Vex Robot Design and Performance Report

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Project Summary

The robot project focuses on students developing an autonomous robot that is capable of navigating its surroundings, discovering beacons turning them both off and on, and dragging the beacon out of the area. The group is divided into 3 roles; software programming, electrical team, and mechanical team. The software programming team focuses on the software by using EasyC V6 and writing down all component parts of the robot, ensuring that the robot follows the program to achieve its goals. The electrical team focuses on soldering an Infrared Receiver board and testing it to ensure that power is distributed and the primary sensor functions. The mechanical team concentrates on the mechanical aspects of the robot, designing a layout that can use the fewest parts and a minimal frame structure to achieve the lowest weight possible. The results of a collaborative group effort were successful and integrated the three runs, as well as demonstrating the performance of the robot during the test was a success. Task 1 was successfully achieved as the robot was able to locate the red beacon and stop the robot. In task 2, the robot had a problem where the arm wouldn't stop hitting the red beacon as it triggers to hit rapidly back and forth, but it was successful after some adjustments to the code and managed to successfully turn off the red beacon. In task 3, it successfully located the green beacon. Task 4 had some problems as the arm was not able to hit the beacon since it kept making a gap after hitting the green beacon, but we were able to successfully hit and carry the green beacon, as well as dragging it out to the area. The final result of the run went really well as there were no problems with the code or the robot design and successfully got the record of the lowest weight.

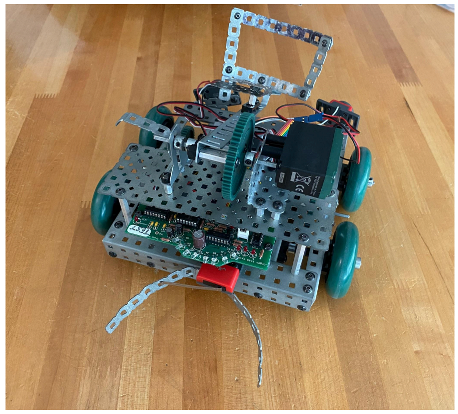

Figure #1: Amazing Robot

Introduction

C vIn this robot project, our group was tasked with building a robot capable of carrying out a few tasks in order to simulate a real-life implication of a robot within the home. The Care-O-bot, developed in Germany, has a scenario where it is helping someone make dinner. The robot is tasked with turning off the stove and then getting a plate for the person to set at the table (San Jose State University). Our robot's goal is to turn off a red beacon (the stove), then go to a green beacon (the plate) and drag it out of the arena all while being under 2500 grams. The arena was 12 feet by 8 feet with 12-inch walls. The beacons were randomly placed 4 feet apart in the arena at least 2 feet away from the walls.

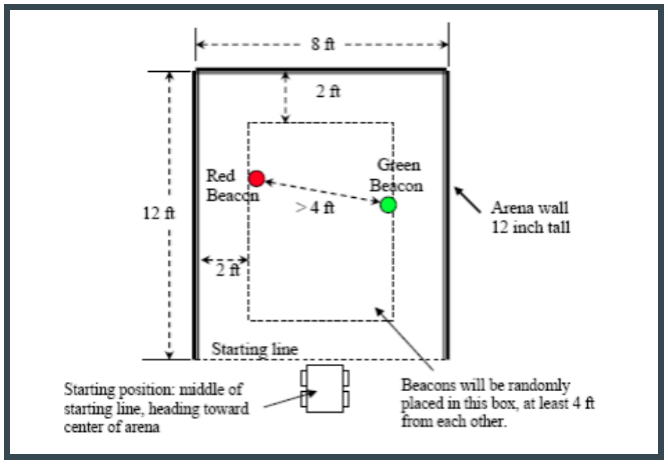

Figure #2: Map layout of project

Our group consisting of six people was split into three groups: mechanical team, programming team, and electrical team. The mechanical team's goal was to design and construct an autonomous robot that had a mechanism capable of hitting a button on the top of the beacons to turn them off and a mechanism capable of dragging the green beacon out of the arena. The robot also had to be able to avoid getting stuck in the walls. The programming team's goal was to code a program for the robot to achieve its goals as mentioned earlier autonomously. The electrical team's goal was to successfully solder components onto the circuit board. To do so, instructions and a sample board were given to the team to reference.

