All Wheel Find

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Abstract **— Project "All Wheel Find" aims to utilize a strong emphasis on robotic vision and machine learning to accomplish search and rescue missions in an autonomous fashion with minimal human interaction. The most significant feature that will be incorporated in our robotic system is robotic vision through the use of a smart vision camera that will be programmed to find and locate a specific object autonomously by utilizing a search algorithm to effectively and efficiently locate a specific object. Once the object has been located, a return algorithm will be then utilized to return the robot to its original starting location.**

Index Terms **— Machine Learning, Computer Vision, Machine Learning Algorithms, Microprocessors, Autonomous Systems.**

I. INTRODUCTION

According to a survey published by Mozy, the average human loses 9 items every single day and spends up to 10 minutes daily to locate lost items. Project All Wheel Find has developed and produced a solution to this frustrating and fatiguing dilemma that we each encounter every single day. Not only can this robotic vehicle be able to locate an item indoors, but it can also be able to scour different outdoor terrains including adverse terrestrial conditions in a constrained environment. Our robotic vehicle utilizes robotic vision to accomplish search and rescue missions in an autonomous fashion with minimal human interaction. The most significant feature that was incorporated in our robotic system is robotic vision through the use of a smart vision sensor which was programmed to find and locate a specific object autonomously by utilizing a search algorithm to effectively locate an item. This vehicle is equipped with ultrasonic sensors in order to efficiently dodge present obstacles. This product also contains both an autonomous mode and a manual mode, which will allow the user to manually control the robot in case human interaction is required. Its compact design also allows the robot to efficiently traverse through difficult terrain. The main goals and objectives of project All Wheel Find are:

- ➢ The robotic system shall be equipped with a machine learning algorithm to efficiently locate a specific object with a 90% chance of success.
- ➢ The robotic system shall have a search algorithm to autonomously find a specific object.
- ➢ Once the object is found, an algorithm shall be implemented to travel directly towards the object.
- ➢ The robotic system shall be able to find the shortest path to travel back from the search area that it has explored to its original starting point before searching commenced.
- ➢ The robotic system shall have a manual override feature to allow the user to manually control the system in the event that it gets stuck.

II. DESIGN OVERVIEW

Project All Wheel Find shall be composed of a robot that operates on four mecanum wheels. It will operate autonomously to search for a specific object, whose location it will record and return back to the user. It will be able to operate manually through a website we have created when connected to wifi as well as autonomously through 3 algorithms we have created. The computer vision algorithm and ultrasonic sensors will locate the specified target's location, while following a search algorithm based on the Archimedean spiral. Once the computer vision algorithm and ultrasonic sensors have flag the specific target's location, a return algorithm will be used to return back to the robot's original starting location using a modified A* algorithm. The robotic system should be able to work autonomously once given the search radius that the target object, up to a search area that can be explored within the timeframe of an hour, which is the limit of the battery that we are using.

III. CASE SCENARIO

Project All Wheel Find has an appeal to a multitude of different target audiences and can be used throughout many different industries. When originally identifying and researching project ideas, we focused on selecting a project that has a real-world application and can be used throughout multiple industries. A few examples of select audiences are identified below:

- ➢ Search-and-Rescue Teams: Project AWF can be used by search-and-rescue teams to assist in locating missing persons in a location that would be otherwise difficult for a human to safely access. This is a dangerous field of occupation, and the addition of AWF could allow for search and rescue teams to know the terrain a little better, as well as the exact location of missing persons.

- ➢ Military: Assume that the armed forces are presented with a search-and-rescue mission to locate a specific person or item in a dangerous zone. Our product will be able to assist the military with locating the specific object/person efficiently and quickly to prevent the military from first having to enter a dangerous scenario without prior knowledge of where the location of said object is. Also with the autonomous function, this robotic system is applicable to remote terrains that are normally hard to reach with robotic systems that are manually controlled.
- ➢ Recreational: We have designed the product to appeal to a recreational hobbyist who would enjoy using the system to locate missing objects that may have been lost around their property. The product will also be open source so that a hobbyist can program in their own desired features.

