrollers to see how well the infrared sensors would act as a guide for the motor system of the robot.

In short, the omni-directional wheeled robot will help the team in the following ways, it will provide an idea of how the omni-directional wheels will operate, and how they feel. It provides an example of how electric motors will operate, and the noise they create. It provides a platform to practice and hone the teams' coding skills required for the programming of the Arduino and Raspberry Pi microcontroller.

8.1.1 ASSEMBLY OF ROBOT KIT

Figure 48 - Prototype for Mecanum Wheels

The image shown above is that of the “Mechanical DIY Robot Car Kit” purchased off of amazon, which will be used as the base prototype for the Autonomously Returning Chair (A.R.C.)

Applying Arduino to make the omni-directional wheeled robot operate. After having purchased the “Mechanical DIY Robot Car Kit” the team proceeded to assemble the device by attaching the motor, Mecanum-wheels, Arduino circuit boards, digital meter, and batteries to the provided platform. Once the device was set up, the team proceeded to wire the device and code the device to provide the basic function such as; move forward, move backwards, move left laterally, move right laterally, make left and right turns, and move in each of the four major diagonal directions. These four directions being forward and to the right, forward and to the left, backward and to the right, and backward and to the left. This code was provided by the manufacturer, and served as a standard for the team to use to test the prototype with. Furthermore, the team would make use of the same code as an educational tool to better understand the Arduino code required to control the device in order to be able to manipulate the Mecanum wheels for our own purposes.

8.1.2 MOVEMENT TESTING

After confirming the movements the robot was supposed to do, we began testing the prototype on various surfaces. We ran the code on multiple surfaces, such as wood, carpet, and smooth plastic. For each, we would document the actual movement of the prototype, how it deviated from the expected (if at all), and how consistent the movements were. The results from testing the movement on different floorings are summarized in Table 4 below.

Note that these are results obtained from the prototype, to help identify changes that need to be made to the final design.

On both the wood and smooth plastic surfaces, the prototype executed its movements as we expected, consistent straight line movements along the eight directions and smooth turns. This was true for multiple repetitions to ensure consistency in its performance.

However, this was not entirely true when we ran the code on the carpet surface. While the robot was able to move in a consistent straight line forward and backwards, it showed deviations when moving laterally left and right as well as when moving in diagonals. That is, the robot would drift in a direction that it is not supposed to move towards. This included straying forward when moving laterally left and right, and advancing unevenly instead of in a straight line when moving at an angle.

Floor Material	Expected Movement	Deviations	Consistency Level
Smooth Wood	Forward/Backward	As expected	High
	Left/Right	As expected	High
	Down-Left/Up-Right	Excessive Spinning	Medium
	Down-Right/Up-Left	Excessive Spinning	Medium
	Left/Right Turns	As Expected	High
Smooth Plastic	Forward/Backward	As expected	High
	Left/Right	Excessive Spinning	Medium
	Down-Left/Up-Right	Excessive Spinning	Medium
	Down-Right/Up-Left	Excessive Spinning	Medium
	Left/Right Turns	As Expected	High
Carpet	Forward/Backward	As Expected	High
	Left/Right	Curved Forward	High
	Down-Left/Up-Right	Excessive Spinning	Medium
	Down-Right/Up-Left	Excessive Spinning	Medium
	Left/Right Turns	As Expected	High

Table 4: Mecanum Wheel Testing Results

That being said, each repetition showed a similar trend in their respective deviation. Each movement that had deviations would drift in the same direction across multiple tests. This would imply that, with proper adjustment, we can achieve consistent, straight line movement in all eight directions on a carpet surface.

This revelation is worth mentioning as the primary surface we expect to travel on is carpet, as the A.R.C. was designed for an office environment with matching terrain. The adjustments will be made on the software level, by fine-tuning the code for the movements that contain the deviations we witnessed until we acquire the consistency we desire.

We also intended to do weight testing, to see how adding weight to the robot would affect the movement of the prototype. However, we could not fully experiment with this because of how the motors were attached to the prototype. Each motor was attached to the base of the prototype by two screws that pass through the holes located towards the corners of the motor. These holes, however, are very thin, and showed signs of stress when we only added five pounds. The prototype still moved well, seemingly unaffected by the extra weight.

Unfortunately, to avoid causing damage to the prototype, we have held off on adding enough weight to simulate the 15 pounds that the motors and wheels must be able to support as per our original design specifications. From this, we have determined that we had to pay attention to how we planned to attach the motor system to our design, ensuring that we avoid recreating a similar issue where we would risk damaging the structural integrity of any of the components due to a concentration of weight on fragile parts.

The benefit of using a prototype is indisputable. The team was not only able to acquire a working design on which we could experiment and improve upon for the final product, but we were also able to economically gain valuable experience with materials capable of being used in the actual product as well as test the limitations these materials might have. Specifically, the team was able to test out the torque and power required to have the prototype operate. Armed with this newfound knowledge, the team can scale this up, expanding that knowledge, utilizing it to ensure the required parts that will support the weight of a chair and consistently move it will be procured for the finished product.

8.2 Mark Designs

Progressing through our project, numerous testing is required to ensure a functioning unit. Mark 1 poses as the initial design to test different components to ensure functionality such as our camera, wheels, and motors. Foundation code was also written at Mark 1. At Mark 2, new components were procured with stronger wheels and a much larger fixture for better component support during testing. Additionally, the program was heavily improved with better timing, tracking, and a new ultrasonic sensor functionality. Moving forward, Mark 3 was later designed after running ample testing with Mark 2 confirming proper programming, peripheral functionality, and working devices. Mark 3 stands as the final design with a sleeker and rigid design. The next few sections showcase each design.

8.2.1 Mark I – Initial Build

For the first design, the chairmen tested newly procured components with emphasis on the Raspberry Pi and Motor Controller. There is no intention to use this device for weighted applications. This design implemented foundational code from different movement commands such as forward, backward, left, and right to a basic object tracking protocol with a camera that was installed to test computer vision. Confirming successfully functional components and code, a secondary design was set to be designed and built.

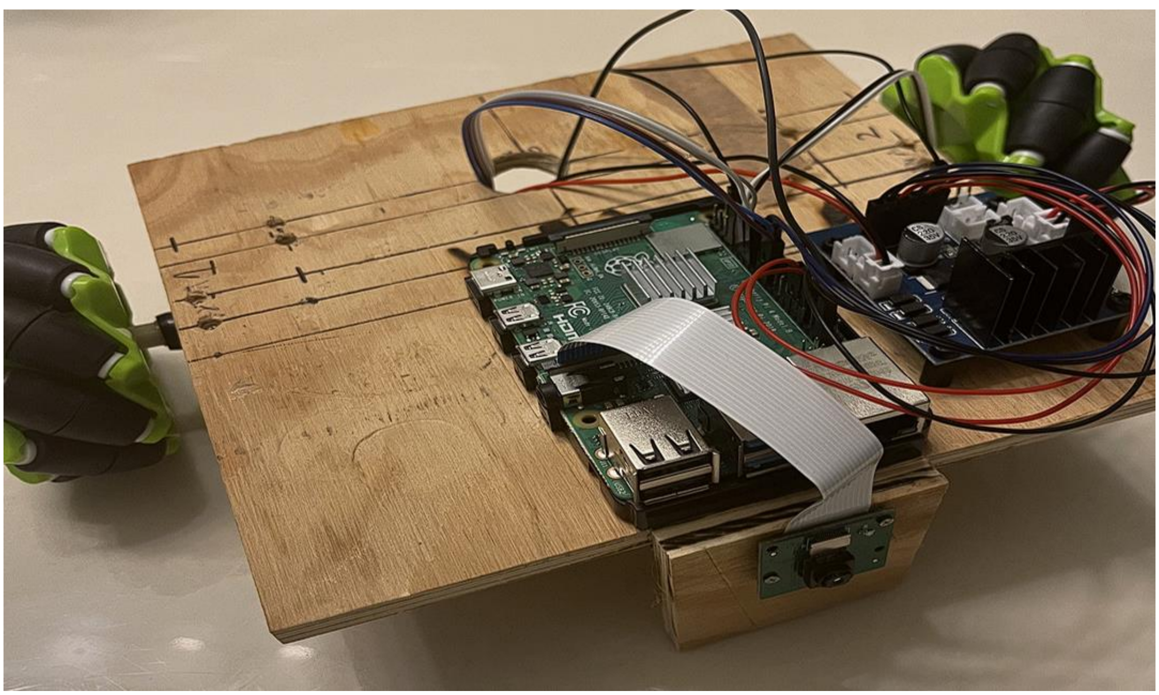


Figure 49 – Prototype Design 1 (Mk. I)

8.2.2 Mark II – Upgraded Build

Taking elements from Mark I, the second design, Mark II implements upgraded components such as stronger wheels, motors, and a newly procured microcontroller development board, the ESP32. This microcontroller serves to isolate mechanical movement from the Raspberry Pi which is tasked to gather environmental data through its camera and a newly implemented ultrasonic sensor for object avoidance. Moreso, the secondary mark essentially implements a form serial data communication between the Raspberry Pi and ESP32 with the Raspberry Pi acting as the main computer for environmental data tasks, and the ESP32 carrying out instructions received from the Raspberry Pi based on that same data.