Design

The base design for the squarebot robot was provided to the mechanical group on the first day which was then used to assemble the drive system. The drive system consists of two motors facing opposite each other connected to gears which power all 4 wheels equally. This splits the high torque of the motors at full speed between 2 wheels each, reducing the amount of wheel slip. The two separate motors allow for the wheels on each side to travel in opposite directions much like a tank. This makes turns much quicker and more precise allowing it to work efficiently in tighter spaces.

The mechanical team finished the base for the bot the first day according to the manual so that the rest of the time could be used for developing the systems for turning off and capturing the beacons. The first and most important addition was an arm on top of the robot, used to actuate the beacon switch on the first beacon and capture the second. The two main features of the arm are the plate used to press the red beacon to turn it off, and the capturing cage at the end used to hold onto the green beacon. Both of these can be seen in Figure 3 which has the robot facing forward with the arm in the raised position for the features to be more visible.

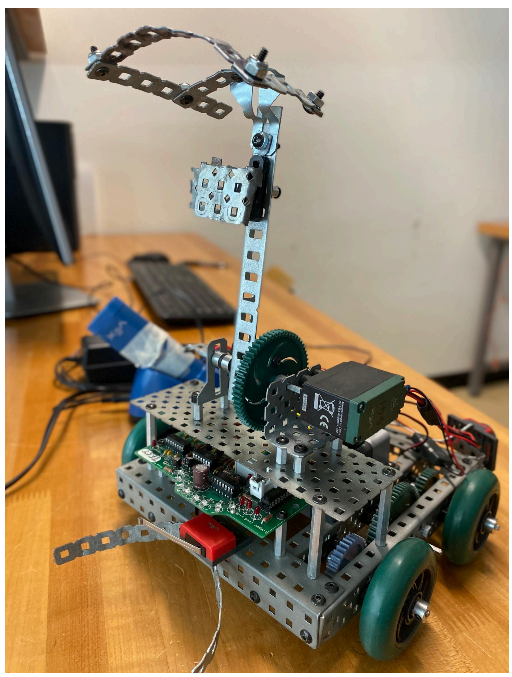

Figure 3: Robot with arm layout

The plate for turning off the red beacon was the most fiddly part of the build. It has to be in the perfect position and just the right height to press the switch consistently without interfering with the capture cage at the end of the arm. While less involved, the cage also required some trial and error as it would let the green beacon slip out when it wasn't close or secure enough. After several iterations, a design was settled on that resembled a piece of dental headgear or a cage. This design proved incredibly effective and was well worth the added weight.

Also visible in Figure 3 is the curved piece at the front of the robot which is used to guide the beacon to the center of the robot where it would press the limit switch. Additionally this piece served to capture the green beacon, as with the setup closed there was nowhere the beacon could slip out.

Moving on to the back of the robot, There are two bumper switches placed at 45 degrees to the rear end of the robot. These are visible in figure 4, and the purpose of these is as follows. After the robot captures the green beacon, it needs to escape the arena to finish the challenge. To do this, the arm remains down and the robot reverses, dragging the green beacon with it using the hooking cage made by the lowered arm. If the robot runs into an obstacle while backing up, such as the wall of the arena, the angled bumper switches will actuate and the code will tell the robot to back up and turn.

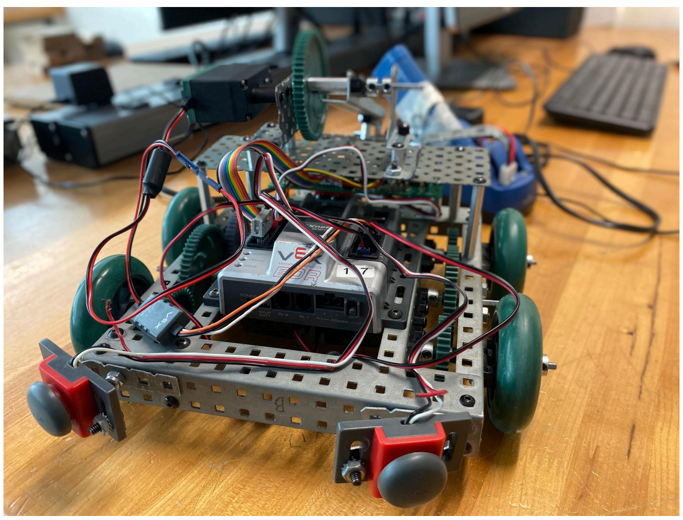

Figure 4: Back of the robot

The bumper switches are angled as they are to ensure that one of them will be pressed whenever the robot runs into a wall as there were issues originally with the bot sliding against the walls and slowing down. The angle also makes it more likely that only one switch will be pressed when coming into contact with a wall because there is a smaller surface area facing directly backwards.