IV. SYSTEM COMPONENTS

For the robotic system to work efficiently as intended, we have conducted extensive research to ensure that all of the components will work flawlessly and maintain power efficiency throughout the circuit. Our chassis is composed of a 9.5” by 12” plywood platform, and the internals of the system are enclosed by a 5” high enclosure to protect the internals of the robotic system from outside debris. The design is small and compact to allow the system to fit in tight terrains in the environment to prevent the system from easily getting trapped or stuck. The enclosure is composed of cutouts for the 3 ultrasonic sensors, the smart vision camera, and the LCD display that will be used to display messages to the end user. Underneath the platform, we have chosen to include dual channel DC motor drivers to supply the power to the Mecanum wheels, which are a form of omnidirectional wheels. All of our components have been carefully chosen through extensive research to ensure that all of the components will work efficiently and as intended during the final demonstration. In this section we will discuss the critical components and their uses in our robotic system.

A. Microcomputer

The Raspberry Pi 4 is the powerhouse of our robotic system. This microcomputer is able to handle our robotic vision algorithm that is incorporated through the use of the TensorFlow Lite framework. The Raspberry Pi 3 is featured with a 64-bit 1.5 GHz Quad-Core arm V8 processor with 8 GB of LPDDR2 memory. This single board computer provides sufficient processing speeds and memory to be able to successfully run our machine learning computer vision algorithm. A significant capability that this device provides is that it contains a CSI camera port for easy camera connectivity to be able to connect an RGB camera to the front of our robot in order to be able to successfully and efficiently run our robotic vision algorithm. The Pi 4 makes implementing object detection and obstacle detection algorithms easier through the use of the YOLO computer vision architecture. This device also contains Bluetooth 5.0 which allows for Bluetooth low energy (BLE). The Raspberry Pi 4 also contains 40 GPIO pins which is sufficient for connecting all of the sensors that this project involves. Since the Pi 4 does not contain any internal storage, we stored files as well as the Raspbian operating system on an SD card. The Pi 4 microcomputer is intended to only run the machine learning algorithms, and the search algorithms which are discussed later on in this paper are intended to run on a separate processor.

B. Microprocessor

To satisfy the PCB requirement of our project, we have incorporated the ATmega2560 processor into our design which feeds data from the Raspberry Pi 4 to the ATmega chip. The ATMEGA2560 is equipped with 256KB of flash memory and 8KB of RAM. With more than triple the amount of GPIO pins than the MSP430, which is another microprocessor which we originally considered, the ATMEGA has 86 of those. It also comes with specialized pins designed for communication protocols and many PWM pins (16) for controlling the motor drivers. It also has clock speeds of up to 16 MHz with potentially higher power consumption depending on the clock speed than the MSP430 microcontroller. To successfully communicate between the Raspberry Pi 4 and the ATmega2560 processor, a level shifter is utilized. A level shifter is used to convert the Raspberry Pi’s 3.3Volts TX/RX pins to the 5 volts used by the microprocessor.

C. Ultrasonic Sensors

Since we have decided to use only one camera, we have no bifocal vision, thus the robotic system will not have the ability to judge distance between itself and any object or obstacles it encounters if no other sensors are added to the system. To solve this issue, we have added a total of three ultrasonic sensors that can sense distance. These sensors use a pulsed laser to generate ultrasonic pulses that it emits into the environment. These pulses reflect off of obstacles and the environment back into the receiver which converts the reflected sound into electrical signals. To generate a visual of the environment, the sensor uses time to calculate the distance between the sensor and an obstacle or environment. It measures the time between when the sound wave was emitted from the transmitter and when it was received back to the receiver, setting that number to the variable T. C is used to represent the speed of sound, which has a speed of 3434 meters per second. To calculate the distance between the sensor and obstacle, a very simple equation is used shown in (1):

$$D = \frac{1}{2} x T x C \tag{1}$$

D. Smart Vision Camera

One necessary component to our project is a camera to take in visual input of the robot's external environment. This data is mainly used as input for the object detection algorithm, where the system will be searching for and trying to identify where the specific object is located. The data is used to a slightly smaller extent to create a two-dimensional grid which will represent the area that the robot has already searched within the given unknown search area. We decided to use the MakerFocus Raspberry Pi 4 camera due to the fact that it was small, compact, and offered 1080p resolution. This camera was also appealing because it contains a night vision feature, so that search-and-rescue teams would have the ability to execute their missions during the night-time.