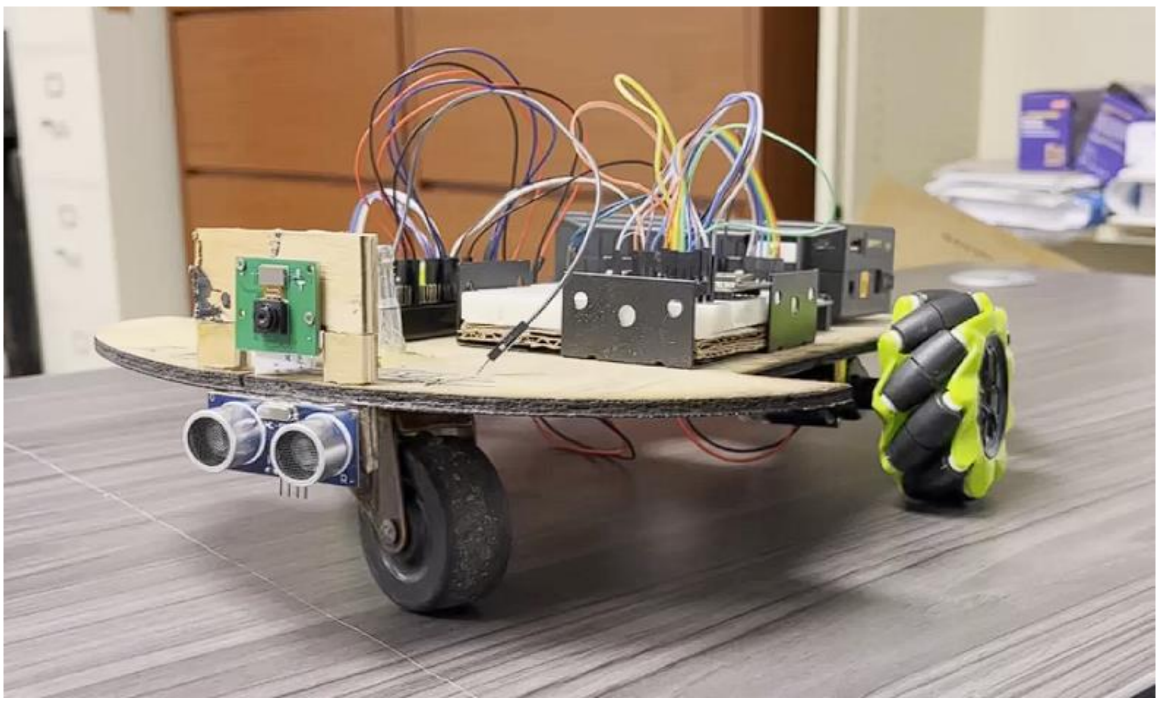


Figure 50 – Prototype Design 2 (Mk. II)

8.2.3 Mark III – Final Showcase Design

All the features tested in previous models have been implemented in this design. The movements have been optimized and smoothed in this design. The final design features an enclosed fixture containing all electronics selected. The chair is also integrated into the final design. The box is designed with air flow openings to ensure the device does not overheat, a hatch to access electronics, and a front panel for sensors and cameras. The enclosure was specifically designed to be rigid and not easily breakable through a method of interlocking. The cuts were also made with a CO2 laser courtesy of the UCF TI Labs.

Figure 51 – Prototype Design 3 (Mk. III)

With each design introduced and constructed, each fixture is pushed to its limits and tested with every possible outcome and feature. Doing so, ensures that our devices function properly before moving into the next design. Having found that all components functioned as we desired, our team ensured that our project will function as designed. The key importance of project building is testing. Without numerous testing and limit pushing, our project may not have reached the success it has attained.

8.3 Printed Circuit Board (PCB) Design

The team was required to include an original printed circuit board design that would be responsible for the movement of the device. The significant printed circuit board designed by the team would be incorporated along with the Raspberry pi 4 model B in its final design. The purpose of the significant PCB in the A.R.C.'s design was to take in commands sent by the Raspberry pi and use its ESP32-WROOM-32D microcontroller to relay commands to the L298N motor controller which would power the motorized wheels and propel the device in the desired direction.

8.3.1 Initial Printed Circuit Board (PCB) Design

The Initial printed circuit board created by the team was intended to power the ESP32-WROOM-32D located on the design, accept commands from the Raspberry pi, send out commands to the respective L298N motor controllers, and show the status of the chair at any given state such as: on, off, searching, home, user present, and error. The PCB was therefore equipped with a 5v to 3.3v buck converter which was used to regulate the 5v input voltage to a respectable 3.3v, 1A output voltage which was used to power the ESP32. Upon arrival the team noticed several issues with the design. Mainly, the design was missing boot and enable buttons, without these devices became unprogrammable, and therefore not usable. The team also noticed that the antenna of the ESP32 was not place on the edge of the device, which ultimately negated future possibilities to implement the ESP32's Bluetooth or Wi-Fi capabilities. Figure 52 – Initial PCB Design displays the initial PCB design.

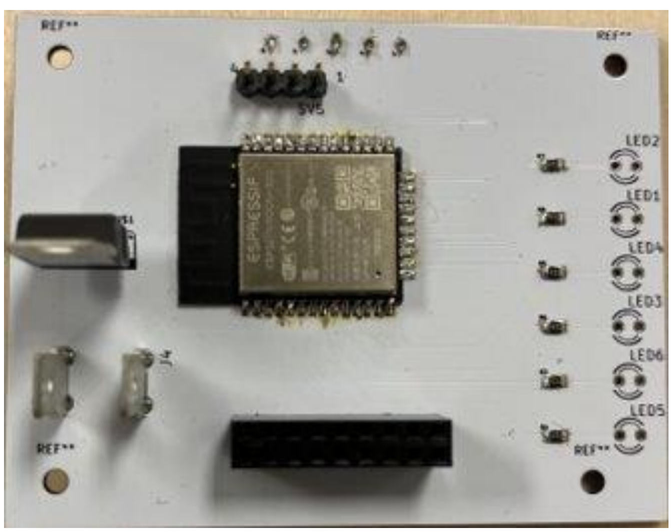


Figure 52 – Initial PCB Design

8.3.2 Final Printed Circuit Board (PCB) Design

After realizing the mistakes from the first PCB, a second one was made with significant improvements. First and foremost, the layout of the board was meticulously designed to ensure the separation of the power and logic components on opposite sides of the board. The Wi-Fi and Bluetooth module of the ESP32 was also oriented to face away from the board and two decoupling capacitors were placed in parallel near the ESP32's power input. These changes were all to maximally reduce noise affected the ESP32 during operation. The status LEDs that were on the initial design were all removed due to redundancy and were replaced by a single LED that indicated when the ESP32 is receiving power. It is placed parallel to the power line leading into the ESP32. The most critical addition to the PCB was the implementation of the boot and enable buttons. Missing from the previous design, these allowed for the ESP32 to become programmable. An L293D motor driver was also implemented onto the PCB to maintain modularity and are used to control the two wheel motors. The board receives 5V of power from an off the shelf regulator into a DC barrel jack, which feeds into the motor driver and the 5V to 3.3V regulator on the board. The output of the regulator is capable of providing 1.5A of current to supply every component of the board at 3.3V.

Although improved, problems were still discovered on the PCB. The board was initially not able to be flashed but it was discovered that the pins of the boot and enable buttons were incorrectly shifted 90 degrees on the footprints provided on Mouser, which ultimately grounded the entire button. Since the buttons were rectangular and not square, they could not be rotated and placed back into the board without breakage of the pins, so they were soldered using short wires to the correct pins in Figure 3 – Final PCB Design. The motor drivers did not have proper cooling hence the risk of prolonged use was questioned. Overall, the design is more organized and functional with the improvements.

Figure 53 – Final PCB Design

8.4 Motor Mount

The motor mount was designed in Fusion 360 and 3D printed to be used as a rigid uniform body to mount the motors and gearboxes. This is to ensure that both wheels are square with the box as well as square with one another. The motor mount is designed to be fastened to the underside of the electrical components housing, and together, they provide amble structural support to the base and the motors.

8.4.1 Initial Motor Mount Design

The initial motor mount design was designed for Mark II of the chair. This design was successful but changed due to releasing the Mark III.

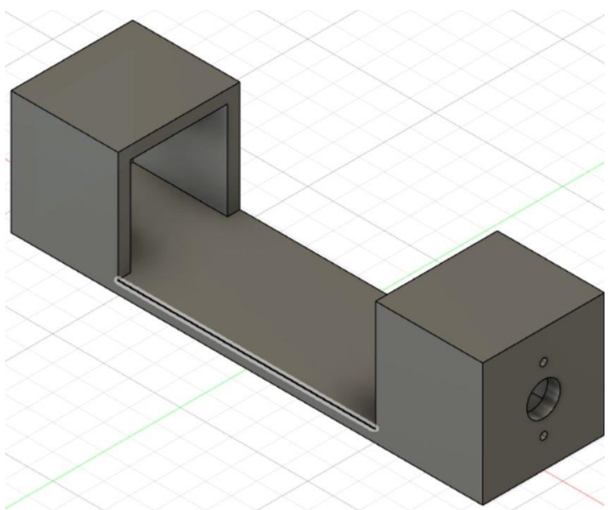


Figure 54 – Initial Motor Mount Design

8.4.2 Final Motor Mount Design

The final motor mount design was designed for the Mark III. We saw that the initial design was bulky and did not have mounting holes so in the final design, we addressed these issues. The main reason for the creation of the final motor mount design was to fit the new gearboxes and the new motors.

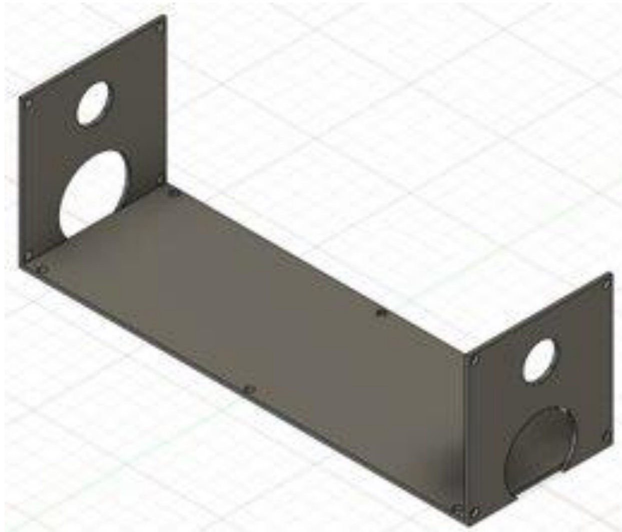


Figure 55 – Final Motor Mount Design

9. Planned Device Operation

In this section, we detail how the device will operate. We discuss the various conditions that the A.R.C. checks for before turning on as well as the decision making process that determines the device behavior. The outline of this procedure is depicted in the flowchart shown below in Figure 56 - Device Operation Flowchart.