IR Board

In order for the robot to “see” both the red and green beacon, there needs to be “eyes”. This is where the soldering team comes into play with the soldering of the IR board. The purpose of the IR board is for the robot to receive light emitting from the beacons, internalize it, and communicate it with the VEX controller. Constructing this, however, requires much more than a simple line of logic. A PCB along with resistors, capacitors, transistors, IR detectors, LEDs, and integrated circuits was provided to build the IR board.

Each component works in tandem for the IR board to function properly and each of them has to be inserted in the correct spaces. Certain components are also polarized, meaning they will only work if inserted in the correct direction. Resistors are not one of these components, but they do provide a very important service for the board, giving a consistent flow of electricity throughout the board. There are also resistors with different resistance values, each of them having to be placed in specific places. There are two types of capacitors, (one polarized, the other not) both of them acting like batteries, storing and releasing energy in intervals. Transistors are used for signal amplification or voltage regulation. The LEDs are used to indicate different functions of the board, like if light is being detected, and is polarized. Lastly, the most important component is the IR detectors, which are a type of LED. These function as the proper eyes of the board and are the component that receives the light emitted by the beacons. A roadmap to a complete IR board is showcased in Figure 5.

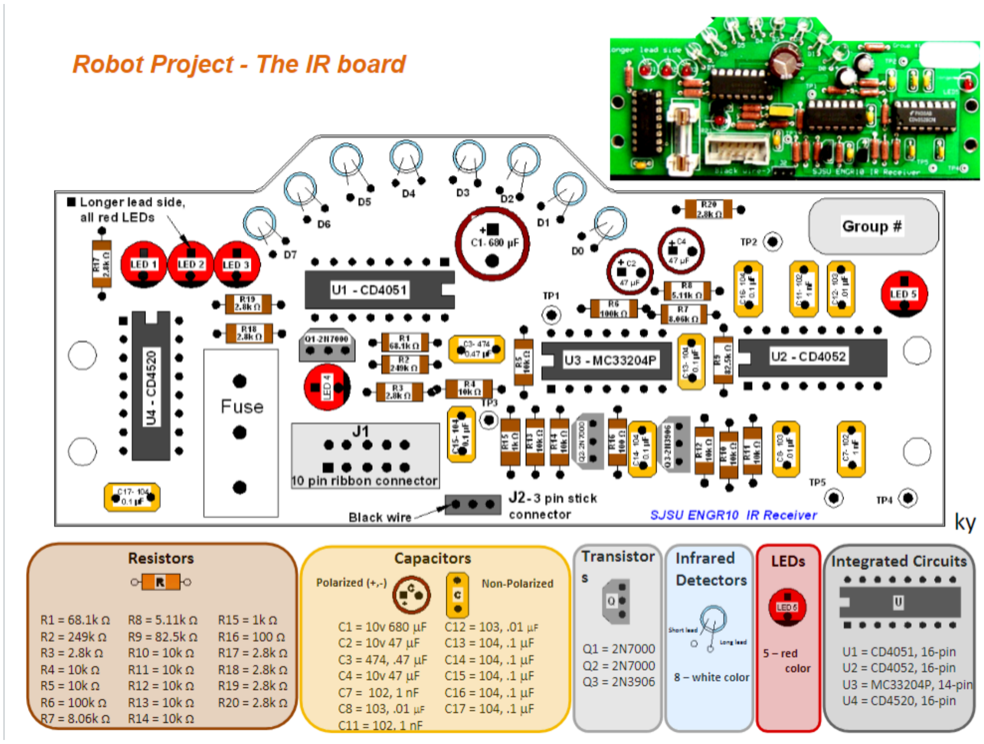

Figure 5: IR Board Roadmap

In order to attach each component to the IR board, each component needs to be soldered. Soldering requires heating lead solder with a soldering iron into sockets to allow electricity to flow through. A proper solder joint is aimed to be shaped like a small volcano, and this was achieved on most joints. Raymond Chin and Sebastian Fiallos spent the beginning weeks soldering each component of the IR board together, which resulted in a board that functioned perfectly. The finished IR board is pictured below in Figures 6 and 7. In week 5 of the project, there was an inadvertent sabotage of our robot, which resulted in our IR board being tampered with. This led to IR detectors 3 and 7 reading values 50 times the expected value, culminating in a total failure of our IR board. Any attempts at troubleshooting resulted in nothing and we settled with a sample IR board.