E. Motor Drivers

Since this project is about searching and potentially rescuing a target object from an unknown place in a constrained area, it should not be a surprise that this robot requires motors to move itself to the desired location. The motors are the subject of many control systems such as the searching algorithm which will directly control the motor to try and find the target object. Additionally, the Deep Learning algorithm that will detect the target object will also directly interact with the motors once it has found a potential match by replacing the search algorithm for a follow and rescue algorithm primarily driven by the camera input that controls the motors to keep the target object within its field of view. Thus, a highly responsive motor that can provide feedback through encoders connected to its axil was implemented. We have implemented the Pololu 99:1 metal gearmotor, which is featured with a high-power, 6 volt brushed DC motor combined with a 98.78:1 metal spur gearbox. It is also accompanied with a 48 CPR quadrature encoder on the motor shaft which provided approximately 4741 counts per revolution of the gearbox's output shaft.

F. Mecanum Wheels

The choice of mobility that we have chosen for our robotic system are the Mecanum wheels which are fairly commonly used in robotics projects. These wheels have the interesting property that they do not require the robot to turn in order to move sideways. By an addition of the wheels force vectors, any direction of movement can be achieved by only rotating them in different directions to produce multi-directional movement with the robot's base standing at the same position that it started. Fig. 1 demonstrates the movement of the wheels based on which direction the wheels are turning. The use of omnidirectional wheels can bring many advantages when the robot's sides are tailored for specific tasks in an enclosed environment such as a room because the auxiliary systems that perform such tasks can be placed strategically on the required sides of the robot that will arrive first at the destination.

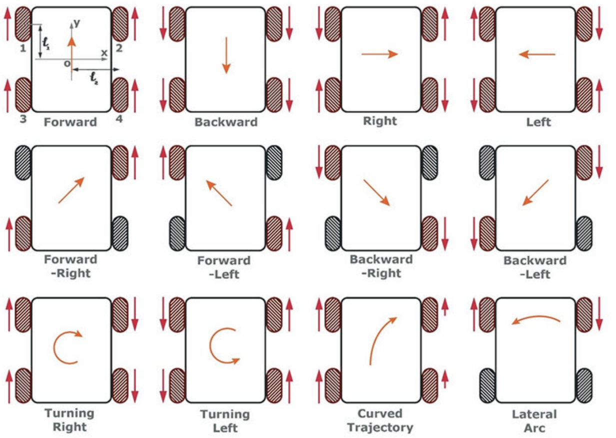

Fig. 1. Capable movements of omnidirectional wheels

G. Voltage Regulator

When powering a circuit, we need to maintain a stable power supply to be able to protect the circuit board and all of the sensors from becoming damaged. The way a voltage regulator works, is that it takes an unstable input voltage and converts it to either a higher or lower constant output voltage. There are two different types of common voltage regulators that were considered when selecting a compatible regulator for our design: linear and switching voltage regulators. For our particular project, we incorporated a voltage regulator that doesn't change the output as the battery discharges as well as a voltage regulator that maintains proper heat management to protect the device from failure. We implemented the UCC283TD-5 linear voltage regulator manufactured by Texas Instruments, that supplies the Raspberry Pi 4 microcomputer with a constant 5-volts and 3 amperes.

H. LCD Display

Our project contains a simple and power-efficient LCD display to display standard output data from our robot that is useful to the end user. Once the robot traverses through a terrain to attempt to locate an object and then returns back to its original position, it will display whether the object was located or not as well as the amount of time the robot spent searching for the specific target object. The display will also output the battery percentage of the robot so that the end user will know if the robot has enough battery life to go on another mission. A 16 x 2 liquid crystal display is more than sufficient to display important information for our project. The AMC1602AR-B-B6WTDW-I2C which is manufactured by Orient Display is a 16x2 character display with white text color and a blue-lit background. The LCD is also featured with a transmissive polarizer which means that it allows light from the backlight to pass through the bottom and top glass of the display. Since the LCD contains a transmissive polarizer, the backlight must be on in order for the display on the LCD to be readable.