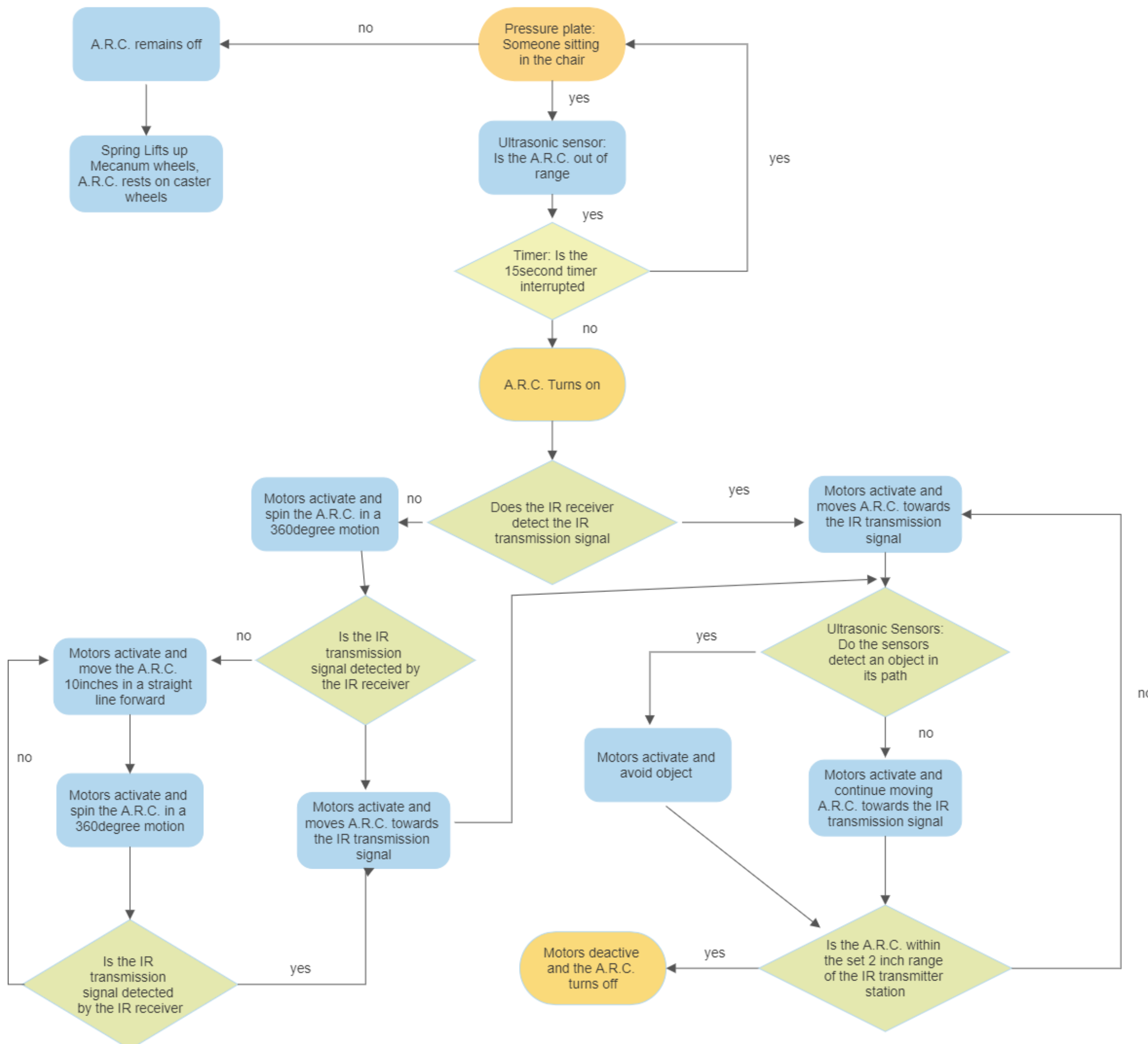


Figure 56 - Device Operation Flowchart

9.1 ACTIVATION REQUIREMENTS

The device is initially in a low power mode in order to conserve battery life and reduce unnecessary power consumption. In order to leave this mode, the A.R.C. must detect that all requirements have been fulfilled in order to begin scanning for and navigating towards its destination.

9.1.1 PRESSURE PLATE REQUIREMENT

The first activation requirement is probably the most important one, for it is a condition that aligns with the creators' vision of not having the Autonomously

Returning Chair (A.R.C.) operate with someone on the chair. Therefore, this is the first activation requirement, for the chair itself uses a pressure sensor to ensure that there is no weight on the seat, once the device confirms that there is no weight on the seat, it completes its first activation condition and proceeds to the next.

9.1.2 DISTANCE REQUIREMENT

After the first condition is satisfied, and the A.R.C. confirms that there are no users in the chair, it proceeds to testing the second condition, which is distance. This condition is crucial towards the activation of the A.R.C. for it to ensure that the A.R.C. is actually away from its home base, and therefore needs to activate to return. This condition is tested via the use of an HC-SR04 ultrasonic ranging detector, placed at the front of the A.R.C.'s base. Once the first condition is satisfied, the A.R.C. will activate the ultrasonic sensor, to determine whether the second condition is satisfied. Once, the ultrasonic sensor is turned on, and determines that the A.R.C. is more than two inches away from the transmitter station, then the second condition will be satisfied, and the A.R.C. will proceed to testing the third and final activation condition.

9.1.3 TIMER REQUIREMENT

The Autonomously Returning Chair(A.R.C.) must satisfy the pressure plate, and the distance condition before testing the third and final condition which is the timer condition. The timer condition operates as you would expect, once the A.R.C determines that there is no individual in the chair, and that the chair is actually away from its supposed location, the A.R.C. will activate a timer of fifteen-seconds, in which both of the prior conditions must hold true, if any of the prior conditions prove to not be true while the timer condition is being tested, then the device will remain off. However, if the timer condition is successfully completed with no interruptions brought to the first two conditions, then the A.R.C. will have officially been turned on, and the process to return to the transmitter location will officially get started.

9.2 HARDWARE USAGE

This section discusses the microcontrollers that will be used in the design and how they will communicate with the other components in the device. Also, this section discusses the weight detection system, in other words, the pressure plate, and the role it plays in the design.

9.2.1 MICROCONTROLLER DESIGN

The Autonomously Returning Chair (A.R.C.) is a very complicated device with several different components, however, without the Arduino and Raspberry pi microcontrollers the device would not operate. The Arduino microcontroller will be connected to the Raspberry pi microcontroller, for the raspberry pi will serve as the “brain” instruction leader, and the Arduino microcontroller will be the “body” and basically relay all the instructions it has received from the raspberry pi. Both of these microcontrollers, along with the motor controllers will be mounted on the top of the Mecanum wheel platform of the A.R.C.

9.2.2 MICROCONTROLLER OPERATIONS

As shown in the operations flowchart from Figure 56 - Device Operation Flowchart, instructions will be relayed from the raspberry pi to the arduino and then to the motor controller. In other words, the Raspberry pi will serve as the A.R.C. 's brain for it will carry out the instructions and collect data for interpretation. The Ultrasonic sensors, IR receiver, and the arduino will all be connected to the Raspberry pi microcontroller. Information from the sensors is relayed to and interpreted by the Raspberry pi. After determining what the A.R.C. should do, it will then send out instructions to the Arduino microcontroller (the body) about what the A.R.C. should do. The Arduino microcontroller will then follow suit and send out mechanical instructions to the Motor controllers that will manipulate the motors, and by extension the wheels, to move the A.R.C. how we desire it to.

9.2.3 PRESSURE PLATE DESIGN

The A.R.C. will be fitted with a pressure plate sensor at the top of the A.R.C. right underneath the seat. The reason for placing the pressure sensor under the seat is simply for aesthetics, this location won’t increase accuracy in any shape or form. However, seeing how the team only needed the pressure plate to account for a weight of twenty pounds and up, they agreed that placing the pressure sensor at that location would not impact the design.

9.2.4 PRESSURE PLATE OPERATION

The operation of the pressure plate is as expected. When pressure is applied the pressure plate will activate. The purpose of the pressure plate is to serve as the first and main activation requirement, in which it is determined whether or not there is a user on the A.R.C. or not.

The team has decided to use the Force Sensitivity Resistor to perform the tasks of the pressure plate. The reason we chose to use this force sensitive resistor, is because the resistor has a round diameter of 0.5” for its sensing area, and it's able to detect weight anywhere from 100g to 10kg. Another benefit this sensitivity resistor provides is that it has a two pin connection with a 0.1” port, in other words this resistor is breadboard friendly, and therefore would be perfect for prototype testing. The image below is that of the FSR that will be used in the design of the A.R.C.

Figure 57: Force Sensitive Resistor

9.3 SIGNAL TRANSMISSION

After the device has successfully met all the requirements and turns on, the signal transmission system will be the determining factor for what action the A.R.C. will take next. In this section, we go into detail about the design of the signal transmission system and its behavior.