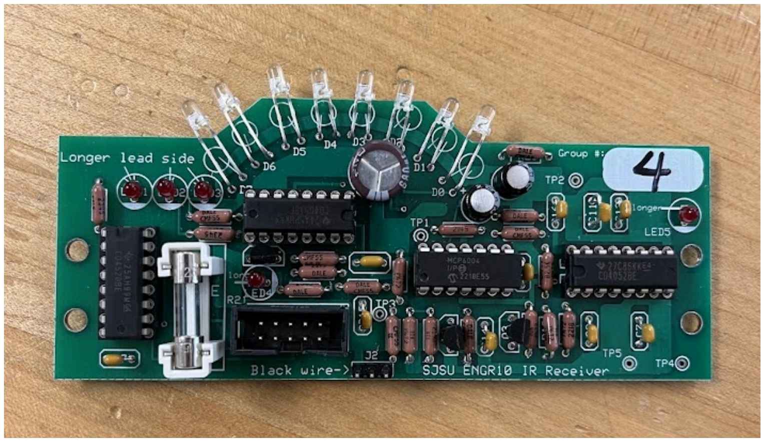

Figure 6: Top View of IR Board

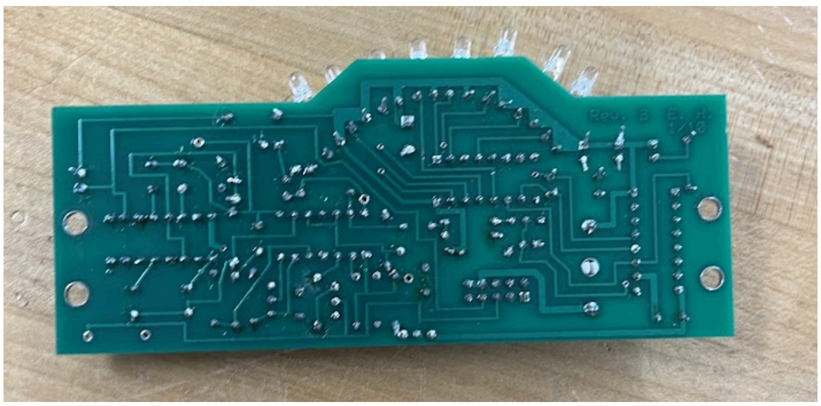

Figure 7: Back View of IR Board

Robot Code

The programming team, consisting of Khoa Pham and An Nguyen, was responsible for writing and designing the code for the robot. With the goal of having the robot be able to autonomously locate and turn off the red beacon, and then capture the green beacon, we decided to split the code into 5 stages for easier handling. To make the process easier, we used the given GO_TO_BEACON from the course website as our framework code. The GO_TO_BEACON code already has pre-built functions that could be used to help with simplifying and shortening the coding. These included the read_PD(), find_max(), and move()

functions. The read_PD() function was used to get readings from the IR sensors located on the circuit board. The find_max() function is then used to locate where the frequency is to locate the beacon's position. Once located, the move() function is for the robot to move and steer accordingly based on the output from the previous function. We also have to coordinate with the mechanical team in regards to where the placements of the switch and bumpers are as well as how they envision the robot to operate to achieve its goal. Through this, we can effectively code the program accordingly.