I. Printed Circuit Board

The printed circuit board for project All Wheel Find was designed using Eagle, which is an electronic design automation (EDA) software, which allowed us to create schematics for our project, and then create a final board layout. Since the PCB is the most vital component to our project, choosing the correct components to use in the circuit was important. Since our PCB design is highly complex as demonstrated in Fig. 2, and contains a large number of components, we decided to go with through-hole components to ease the soldering process. The center of the board is featured with the ATmega2560 microprocessor and is routed to pin headers so that the external components such as the motor drivers, LCD display, and ultrasonic sensors can be wired to the circuit. The circuit also contains the level shifter, crystal oscillator, pull-up resistors, and various capacitors and resistors throughout the printed circuit board. Pins have also been incorporated to allow us to bootload the ATmega2560 chip through the use of an Arduino Uno.

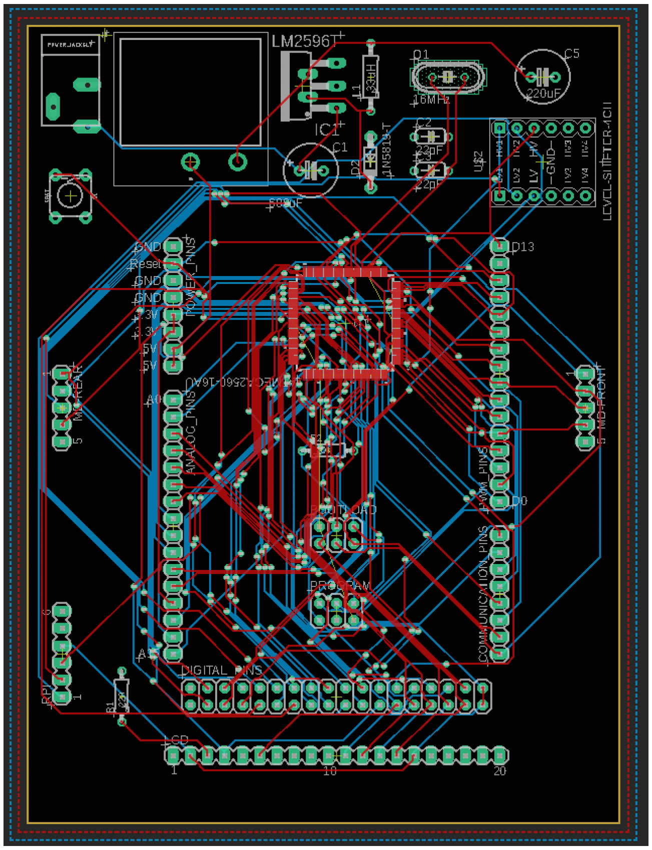

Fig. 2. Printed Circuit Board

J. Battery

Every project needs a battery seen that anything that desires to move or makes changes in the world must consume energy to do so, therefore the choosing of a good power source in the form of a battery is paramount to our very energy hungry robot, which runs 4 motors, 1 microcomputer, 1 microcontroller and a multitude of sensors such as a camera and laser-based distance sensor. With that consideration in mind, we decided to compare the arguably three most popular battery pack technologies NiMH (Nickel-Metal Hydride), LiPo (Lithium Polymer) and NiCd (Nickel-Cadmium) in order to decide which one to choose. After further analysis, the optimal choice was the NiMH 6-cell, 7.2V, 3600 mAh battery pack due to the fact that they hey have more energy density (140-300 W·h/L) typically than the NiCd battery packs, which makes them smaller and lighter than the NiCd packs, which was more important than the lower price that the NiCd battery packs carry, so the choice was in favor of the NiMH technology.

After conducting testing of the battery in the system, the robotic system is able to run for approximately 1 hour while actively traveling at a distance of 8.5 meters per minute during the execution of the search algorithm. We originally anticipated the battery to last for a distance of 250 meters, so in hindsight, choosing the NiMH battery resulted in increasing the run-time of our system by a factor of 2.