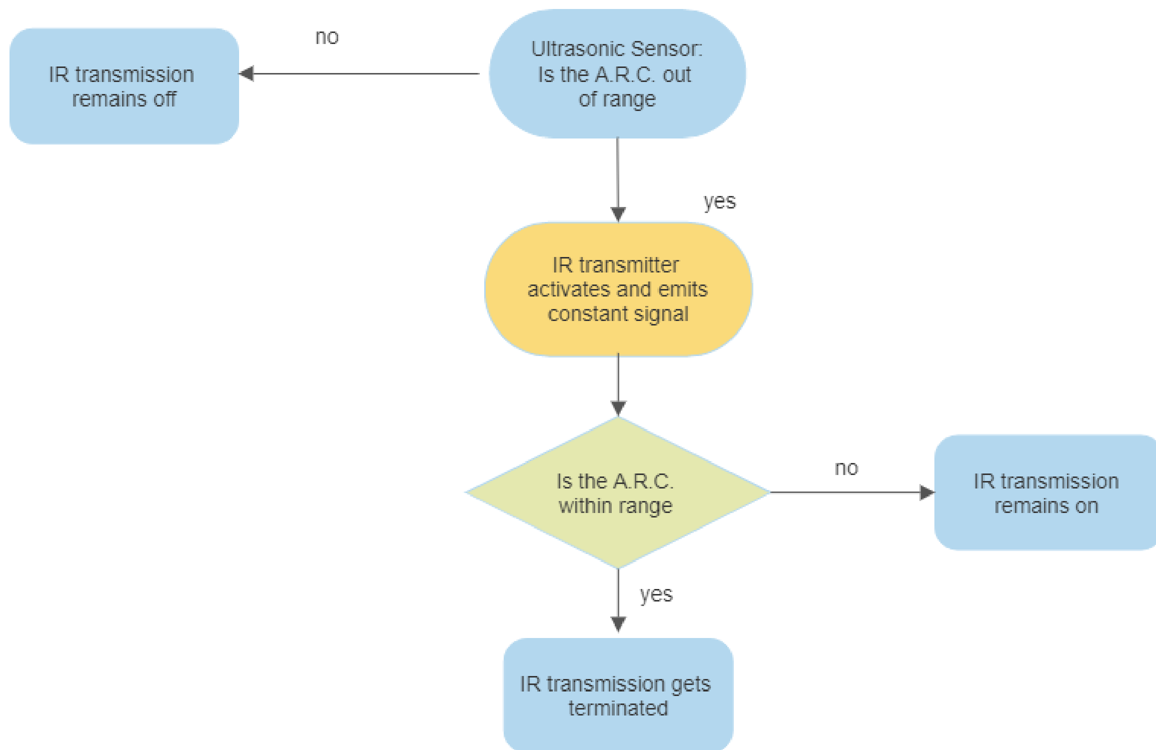


Figure 58 - Transmitter Station Flowchart

9.3.1 IR TRANSMITTER DESIGN

The way the IR Transmitter will be designed is as follows. The Infrared Transmitter station will be an independent unit that is separate from the A.R.C. and can be placed at any location, determined by the user, to be the destination point. The transmitter station will have its own circuit design as well as its own power supply, which will allow it to be portable. Therefore, the transmitter is not restricted to a single location. The transmitter station will hide the circuit and battery set up within a box like structure, which will have a small circular opening for the infrared Led to transmit its signal out of. The only restriction on the placement of the transmitter is that the opening that allows the infrared signal to be sent out must not be covered up in order to allow the signal to be sent out.

9.3.2 ACTIVATION CONDITION

Seeing how the transmitter station will have its own circuit design and power supply, it is only fitting that it has its own activation condition. The purpose of installing an activation condition on the transmitter station is simply to conserve battery life by reducing the amount of time the device is on unnecessarily. This would also extend the life of the infrared led itself by not forcing them to constantly emit a signal continuously. The activation condition that will be used for the transmitter station is based upon the distance between the transmitter and the A.R.C. This condition will be carried out via the use of a HC-SR04 ultrasonic ranging distance sensor. Once the ultrasonic sensors determine that the A.R.C. is further than two inches away from the transmitter station, then condition will be satisfied, and the transmitter station will start emitting a constant IR transmission signal that will only stop once the A.R.C. returns within the two inch distance of the transmitter station, therefore, rendering the condition not satisfied. The benefit of this condition is that it will later on serve as a method of stopping the A.R.C. by ending the IR transmission, resulting in the A.R.C. stopping within the desired range of the destination.

9.3.3 IR TRANSMITTER

For the transmitter station, the team will be utilizing the powers of infrared sensors. More specifically the team will be using a WL-TIRW series infrared Led, which depending on the voltage supply can project an infrared beam anywhere from two-centimeters to about ten-centimeters with a 35degree detection angle. Seeing how this signal range would be insufficient to perform the tasks that the team expect, the team will be attempting to create a long range IR transmitter circuit. The purpose of this long range IR transmitter circuit is to satisfy the goal set forth by the team. Seeing how one IR LED did not provide sufficient emittance range, the team plans to connect three different IR LEDs in series, on the long range IR transmitter circuit. In doing this, the team hopes to add to the emittance distance by approximately one-hundred centimeter, and in doing so, the team hopes to have created a long range infrared transmitter which can be used to better reach the A.R.C. 's Infrared receiver. This design was motivated by “circuitdigest.com.” During the testing phase of this project the team will be attempting to create a transmitter signal which is as long as possible, while also being efficient. In the example above, the long range IR transmitter is created by connecting three different WL-TIRW series infrared Leds in series to each other, to increase the beam length and the degree detection angle.

In order to determine the best design, the team will be making several calculations to support the scaling that will be needed in order to have this long range IR transmitter be as efficient as possible. In other words, the team has to determine the ideal distance the transmitter has to project that doesn’t drain an excessive amount of battery. In the example above, the IR transmitter uses 3 different WL-TIRW Leds placed in series to increase the transmission distance from ten centimeters to one-hundred centimeters. For the project, this signal might be stronger than necessary or not strong enough, depending on the size of the room, the team will have to create a long range IR transmitter that will project shorter or longer distances than one-hundred centimeters, to ensure maximum battery efficiency and battery life.

9.4 SIGNAL RECEIVING

Following the transmission system, we now discuss the other end of the signal: the receiver. We cover the optimal placement of the receiver, its construction, and how it will behave to benefit our design. Furthermore, we note how it will interact with the rest of the design, specifically with the microcontrollers.

9.4.1 IR RECEIVER DESIGN

The infrared receiver will be placed in the center front of the Autonomously Returning Chair (A.R.C.)'s base. There are several factors that contributed to the teams' decision for this design, such as cleanliness, minimization of interference, and ease of connecting. However, the main reason the team opted for this design was convenience and ease. More specifically, with the infrared receiver being placed at the center front of the device, a substantial amount of coding would be prevented, trying to have the A.R.C. face the transmitter station in a correctly facing manner.

9.4.2 IR RECEIVER

For the infrared receiver which will be placed in the center on the front of the A.R.C., the team has decided to utilize the power of a SEN0158 IR Positioning Camera from Arduin. There were several candidates for an infrared receiver, however, ultimately the team thought that the SEN0158 IR receiver was the best fit for our design. This infrared receiver can operate using the limited power supply that will be provided by the batteries. This infrared receiver also has the capability of detecting four infrared emitting objects, within a distance of 3m. The infrared receiver has a vertical detecting angle of 23degrees and a horizontal detecting angle of 33 degrees, hence making it perfect for increasing the possible distance that the A.R.C. can be before being out of range. Most importantly, the team chose to use this infrared receiver, because it was compatible with the Arduino microcontrollers which will be used on the A.R.C. Overall, this powerful infrared receiver along with the teams' long range IR transmitter, should have no issues detecting each other within the confinements of an office, and using each other to guide the A.R.C. to its set location.

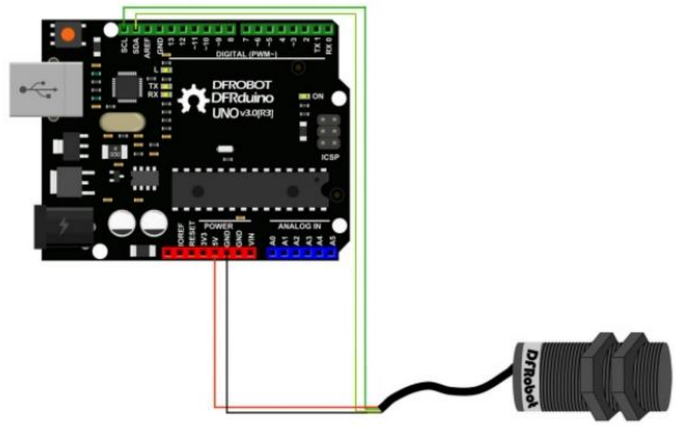


Figure 59: SEN0158 IR Positioning Camera/Arduino Pinout

The SEN0158 IR Positioning Camera from Arduino will serve as the A.R.C.'s guiding system, for it will be located on the center front of the A.R.C. and will be used to detect the signal transmitted by the IR Transmitter (home base). The benefit of using this infrared receiver is its capability of detecting four infrared emitting objects, within a distance of 3m. The SEN0158 infrared receiver has a vertical detecting angle of 23degrees and a horizontal detecting angle of 33 degrees, making it the perfect IR Receiver to use for guiding the A.R.C. back to its desired location.

The SEN0158 will be used as follows; when conditions are met and the A.R.C. has been turned on, the first thing that will happen is that the SEN0158 will make a scan to attempt to detect the IR transmitter signal. If the signal is detected then the signal will be sent from the arduino to the raspberry pi, which will send out the instructions to have the A.R.C. proceed towards the signal. However, if no signal is detected, then the A.R.C. will make a 360 degree turn in search of the IR transmission signal. If there is still no signal found then the A.R.C. will move forward ten inches and repeat the process till a transmission signal is found.

9.5 OBJECT DETECTION /AVOIDANCE

A possibility we must consider while the device is on the move is if an object that would hinder the A.R.C. 's movement is encountered. This obstacle would prove fatal to our design, as it could result in our device being unable to move forward, or worse, cause it to topple over and fall. As such, this section outlines the procedure we to implemented into our device to detect if there is an obstacle and what to do if one is encountered.

9.5.1 OBJECT DETECTION/AVOIDANCE DESIGN

HC-SR04 ultrasonic ranging distance sensor to detect objects that may appear on the return path of the A.R.C. and the transmitter station. The way the team will be using the ultrasonic sensors, is by placing eight different ultrasonic sensors (two in each corner) on the A.R.C.s' base. The reason the team is adopting this design is simply to always have a 360degree detection around the A.R.C. This design will serve to detect and avoid objects in its path, and it will also benefit the A.R.C. by being used to determine the best course of action when it comes to avoiding objects.