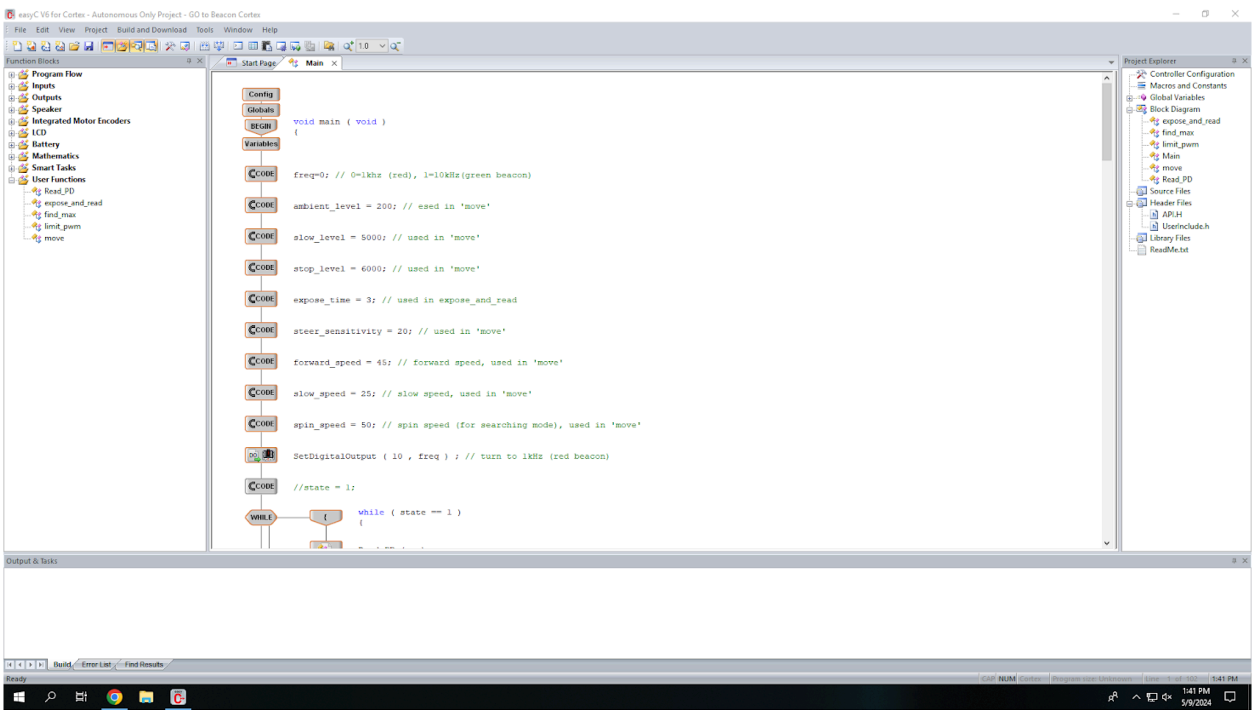

Figure 8: Start of robot code

The figure above shows the various variables that we have in place to use repeatedly throughout the entire program. The ambient level defines the frequency where no beacon is detected. The freq variable is either set to 0 or 1 for red or green frequency. The other level is to help coordinate the move() function for the robot to move accordingly based on where the beacon is located.

The code is split up into 5 stages. The first stage is to locate the red beacon and move towards it. The robot will use the 3 in-built functions to move towards the beacon and will hit the beacon. This will trigger the limit switch and stop the robot, transitioning to stage 2. In the second stage, the robot will lower the arm and hit the button on top of the beacon to turn it off. This process is in a while loop and a read_PD() function is used to check if the beacon is off or not, the loop will either break, move backward for half a second and move to stage 3 or loop back to the beginning of stage 2 until the beacon is turned off. In stage 3, the variable freq will be set to 1. This will indicate the robot to look for the green beacon, we will then proceed the same way as stage 1 did and proceed to stage 4. For stage 4, the robot only needs to lower the arm to capture it since the arm will have and will move forward to stage 5 as shown below.