V. SOFTWARE DESIGN

For the software design of our robotic system, we implemented a few different algorithms, such as an Object recognition algorithm, a search algorithm, and a modified A* return algorithm, to accomplish the variety of tasks that the robotic system must complete within the unknown search area. We designed our own unique search algorithm to find the target object referred to as the Find Target algorithm. It identifies the search area and the robot's initial placement in that search area. These variables are provided to the robot, but it shall look for and identify the target object autonomously. We implemented an algorithm that will find the most efficient way to thoroughly look through the given search area, until a flag is raised from the computer vision algorithm that indicates the object has been identified and its coordinates marked. Once the flag has been raised, the robotic system will switch to utilizing the Go Back Home algorithm. Fig. 3 demonstrates the software block diagram and how the different algorithms will interact with one another.

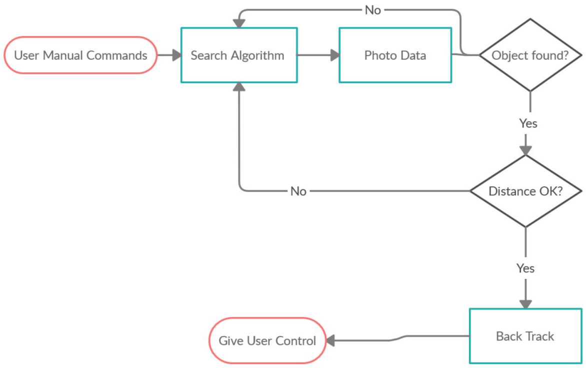

Fig. 3. Software Block Diagram

This will be a slightly modified version of the A* star algorithm, which will use the area that the robot has explored while searching for the object in its algorithm to find its way back to its initial starting location. We could just simply have the robot follow back the same path that it took to reach the target object, but that would have been highly inefficient and time consuming, and we would like to make our robotic system fast and efficient. We are prioritizing efficiency in the search aspect of our algorithm, and efficiency in the return aspect of our algorithm.

A. Object Detection Algorithm

One of the most interesting aspects of this project is the use of Deep Learning based techniques for image recognition that will detect the target object. It is important to notice that the Object Detection Algorithm described here only refers to the Deep Learning model used to classify images with bounding boxes around the object of interest based on the camera input. The execution environment of this algorithm will be inside the Raspberry Pi microcomputer, which will process the image data in real time and then execute the Object Detection Algorithm in its operating system to generate some digital output which will be used by the microcontroller to control the robot's direction.

The framework used to implement this task is the YOLOv3 framework, which is implemented in the Python language. It is important to make evident that this technology has been invented fairly recently and this can be considered cutting edge technology in object detection especially for undergraduate levels. Even though the YOLOv3 libraries can be imported and implemented in any python compatible environment this project's challenge lies in training the model for a specific object, which requires hundreds of images and labeling of these images alongside with the expertise to implement the model correctly.

B. Archimedean Spiral

The Archimedean spiral was not created by Archimedes, but by his disciple Conon. This spiral is unique because the distance in between each continuing spiral is equal to each other. Fig. 4 displays what the Archimedean spiral looks like and how the measurements on it are calculated. Due to time constraints, we shall be modifying this algorithm to follow a square rather than circular pattern. How this works is that we provide the robotic system with the unknown search area, which will be a square area. From this square area, the robotic system will find the midpoint and generate a modified

Archimedean spiral from the midpoint that ends at the starting position where the robot is first placed. Then the robot will follow the path of the Archimedean spiral to the center of the square area.

This equation is especially useful to our search algorithm as we can set the distance between each successive spiral to be equal to the width of the area that the sensor and camera can collect data from. If the camera and sensor have different widths of the area that it can collect data from, then we can use the smaller size of the two so as to not miss any area of the search area. This is a lengthy process to search the unknown area, but for the search aspect of our algorithm, we are not aiming for speed, but for efficiency, and utilizing the Archimedean spiral was the most efficient way to search the unknown search area for the target object.