9.5.2 OBJECT DETECTION

As stated before, there will be eight different HC-SR04 ultrasonic ranging distance sensors located on the A.R.C. Each of these ultrasonic sensors will be working independently to detect objects. The logic behind using the ultrasonic sensors is to help detect an object's size when detected. If the object is larger, then it will be picked up by two different ultrasonic sensors, however, if it is a smaller object, then it will most likely only be detected by one of the ultrasonic sensors. The ultrasonic sensors will be programmed to detect objects that are approximately ten inches away. The ultrasonic sensors will also constantly detect its surroundings i.e. measure the distance from the A.R.C. to any given wall. The purpose behind using the ultrasonic sensors in this way, is simply to increase efficiency when returning towards the transmitter station. If for example, the A.R.C. is pushed against a wall, then the ultrasonic sensors will be able to determine not to have the A.R.C. move in that direction.

The ultrasonic sensors on the A.R.C. are in short acting as a 360 degree object scanner, the reason the team has decided to adopt this approach is to ensure that the A.R.C. will be able to detect more than just one object at a time. The placement of the ultrasonic sensors is also beneficial for they help determine the importance of an object detected. If any one ultrasonic sensor detects an object that is in any direction other than the direction of the IR Receiver than that object detection might be viewed as unimportant by the raspberry pi. In order to avoid running into a wall, the raspberry pi will be programmed to deem an object important, even if it isn't in the same direction as the IR Receiver, when said object is detected by more than one ultrasonic sensor.

9.5.3 OBJECT AVOIDANCE

After having detected an object, the next course of action would be to avoid said object. The way the A.R.C. will go about this process as follows. Once an object has been detected approximately ten inches away from the A.R.C., the A.R.C. will assess the size of the object by determining if the object is detected on multiple ultrasonic sensors. If the object is detected on only one ultrasonic sensor, then the A.R.C. will use its remaining ultrasonic sensors to determine to either avoid the object at a 45degree angle to the left or to the right, depending on the route that has been deemed most efficient by the ultrasonic sensors. The A.R.C. will make a 45degree angle return to its original route, when the object has been determined to be passed by the remaining ultrasonic sensors. However, if the object is detected by multiple ultrasonic sensors, then the A.R.C. will proceed to move in a 90degree angle to the left or to the right, depending on the route that has been deemed most efficient by the ultrasonic sensors. The A.R.C. will then move in a straight line, and make a 90degree angle return to its original route, when the object has been determined to be passed by the remaining ultrasonic sensors.

The ultrasonic sensors will determine the path that is most efficient as follows. Once the ultrasonic sonic sensor detects an object approximately ten inches away from the A.R.C., it will cause an alert, which in turn will activate the remaining seven ultrasonic sensors mounted around the A.R.C., these sensors will then provide a 360 degree scan with a radius of one and a half feet. All the information from this scan will be sent to the raspberry pi. The raspberry pi will then decide which ultrasonic sensors showed the least amount of objects or obstacles in their path. After having made that decision, the raspberry pi will send a signal to the arduino, which in turn will relay the information to the motors, which will then travel the most efficient path, as assigned by the raspberry. whether that is the 90degree avoidance path or the 45-degree avoidance path as mentioned before.

Similarly, the A.R.C. will also be prepared for multiple object detection. As stated before, when an object is detected by the ultrasonic sensor, an alert will occur and activate all of the remaining seven ultrasonic sensors. After having activated and had the preliminary 360-degree scan take place, and another ultrasonic sensor detects an object, then the following will take place. Depending on the location of the IR transmitter, the Raspberry pi is prepared to determine whether the object needs avoidance or not. This process will take place as follows. If the object is detected in the opposite direction of the IR Receiver, then the raspberry pi will ignore this object, the same will apply for any objects detected on either side of the A.R.C., the Raspberry pi will only focus on objects detected on its path towards the IR transmitter.

9.6 MOTOR USAGE

In this section, we discuss how the device will move through the use of DC motors in conjunction with the wheels of the device. We outline the design of the motors, including their placements and connections to the rest of the A.R.C., as well as how they will operate.

9.6.1 MOTOR DESIGN

The A.R.C. will be equipped with four 5V brushless DC motors, and these will be placed at the bottom of the platform. This design is mainly to ensure balance, and achieve some form of ground clearance to possibly go over a potential carpet or wires that may be on the floor. The two front motors will be controlled by one L298 Motor Driver and the two rear motors will be controlled by another. This separation of one pair from the other allows for control over each wheel to manipulate the movement of the device to our preference.

9.6.2 MOTOR FUNCTION

The reason the group decided on equipping the A.R.C. with four 5V Brushless DC motors is due to the fact that these motors are most compatible with the team's goals. These motors have a low power requirement, they provide instantaneous torque, they are inexpensive and they also offer an ease of implementation. These four motors will be operated via their respective L298 Motor Driver, however, this doesn't mean that they will have to operate together. Based on the connection described in the design, each of the wheels can be controlled by their motor controller.

These motors only have two functions, forward and backwards, it is up to the L298 Motor Drivers to send out the appropriate signals, so that the motors can utilize the design of the Mecanum wheels and go in any given direction. The function plus direction of the A.R.C. will be as follows; if the A.R.C. wants to move forward then all four motors will activate and propel in a forward direction. If the A.R.C. wants to move backwards, then all four motos will activate and propel in a backward motion.

If the A.R.C. wants to move in a diagonal direction then depending on the direction, two (diagonally placed) of the four motors will activate and depending on the command, propel forward diagonally or backwards diagonally. If the A.R.C. wants to move in a side direction then depending on the direction, all four motors will activate, two (diagonally placed) motors will propel forward, while the remaining two propel backwards. And finally, if the A.R.C. want to turn in any given direction then depending on the direction all four motors will activate, two (same side) motors will propel forward, while the remaining two propel backwards. Below is an image representing how the motors utilize the Mecanum wheel design.

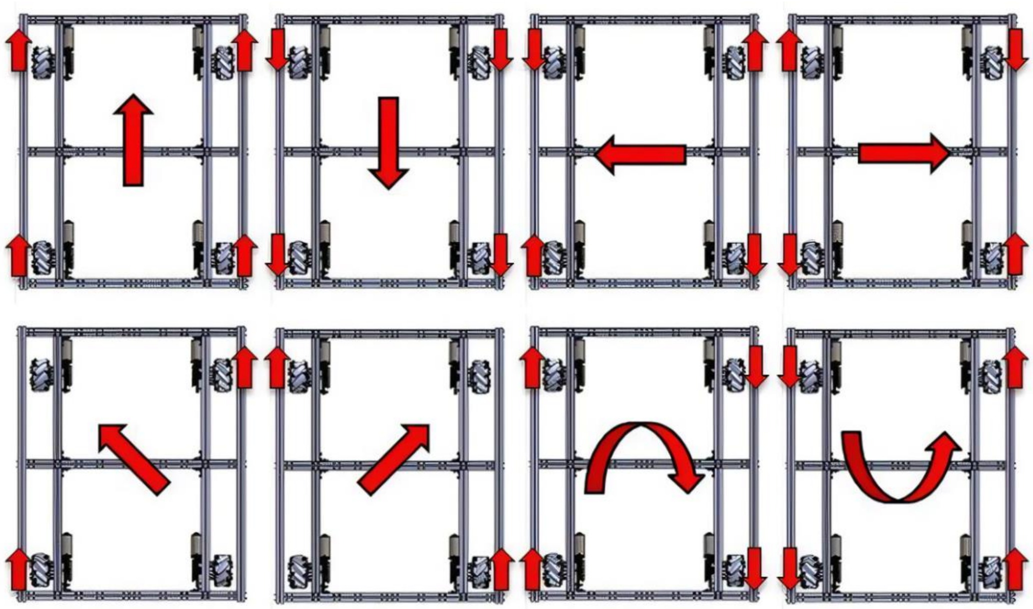


Figure 60 - Motor Activation vs Direction of A.R.C.

9.6.3 MOTOR LIMITATION

After having discussed the Motors and the Motor Drivers that will be used, we are now faced with the task of identifying the limitations these motors will bring to the overall design of the A.R.C. As beneficial as these motors are, they do have one flaw. They are not rated for high torque, or for high weight capacity. In other words, these motors will be sufficient in moving the A.R.C. by itself, at lower speeds. However, they do not have enough torque, or weight resistance to move the A.R.C. while holding a user in the seating unit or at high speeds.

The team is still considering using larger motors, however, for the time being there have been no calculations that would show any benefit in increasing the size of the motors. Increasing the size would eliminate the current limitation, but overall will cause different types of limitations later on. Therefore, the team has weighed the options and decided that these limitations do not surpass the overall benefits that these motors provide, such as affordability, and efficiency. The current motor weight limitation falls inline with what the team wants to achieve, therefore, it is seen as an accepted limitation.

9.7 BATTERY USAGE / POWER SUPPLY

For the case of batteries, please note that Lithium-Ion batteries will be used. The batteries act as the general storage for energy and functions to power all auxiliary components of the chair. In order to keep the batteries stored with energy, a charging system connected to a power supply is implemented.

9.7.1 BATTERY DESIGN

Simply a configuration of multiple energy cells in both parallel and serial. Serial to increase load voltage, and parallel to allow for shared capacity. Placement of batteries is essential to ensure proper weight distribution.

9.7.2 BATTERY FUNCTION

Distributes energy at variable voltages with an implemented regulator and converter. Voltages stepped to are 3.3V, 5V, 12V, and 24V. Each voltage level is required to operate microcontrollers and motor systems. Note that incorrect voltages connected at certain devices can result in overloading and can break the system.

9.7.3 BATTERY LIMITATION

Some limitations and constraints are listed below.