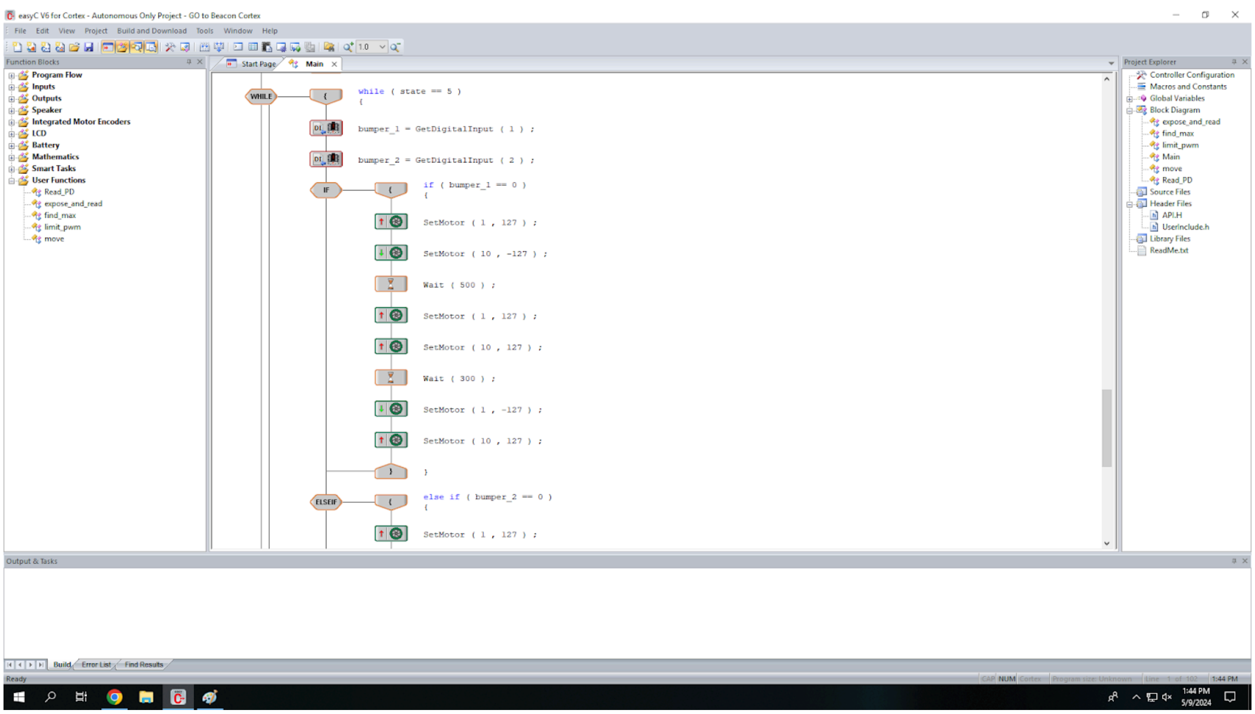

Figure 9: Robot code stage 5

In the figure above is the code for stage 5. For this stage, we have to cooperate with the mechanical team to understand how the robot would retrieve the green beacon and exit the arena. After some collaboration and discussion, we decided that the robot would exit the arena by going in reverse as the 2 bumpers are located on the opposite end. Since there is no clear indication that the robot can autonomously use to determine whether it is in the arena or not, we set the entire stage 5 in a while loop. The code is set to have an if condition to check whether the bumpers are triggered or not. If the left bumper is triggered, the robot will stop, go into reverse, and turn for 300 milliseconds. The same concept is applied for the right bumper. If none of the ifs conditions are triggered, then the robot will move forward at maximum speed.

Robot's Performance

Final testing of our robot was mostly successful, although there were a few minor hiccups. The robot had to achieve several criteria within one test to simulate real-life household assistance scenarios.

The first criterion was to find and approach the red beacon. The robot successfully used its IR sensors and navigational algorithms to find and approach the beacon. Upon reaching the beacon, the robot did stop in place, indicating successful transfer to the next stage.