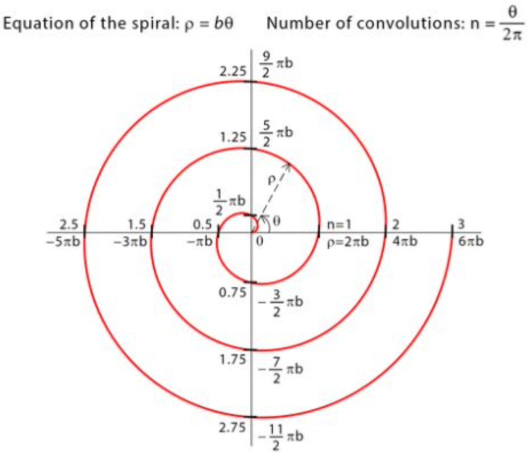

Fig. 4. Archimedean Spiral

C. Go Back Home Algorithm

Once the target object has been found and its coordinates marked and saved into memory, the robot shall now return to the location where it was first placed to give the person the coordinates of the target. Our aim was to not grab the target, nor to have the robot send the coordinates to the programmer, but for it to save these coordinates and travel back to its initial starting point, bringing the coordinates to the user. If not manually bringing the coordinates to the user, at least the initial starting location will be in an area within proximity and ability to send a clear signal to the programmer about the coordinates. This is because we aimed to have this be a small robot that can easily traverse through small areas and complex terrain, and depending on distance and terrain, communication between the user and the robot can be unreliable. This is the second part where the robot's autonomous nature will be demonstrated. Using the Go Back Home algorithm it will take into account several variables and map its own way back to its initial starting point.

While in use, the robot will be keeping track of its coordinates within the designated search radius. It will also be marking known areas and known obstacles. From this knowledge, the robot will use the path it took to reach the target object, the obstacles it has encountered, and what area has been explored and not explored, and find its way back to its initial starting location in the shortest path possible. Since the goal of this robot is for use in search and rescue applications, we wanted it to find its way back to its initial drop off location as quickly as possible. So, while efficiency was prioritized in the first Find Target algorithm, now we focused our efforts on speed and reaching our initial starting point that the robot was dropped off at as quickly as possible.

D. Website

In the event that the robotic system was to get itself stuck in a difficult location, we had to come up with a solution of how to free the robot. To solve this issue, we have implemented a manual override feature so that the user can intervene, and temporarily pause the robot's autonomous algorithm. Since the Raspberry Pi 4 has a built-in Wi-Fi module, we were able to take advantage of this and create a website for the user so that he/she can connect to the website on their local browser and control the movements of the robot autonomously. After the system gets placed back in its correct position, the autonomous mode can continue its execution so that the system can continue with its search-and-rescue mission. We have incorporated forwards, backward, sideways, and diagonal commands which can be seen demonstrated below in Fig. 5.

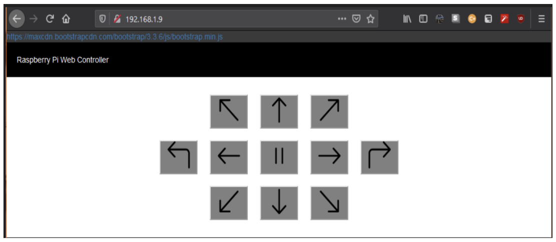

Fig. 5. User interface displaying the manual override features to manually control the robotic system.

VI. PROJECT CONSTRAINTS

By identifying various relevant project constraints that are applicable to our search and rescue vehicle, we were able to identify the limitations on the design of our project. The subsections within this section identify and define the design constraints that are applicable to our project.

A. *Economic and Time*

First, we shall discuss the economic constraint of having a lack of funding for project All Wheel Find. Being that we are a group of three engineering college students, we do not have the resources to use the most high-end components for our project. By identifying the economic constraint to our project, we have concluded that our project shall be limited to a $700 budget. As such, we resorted to using cheaper components for the body and wheels and stick to qualifications needed to do what is stated in our plan. We were able to use the most recent hardware that meets the standards set for us by the IEEE and by our idea for our goal. A table for our budget can be seen below in Table 1.

ITEM	**QUANTITY**	**TOTAL PRICE**
Raspberry Pi 3	1	$50
Smart Vision Camera	1	$60
Robot Chassis	1	$100
Ultrasonic Sensor	4	$40
PCB	5	$50 - $100
LCD Display	1	$10
6-Cell NiMH Battery Packs (*)	2	$36
Motors	4	$140
Motor Drivers	2	$40
Misc. Parts	-	$100

Table 1. Budget Summary

The second major constraint for our project is time. Projects similar to ours, such as the RHex robot, were built over the course of several years with teams of 30 researchers or more. We are a team of three students building our robotic system over the course of two semesters, so many aspects of our robotic system had to be simplified for it to be completed within our limited time frame.