- Weight - Materials have weight. Batteries must be placed in a specific location to ensure the system does not tip or collapse.
- Charging port - Must be user-friendly in which the port is not difficult to find and plug into.
- Battery location - Must be stored in the chair system where batteries can be easily replaced.

9.8 WHEEL USAGE/ SPRING SYSTEM.

This section details the design of the Mecanum wheels we are planning to incorporate into our design as well as the spring system that will control whether or not the Mecanum wheels are in contact with the ground. We cover the design, why we decided to incorporate that design, as well as the interactions with other components within this section.

9.8.1 WHEEL DESIGN

The A.R.C. will be fitted with four Mecanum wheels, which will get directly mounted onto the four 5v brushless DC motors located at the bottom of the platform. The Mecanum wheels will be mounted in a diagonal pattern, meaning, the front left and the rear right Mecanum wheels will be facing in the same direction. While the front right and rear left Mecanum wheels will be facing in the opposite direction. The reason the Mecanum wheels will be mounted this way is because that is the only way to have the Mecanum wheels perform all the tasks that will be expected of them.

The A.R.C. is also fitted with a set of caster wheels, which will be mounted in four locations around the platform of the A.R.C. The reason the team is opting for the use of caster wheels, and for the design of these wheels on the A.R.C. is mainly due to budgetary constraints, weight restrictions on the teams' Mecanum wheels & motors, and to avoid an uncomfortable(novice) feeling that the Mecanum wheels might cause the user.

9.8.2 WHEEL FUNCTION

The use of Mecanum-wheels on the A.R.C. was a conscious and unanimous decision by the team. The reason the team chose to use these wheels is solely based on the novelty and their functionality. Mecanum wheels have an extremely utilitarian build, for these wheels allow the device to turn/ move in any given direction without having to steer. In other words, these wheels can remain mounted in one position, and can move the device in any way desired.

The use of the Caster wheels on the A.R.C. was chosen due to the concerns the team had about applying weight to the current parts list, and to increase the balance aspect, and to avoid a complaint of an uncomfortable(novice) feeling that the Mecanum wheels might cause the user. Caster wheels function just as any desk chair functions, the wheels move around aimlessly depending on the way the user pushes them.

The wheels themselves are isolated from the rest of the system, a reasonable idea considering how they are located at the end of the A.R.C. The Mecanum-wheels will only interact with the motor system of the device. The Mecanum-wheels are only a tool used by the motor system to move the A.R.C., as all of the movement instructions from the Arduino microcontroller are used by the motor system alone.

9.8.3 SPRING SYSTEM DESIGN

The Autonomously Returning Chair (A.R.C.) will be fitted with a spring system to alleviate pressure that might have otherwise been placed on the Mecanum wheel platform of the A.R.C. This spring system will be placed between the bottom of the chair, and the Mecanum wheel platform.

Implementation of this system requires mounting a hollow pipe or tube to each of the legs, which would house the springs and give structural integrity to the system. Blocking off certain lengths of space within the tube depends solely on the spring length and spring constant of the spring. To keep the spring system light, PVC pipes will be used, also because it is easily adjustable compared to metal pipes. The bottom half of the system as seen in Figure 42 - Spring System will not be fastened onto the legs of the chair to allow sliding when the seat is being lowered onto the ground. A lock will be used to hold the piece in place but still allow sliding since it is not fully fastened.

A fail-safe mechanism can be implemented alongside the spring system in case there are any faults with the springs. Implementing a manual feature that allows the user to pull up the Mecanum wheels would help with ensuring that the chair can still operate. A system that allows a lever to be manually pulled to lift the wheels up from the ground would be the easiest and most practical way to implement it.

9.8.4 SPRING SYSTEM FUNCTION

The purpose of adding this spring system to The A.R.C. is to alleviate pressure that can get placed on the Mecanum wheel platform. The Mecanum wheels are not designed to withstand much weight so the spring system will function as a lift to get the Mecanum wheel platform off the ground when there is a user in the seat, therefore having the A.R.C. rest on the caster wheels. The purpose behind this is to avoid an uncomfortable (novice) feeling that the Mecanum wheels might cause the user. The spring system's function is to not only alleviate the weight bearing of the Mecanum wheels but would also allow the full usage of the caster wheels.

10. PROJECT OPERATION

In contrast to the previous section, this section was intended to specify the capabilities of the A.R.C. at the time of submission. Upon completion of the device, we were able to realize the main functionality, the Autonomous Mode. We were also able to realize the User Mode to a certain extent. We also cover additional features and components added to our design.

10.1 USER MODE

The A.R.C. can detect when a user is seated in the chair and stops all autonomized movement. Originally, we planned to incorporate freedom of movement to the device while a user is seated to allow for usage as a normal office chair. Unfortunately, this feature was not able to be achieved and the A.R.C. shall not be rolled around while a user is seated.

The team had planned to implement this design using a lifting mechanism, which consisted of a 24v motor which would lift the motorized wheels of the A.R.C. off the floor when the pressure sensor indicated that a user is present. When autonomous mode is activated, meaning that no user is present, the lifting mechanism would lower the A.R.C. so that the motorized wheels could gain traction to push the whole device towards its home marker. Figure 61 – Motorized Lift Design demonstrates the design that the team attempted to implement.

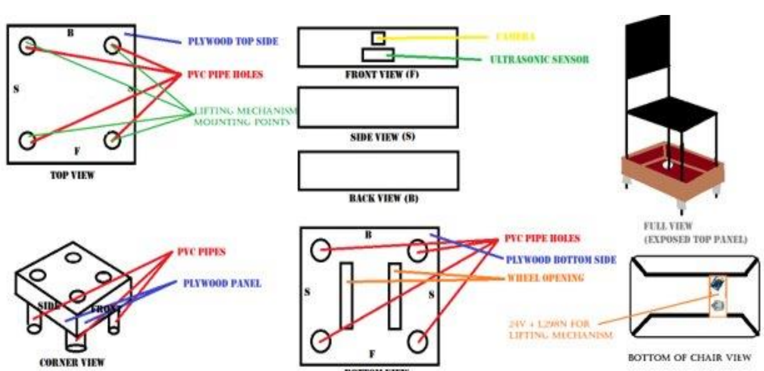


Figure 61 – Motorized Lift Design

10.2 AUTONOMOUS MODE

When a user leaves the seat, the A.R.C. waits five minutes before engaging in autonomous mode. In this mode, the A.R.C. turns right continuously, searching for the home marker. When the camera identifies the home marker, the device aligns itself so that the marker is directly ahead and begins moving towards it. Upon encountering any obstacles, it will dodge around them. If the obstacle is towards the right side of the device, the A.R.C. will go to the left and then resume searching and navigating home. If the obstacle is towards the left side, the A.R.C. will dodge right before resuming search and navigation.

Once the device reaches home, all movement is stopped, and it enters an idle state. Every 10 minutes it will check to see if it is still close to home or if a user is seated. If home is not seen, it will once again search for (and navigate towards) the home marker. If a user is detected in the seat, the device will enter User Mode.

The A.R.C. never shuts off on its own. Until switched off, the A.R.C. will always remain in one of the two previously mentioned modes, waiting for a change or response that will trigger its next actions. The only way to turn off the A.R.C. is through flipping the power switch located inside the wooden housing.

10.3 WHEELBASE DESIGN

The team’s design for the wheel was altered after testing. The team's original design included the use of four Mecanum wheels along with four caster wheels to distribute the weight of a user. However, upon testing the team noticed that four motorized wheels were excessive for our design. Utilizing four 24V motors would drain a lot of battery. To improve the overall design, the team opted to use two 24V motorized wheels instead of four. Two motors still provided the necessary force required to move the device forward at a lower power usage.

As previously stated, the A.R.C. also uses four caster wheels in its wheelbase design. These caster wheels were chosen to handle the weight of the user in place of the motorized wheels. These caster wheels were rated for approximately 275lbs. In addition, the placement of these caster wheels was chosen to allocate enough room for the housing for the electronic components we incorporated in our design. The commonly seen centralized chair leg (denoted with the red X icon in Figure 64 – Wheelbase Design of the A.R.C.) would not allow for the housing design we planned to be used due to the overlap of the motorized wheel system and the legs of the caster wheels. Figure 62 – Wheelbase Design of the A.R.C. demonstrates the design the team used for the wheelbase.

Figure 62 – Wheelbase Design of the A.R.C.

During testing the team noticed an issue with the Mecanum wheels. The team noticed that the Mecanum wheels were not providing the traction required to move the A.R.C. in any given direction. To rectify this the team implemented the use of PR Racing rubber RC truck tires which provided more traction which was required to propel the A.R.C. along with the caster wheels in any desired direction. Figure 63 – RC Tires Used displays the specification of the RC tires used.

Figure 63 – RC Tires Used

10.4 COMPUTER VISION

We changed our original home detection mechanism from infrared sensors to camera vision. Specifically, our device uses color as an identifier for the home marker. We programmed the pi camera used in our design to isolate a specific shade of yellow and utilized a panel of the same color to indicate the home destination for the A.R.C. While in autonomous mode, the A.R.C. would spin until it saw this marker, where it would then center the device to face towards the marker and begin moving forward.

We programmed the raspberry pi to interpret the camera's vision to only target the specific shade of yellow that we used for the marker. Initially, other similar shades of the same color were interfering with the performance of our device, causing it to move in the wrong direction. To solve this, we narrowed the range of acceptable target colors and caused it to ignore these similar shades. Figure 64 – Computer Vision Example shown demonstrates how the camera of the computer sees the colored object.