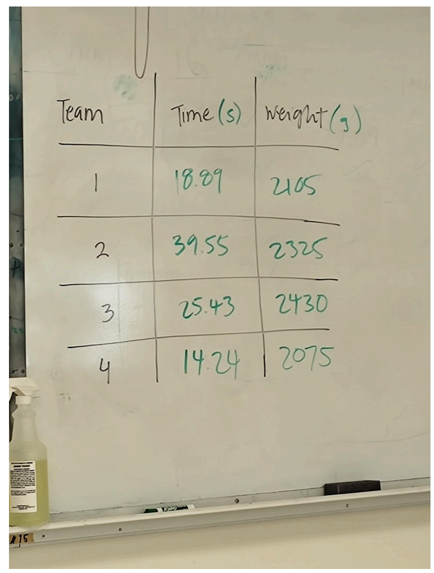

Figure 10 : Team Scores

The robot was then needed to turn off the red beacon by pushing the button on top of the red beacon using its arm. A first problem experienced was the arm repeatedly smashing the beacon due to a rapid trigger mechanism. This was fixed by adjusting the code using the timings and force settings, and the robot successfully turned off the red beacon. The third criterion was to find the green beacon. The robot successfully used its IR sensors for the third time to find the location of the green beacon and approach it with no major problems. This further indicated that the algorithm created by the programming team was robust and able to detect the correct beacon of interest when multiple frequencies were present. The fourth and final criterion was to grab the green beacon and drag it out of the arena. The first problem was with the arm failing to grab the beacon successfully. As a result, a gap remained between the arm and the beacon. After some fine-tuning of the mechanical design and positioning of the arm, the robot was able to grab the green beacon and proceeded to drag it out of the arena. It was at this stage that the robot was required to back out of the arena while dragging the green beacon. This was done using the bumper switches, which allowed the robot to find and respond to obstacles in the arena, including the arena walls, by reversing and realigning its course. The robot successfully backed out of the arena while still holding the green beacon, indicating successful completion of the whole stage.

Our robot was also remarkably lightweight, weighing in at 2075 grams, which was just 15 grams heavier than the lightest robot in the competition (fig. 10). Additionally, our robot clocked in at a speed of 14.24 seconds, showcasing its efficiency and speed in completing the tasks. Overall, the robot's performance showcased the effectiveness of the collaborative effort between the mechanical, electrical, and programming teams. Despite some initial challenges, the robot was able to complete all tasks within the weight limit and demonstrated reliable functionality.

Conclusion

In conclusion, the project was a resounding success, fulfilling the objectives set out at the beginning. Our group effectively designed, built, and programmed a robot capable of performing tasks that simulate real-life household assistance scenarios. The mechanical, electrical, and programming teams each contributed essential components for integration into the final deliverable. In this respect, the mechanical team designed a lightweight and structurally sturdy robot containing an effective arm mechanism for interaction with the beacons. The electrical team provided an IR board of reasonable quality in order for the robot to 'see' and pick up the beacon message adequately. The programming team came through with code of great strength that made the robot capable of navigating and finishing the required tasks in an autonomous fashion.

This project was really beneficial in the sense that it provided us with valuable experience in integrating diverse engineering disciplines into one for the achievement of a common goal. Difficulty was experienced in the extremely fast trigger mechanism of the arm and the tampered IR board, which showed us how important troubleshooting and improvement in an iterative manner are. The success of this project technically proved our skills and attested to the importance of teamwork and good communication. In fact, many obstacles to the set objectives were largely overcome because of the dedication and collaboration of each member. We believe that this project has thus equipped us for most, if not all, similar, as well as dissimilar undertakings in the vast field of engineering. In other words, this project lays a good foundation for further design, construction, and programming of autonomous systems. We look forward to applying the lessons learned in this project to more complex challenges in our academic and professional careers.

Conclusion

Through the effort of the mechanical, electrical, and programming teams, we successfully designed, built, and programmed an autonomous robot capable of completing the tasks given. The mechanical team managed to construct a robot base and design mechanisms that interact with the beacons while being efficient and reliable. The electrical team successfully soldered the components onto the IR board, which allowed the robot to “see” and interact with the beacons. The programming team completed their equally important job of crafting a code framework that enabled the robot to navigate the arena, locate the beacons, and execute the required actions. Their ability to adapt to obstacles was showcased as if there was faulty code, they would communicate with the other team members and provide working code after working it out. When testing the robot, we had to overcome obstacles such as adjusting the timing to successfully grab the green beacon and backing out of the arena swiftly. Our robot exceeded expectations in terms of both functionality and efficiency. It was one of the lightest while being the fastest among the other groups. By leveraging the strengths of each member of the group, we were able to create a robot that met the project requirements as well as showcasing our innovation, adaptability, and resilience. Reflecting on our robot building journey, we are proud of what we accomplished and are excited to continue our path of engineering.

References

Robot Project Guidelines, 2024. Charles W. Davidson College of Engineering. Lab section 12.

Robot project overview. Charles W. Davidson College of Engineering. Lecture section 1&2.

Robot Week 1 programming. Charles W. Davidson College of Engineering. Lab section 12.