B. *Ethical*

There are concerns raised about the ethicality of our project. If used improperly, our robotic system could be used to spy on unsuspecting people. Its intended small size and ability to traverse through small and tight terrain could pose a risk to it being used to break into people's homes and locate valuables without a perpetrator ever having to first enter the home. To help avoid scenarios such as the one mentioned above, we have programmed the system so that it will only work in a confined area. A constraint we can add in the future in case this product was to ever go into production in the future is a license that is needed to operate and own our robotic system, and a commercial, more limited one could be made available for aspiring roboticists to learn how to use and code but will have the added function of being more limited in the distance from the user that it can operate within.

C. *Health and Safety*

Search-and-rescue is a dangerous occupation. There is the chance to save many lives, but the price for that can oftentimes be that of the rescue team. Due to the nature of this robot where it shall be small to have more maneuverability, as well as record the area it has searched, this can give search and rescue personnel a little more knowledge on the location of victims, and hazardous obstacles the robot might have crossed. This would allow for safer conditions with the gained knowledge about the environment where a person or object must be rescued from. This will only be helpful if the sensors and the camera are accurate. Returning incorrect information about obstacles and locations of targets is as dangerous as having no knowledge about the environment that we are working in. Our constraint for our sensors and algorithms will be that it must be accurate at the very least 90% of the time. The use of machine learning will also help to reduce the error rate of the robotic system as it gains more experience through testing.

VII. CONCLUSION

In conclusion, our team was able to put together a successful and conforming senior design project that met our project standards and requirements through extensive research and testing of our robotic system. Though battling a global chip shortage during a pandemic made finding compatible and cost-efficient components difficult, we were able to successfully piece together all critical parts of our project.

Throughout the implementation of our project, we always had our goal in mind, to develop a search-and-rescue robot that has a real-world application, and that can be used to autonomously identify and locate a specific object or person through the use of a machine learning algorithm. Since machine learning is growing at such an exponential rate in today's times, all members of our group were inspired to contribute to a project which has such a heavy emphasis on machine learning and robotic vision to prepare us for our future careers as Computer Engineers.

Setting important goals, following strict guidelines and due dates contributed to the success of project All Wheel Find. Doing extensive research early on during the project helped set a guideline for what to expect when it came to finally constructing the final product. To add, following common industry-wide standards developed by IEEE, ASTM, and IPC, gave us knowledge on how to build a conforming system, and therefore gave us a good introduction of what to expect when it comes time to entering the engineering workforce.

Most importantly, this project has taught us how to work as part of a team. Our senior design team was able to build strong team dynamics throughout this design process in order to identify skills and talents that we each possess. By successfully identifying each other's strong points, we were able to delegate tasks accordingly to contribute to the success and execution of this design process. Such as in the real world, working engineers have to be able to commit and accomplish critical deadlines to ensure the success of any given project. To accomplish this, we as a team have set and met important deadlines and have conducted frequent meetings to ensure the success to project All Wheel Find.

Acknowledgment

The authors wish to acknowledge Professor Lei Wei at the University of Central Florida for his assistance in ensuring our project is successful and giving us the proper guidance to prepare us for our careers after graduation.

We would also like to offer our thanks and our utmost gratitude to the ECE review committee who have taken time out of their busy schedules to review and critique our final demonstration.

Biography

Elias Jucevicius is a 23-year-old senior enrolled in the Computer Engineering program at the University of Central Florida. Post-graduation he will be pursuing a master's degree in business, and then intends on pursuing a career in hardware engineering at a major defense contractor.

Luiz Rocco is a 23-year-old senior enrolled in the Computer Engineering program at the University of Central Florida. Post-graduation he intends to gain experience in his field by working in the field before pursuing more education.

Adriana McCabe is a 23-year-old senior enrolled in the Computer Engineering program at the University of Central Florida. Post-graduation she intends to pursue a career in software engineering for robotic systems, with an interest in animatronics.

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