Figure 64 – Computer Vision Example

10.5 POWER SUPPLY AND IMPLEMENTATION

The team implemented two 12v, 2000mAh nickel metal hydride batteries to power the A.R.C. These 12v batteries were connected in series to generate a 24v output voltage, which was used to distribute power to the L298N motor controller which in turn powered the two 24v motors which are responsible for the A.R.C.'s movement. These batteries also powered the Raspberry pi 4 model B, through the use of a 24v to 5v buck converter. This converter was used to take the 24v voltage input from the two 12v batteries and convert that into a respectable 5v output which was required to power the Raspberry pi. These 12v batteries also power the ESP32-WROOM-32D which was located on the device it's significant printed circuit board, by having the Raspberry pi send a 5v output voltage to the significant PCB which was equipped with a 5v to 3.3v buck converter which is used to power the ESP32. Figure 65 – Power Supply Layout shows the power supply system of the A.R.C.

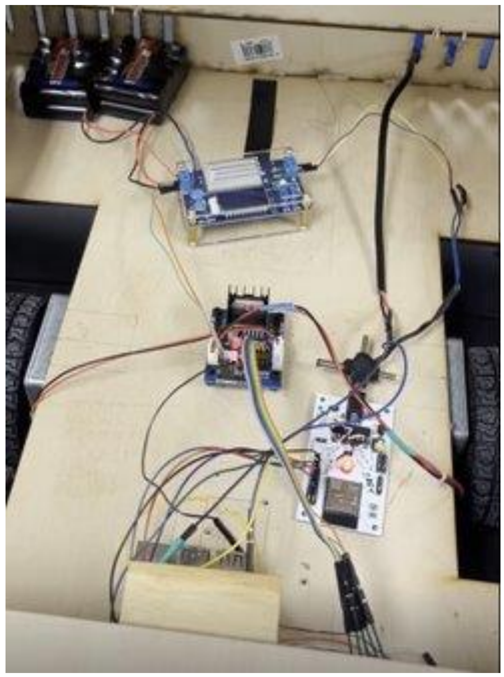


Figure 65 – A.R.C. Power Supply Layout

During testing the team first used 24v, and 5v battery packs to power the device. These battery packs were used to test the components on the A.R.C. and the power supply which the team would later-on implement. The 24v battery pack was used to power the L298N motor controller which powers the two 24v motors, and the 5v battery pack was used to power both the Raspberry pi and the ESP32. Figure 66 – A.R.C. Battery Pack Layout demonstrates the battery pack design which was used during testing.

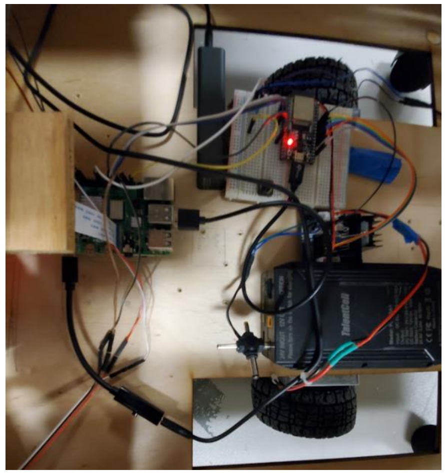


Figure 66 – A.R.C. Battery Pack Layout

11. ADMINISTRATIVE CONTENT

This section of the document will be used to show how the team plans to manage both their budget and time. This includes a breakdown of the project milestones throughout both Senior Design 1 and Senior Design 2, as well as a breakdown of the cost of the project and how we financed it.

11.1 MILESTONES

This section will discuss the initial project milestone set for this project. This project milestone will serve as a guide for our group and, by referring to it, we ensured that we stayed on track and did not fall behind. We kept ourselves in check and held each other accountable. As time management was a key factor in being able to meet the various deadlines set out for us, having a project milestone laid out ahead of time is remarkably advantageous.

Table 5, shown below, breaks down each task and start date throughout Senior Design 1 in the Fall 2021 semester and Senior Design 2 in the Spring 2022 semester. The tasks begin with the initial idea creation within and end with a presentation.

Task/Milestone	***Start Date***
Senior Design 1	
Idea Deliberation	08/21/2021
Project Selection	08/28/2021
Initial Document- Divide & Conquer	09/03/2021
Identify Items to Prototype	09/24/2021
60 Page Draft of Final Documentation	10/08/2021
100 Page Draft of Final Documentation	11/05/2021
Complete Initial Bill of Materials	11/12/2021
Finish Final Documentation	11/19/2021
Senior Design 2	
Assemble Prototypes	12/04/2021
Testing and Redesign	12/19/2021
Finalize Prototype	01/21/2021
Peer Report	02/18/2021
Final Documentation	02/25/2021
Final Presentation	03/25/2021

Table 5: Project Milestones

11.2 BUDGET AND FINANCE DISCUSSION

This section discusses the estimated cost of the project and breaks down the individual cost of each item. Considering how this project has no sponsor, we financed the project ourselves. The suppliers are also itemized detailing what set of items are offered. To clarify, each supplier is named to show where we purchased each part from and will not be partaking in any sponsorship. A completed financial report that itemizes all the purchases made regarding this project will be generated once all required items have been acquired.

To note, returning shortly after the quarantine due to the recent COVID-19 pandemic has resulted in a large scarcity in products. This is especially true for electronic parts as the amount of supply available has led to an increase in the costs of items. In addition, not all items purchased will be fixed in either cost or materials. Due to these modern supply and demand constraints, the costs we find and document are completely variable and subject to change. Materials procured may also not be in the named quantity as some materials may be faulty, or more materials are needed to be purchased as a result of testing and prototyping. As such, all purchases, whether they are itemized in this document or are obtained later, will be reported in a financial report of receipts in the document for Senior Design II.

11.2.1 BILL OF MATERIALS

As we proceeded with the research and design of our project, the team started to identify the equipment and components that would be required to make this project come to fruition. While conducting research of these required parts, the traits that the team made sure to take into account were the quality, parameters, and cost of each item. The reason for this is that as a team, we did not want to simply create one high-quality chair.

Eventually, the goal was to create a working product that is capable of being mass produced without compromising on its reliability. In other words, we desire to create a sound, working, and affordable product. Based on these considerations, the team has compiled a list of required materials needed to realize this goal. A summation of these items as well as a breakdown of their estimated costs are shown below in the Table 6:Project Budget.

Item No.	Name	Quantity	Cost per Unit	Total Cost	Seller
1	2 Pcs 550 35000RPM Electric Motor for 24 Volt Kids Ride On Car, RS550 24V Motor Gearbox Accessories for Children Ride On Toys Replacement Parts	1	$26.98	$26.98	Amazon
2	TalentCell 24V Lithium-ion Battery PB240A1, Rechargeable 22400mAh 82.88Wh Li-ion Batteries Pack with DC 24V/12V and 5V USB Output for LED Light Strip, CCTV Camera, Smartphone and More	1	$69.99	$69.99	Amazon
3	EVAL BOARD FOR ESP-WROOM-32	1	$10.00	$10.00	Digi-Key
4	BREADBOARD TERM STRIP 3.40X2.20"	1	$5.00	$5.00	Digi-Key
5	JUMPER WIRE F/F 6" 20PCS	1	$1.95	$1.95	Digi-Key
6	JUMPER WIRE M/F 6" 20PCS	1	$1.95	$1.95	Digi-Key
7	JUMPER WIRE M/M 6" 20PCS	1	$1.95	$1.95	Digi-Key
8	Arducam 5MP Camera for Raspberry Pi, 1080P HD OV5647 Camera Module V1 for Pi 4, Raspberry Pi 3, 3B+, and Other A/B Series	1	$9.99	$9.99	Amazon
9	Raspberry Pi 4 Starter Kit	1	$139.95	$139.95	CanakKit
10	FSR402	1	$11.67	$11.67	Digi-Key
11	Black Mobile Desk Chair	1	$71.63	$71.63	Home Depot
12	Gearhead Motor With Wheel	2	$9.95	$19.90	SkyCraft
13	Dozen 10-32 9/16 Flathead Screws	1	$0.25	$0.25	SkyCraft

14	Plywood Plank	1	$9.95	$9.95	Lowes
15	1/4 2X4 Birch Plywood	2	$19.56	$39.12	Home Depot
16	1" X 10' PVC Pipe	1	$5.96	$5.96	Home Depot
17	Osoyoo Mechanical DIY Robot Kit	1	$76.64	$76.64	Amazon
18	Pcb rev1	1	$10.86	$10.86	JLPCB
19	Tenergy 2 Pack 12V 2000mAh Battery Packs RC Battery w/Bare Leads for RC Airplanes, RC Car, DIY and More	1	$42.79	$42.79	Amazon
20	Adjustable CC CV Buck Converter Power Supply Module 12A 160W DC to DC 5.3V-32V to 1.2V-32V Voltage Regulator 12V 24V Step Down Voltage Transformer	1	$18.06	$18.06	Amazon
21	pcb components	1	$23.08	$23.08	Digi-Key
22	pcb rev2	1	$15.86	$15.86	JLCPCB
23	pcb components	1	$22.07	$22.07	Mouser
24	PR Racing SCT-P006 2.2"/3.0" Short Course Truck Tires with Foam Inserts & Black Wheel Rims 12mm Hex 2Pcs	1	$21.99	$21.99	Amazon
	Grand Total			$657.59	

Table 6: Project Budget

11.2.2 Part Explanation

The following itemizes all components found in our bill of materials. Each item named is to provide a reason of purchase and how the product will be implemented. Throughout the document every component's functionality has been defined in detail. This section simply summarizes those sections at the end of our documentation.

Black Mobile Desk Chair

The project requires a seating unit in which the user will be perched. A simple chair with a backside will be purchased. The chair will also hold the entirety of the electronic system ranging from the microcontrollers to the motor controllers to the energy storage underneath the seat. The chair will also house both sets of wheels and the infrared receiver.

Jumper Wires:

Simple set of copper male to male, male to female, and female to female wires with a small gauge to transmit electricity and data throughout the system. The chair system is not high voltage; therefore, no special precautions need to be taken to insulate the wires as they will come with rubber insulation. No other wires are necessary for our project.

Microcontroller

Consists of both the ESP32-WROOM-32D and Raspberry Pi 4 model B. Each device is programmed in Python and micro python respectively. They will be the devices for computing instruction sets, communicating with other electrical components as well as with each other, serving as decision makers and task givers.

PCB

To ensure proper management of cabling in the system, a PCB for most of the electrical components was designed. The PCB routes electric data and power to the proper components. In addition, it helped ensure that the entire system shared the same ground.

Motor Controller

Motors cannot operate on their own without specific instructions. The motor controller will interpret given data to control the motor in specific directions. With a Motor controller, each motor can perform independently.

Gearhead Motor

The A.R.C. consists of two 24v gear motors that power the device to move in any desired direction. These motors are used for the provided the required torque needed to move the A.R.C.

Mecanum Wheels

Omni-directional wheels that allow for smooth and full-range of movement of the chair system. Prevents the system from resulting in path-finding errors. Removes the need for dual axis motor wheel by requiring a single motor attached to the omni-wheel.

Caster Wheels

Considering weight constraints, a second set of wheels not controlled by the computer will be implemented. This will allow for free range of movement of the user when the system is not in parking mode.

PR Racing RC Wheels

Considering how the mecanum wheels did not allow for enough traction, the team opted to use these rubber RC truck wheels instead. These truck wheels provided more than enough traction for the A.R.C. to move without slipping.

Plastic Box

Will serve as the transmitter station or home base, the long-range IR transmitter will be located on the inside of this plastic box and will project an IR beam out of a hole that will be cut out in the front.

LED

For signaling statuses of the chair system such as battery level and error flagging.

Infrared Sensor SEN0158

This is an Infrared positioning camera that is compatible with Arduino. This infrared receiver can operate using the limited power supply that will be provided by the batteries, it also has the capability of detecting four infrared emitting objects, within 3m, with a vertical detecting angle of 23degrees and a horizontal detecting angle of 33 degrees.

Pressure Plate FSR 402

A small force sensing plate that calculates weight and determines whether a user is actively sitting on the chair. Will help to know when to activate instructions.

Tenergy Batteries

Two 12v, 2000-mAh nickel metal hydride batteries will be used. These set of batteries are rechargeable and reusable as well as easy to replace.

Ultrasonic Sensor

For use with rangefinding, object avoidance and detection. Assists in calculating distances from the home base programmed.

Plywood

Plywood was used for the overall design of each of the marks. The final design included a laser cut box made from plywood. This box houses all the components that make up the A.R.C.

Prototype

For testing purposes such as to observe how wheels will operate and how microcontrollers can be programmed.

Adjustable CC Buckconverter

This is a simple 24v voltage to 5v voltage buck converter which is used to regulate the 24v voltage output of the batteries and converter it into a 5v output to be used to generate power to the Raspberry pi.

11.2.3 FUNDING

In terms of funding, this team will be independently funding the project. This team is not a sponsored team; therefore, the team has decided to pool funding among each other to cover the cost of the project. In other words, the total cost of the project will be divided evenly among the four members in the team, hence, making this project a lot more affordable for each involved. However, with this case there has been an agreement on a budget as well. The team had decided that the total budget was not allowed to exceed three-hundred dollars per person, therefore, the total budget is twelve-hundred dollars. Based on the current “BOM,” and taking a margin of two-hundred dollars (for miscellaneous costs), the team was able to determine that the budget was plentiful.

11.2.4 SUPPLIERS

McMaster Carr

Private American supplier of a variety of raw materials, hardware, tools, and equipment. Supply ranges from electrical to mechanical. This supplier will be utilized mainly for mechanical components such as the wheel system, and/or motors.

McMASTER-CARR

Digi-Key

Another private American supplier of electrical components such as microchips, digital signal processors, semiconductors, etc. All supplies are electrical material. This supplier will be utilized for its electronic supply such as our microcontrollers.

Digi-Key MARKETPLACE

Mouser

An alternative to Digi-Key in which the supplier is a global distributor of electronic components. Should materials and/or supply not be available on Digi-Key, or any other electronic source, Mouser will be the general alternative.

MOUSER ELECTRONICS

Amazon

An American-owned multinational company in e-commerce that markets an endless amount of materials with no limit to its variety. This supplier will be utilized when an item may be available at a lower cost, or when an item is found beneficial, such as project kits.

amazon

JLCPCB / PCBWAY

Chinese printed circuit board and assembly manufacturers for designed circuits on any design software such as EAGLE, Circuitmaker 3, KiCAD, or Altium Designer.

This supplier is a potential option should team members decide to create a circuit board. Both suppliers are credible due to quality and general use.

Lowe’s and Home Depot

Brick and mortar home improvement retailers in North America that provide tools, appliances, supplies, and services. Lowe’s and Home Depot were utilized during the assembly of the project for quick and easy access to materials.

11.3 Facilities and Equipment

Throughout the culmination of this project, we utilized the workspace and equipment of ApECOR, short for Advanced Power Electronics Corporation. This included soldering stations, heat guns, and other common tools (such as drills, clamps, tape, and screwdrivers). They also provided access to large machinery such as a bandsaw, a drill press, and a laser cutter.

We also made use of the TI Innovation Lab at the University of Central Florida for the laser cutting of the wooden container for the electrical components of the A.R.C.

The 3D printed component which mounted the motors were printed by friends who owned personal printers. This allowed for quick prototyping and ease of access.

12. CONCLUSION

After weeks of discussion and research, the team is now more energized than ever to see this project come to fruition. The discussions on which materials to use, and the implementation of the materials has been decided and will be implemented as discussed throughout the report. The thought process and the decision making were thoroughly documented as we walked through them. The use of a prototype serves as great motivation and practice for the overall completion of the Autonomously Returning Chair (A.R.C.). The A.R.C. will be built with the primary function of being a returning desk chair. The A.R.C will be fitted with electric motors, Mecanum-wheels, an Arduino microcontroller, and a Raspberry pi computer module. The A.R.C. will feature pressure plate activation seating, self-returning mode via the use of infrared signaling, and object detection and avoidance via the use of ultrasonic sensors. As stated in the introduction, the team wishes for the A.R.C. to retain all the creature functions of a regular desk chair when used, such as free roaming without interference, and comfortability. And when not used the team wishes to see the Autonomously Returning Chair (A.R.C.) return to the location set by the user. Overall, the team is very enthusiastic about delivering a working model by the end of their senior design course.

APPENDIX A: REFERENCES

"Alkaline Battery." *Wikipedia*, Wikimedia Foundation, 17 Nov. 2021, https://en.wikipedia.org/wiki/Alkaline_battery#Recharging_of_alkaline_batteries.

"All about Force Sensors." *Types and How They Work,* https://www.thomasnet.com/articles/instruments-controls/all-about-force-sensors/.

Ashlin. "What Is a Load Cell?" *Instrumentation and Control Engineering*, 17 July 2021, https://automationforum.co/what-is-a-load-cell/.

"Build an Autonomous Arduino Robot with Bump Sensors: Science Project." *Science Buddies*, https://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_p034.shtml.

Butt, Usman ali. "How to Use a Lidar Sensor with Arduino." *Engineers Garage*, 26 Mar. 2021, https://www.engineersgarage.com/how-to-use-a-lidar-sensor-with-arduino/.

Controlling Arduino with Blynk via Bluetooth - Researchgate. https://www.researchgate.net/publication/311571110_Controlling_Arduino_with_Blynk_via_Bluetooth.

"How Does a Force Sensing Resistor (FSR) Work?" *Tekscan*, 10 July 2019, https://www.tekscan.com/blog/flexiforce/how-does-force-sensing-resistor-fsr-work.

Hrisko, Joshua. "An Introduction to RFID with Arduino." *Maker Portal*, Maker Portal, 12 Aug. 2021, https://makersportal.com/blog/an-introduction-to-rfid-with-arduino.

"Lead–Acid Battery." *Wikipedia*, Wikimedia Foundation, 1 Dec. 2021, https://en.wikipedia.org/wiki/Lead%E2%80%93acid_battery.

"Lithium Polymer Battery." *Wikipedia*, Wikimedia Foundation, 26 Nov. 2021, https://en.wikipedia.org/wiki/Lithium_polymer_battery.

"Long Range IR Transmitter Circuit." *Circuit Digest*, 15 Mar. 2018, https://circuitdigest.com/electronic-circuits/long-range-ir-transmitter/.

"Nickel–Cadmium Battery." *Wikipedia*, Wikimedia Foundation, 28 Oct. 2021, https://en.wikipedia.org/wiki/Nickel%E2%80%93cadmium_battery.

Perabo, Chris. “How Do Force Sensitive Resistor (FSR Sensor) Work?” *CAPLINQ BLOG*, 8 Dec. 2016, https://www.caplinq.com/blog/force-sensitive-resistor-fsr-sensor_1638/.

“SEN0158.” *Digi-Key*, https://www.Digi-Key.com/en/products/detail/dfrobot/SEN0158/7087147?s=N4IgTCBcDaIJICUAEAFA9gZwJYBctoDssCBzJAYQEMBbAUwCdKQBdAXyA.

Staff, Editorial. “Advantages & Disadvantages Induction Motor.” *Inst Tools*, 26 Apr. 2016, https://instrumentationtools.com/advantages-disadvantages-induction-motor/.

Staff, Editorial. “Advantages & Disadvantages of Synchronous Motors.” *Inst Tools*, 21 Dec. 2018, https://instrumentationtools.com/advantages-disadvantages-synchronous-motors/.

“Ultrasonic Sensor with Arduino Uno.” *Arduino Project Hub*, https://create.arduino.cc/projecthub/csw1/ultrasonic-sensor-with-arduino-uno-f33ca1.

“What Is the Difference between AC Motors and DC Motors?” *Power Electric*, 20 June 2019, https://www.powerelectric.com/motor-resources/motors101/ac-motors-vs-dc-motors.

Xander. “Infrarred Ir Led and Photodiode with Arduino.” *Infrarred IR LED and Photodiode with Arduino*, 1 Jan. 1970, https://profeitm.blogspot.com/2017/03/infrarred-ir-led-and-photodiode-with.html.