Executive Summary

Group 14
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EXECUTIVE SUMMARY

The Executive Summary begins with an Introduction section. The goal of the project is to design, assemble, and program a robot that functions as a follower. The robot and its design process should inspire students to build a robot of their own and spark curiosity in a new generation of engineers. Project-based learning encourages students to investigate solutions to a real-world problem through a project. This helps students develop skills that are applicable to their careers. The core technology of the project is Arduino Uno, which takes input from devices and supplies output to others. This includes a sensor, H-bridge, and geared motors. The Project Plan section comes next. The design lead printed the chassis of the robot early on. The hardware lead and the software lead have been working together to implement the robot's movement as the project lead documents the team's meetings. The test lead will review the robot's functionality as the presentation deadline approaches. The total cost of the robot is $28.40. The team's strength is communication and the team's weakness is promptness. The Prototype Design section comes after. Engineering specifications are criteria that the design must meet to fulfill customer needs. The final candidate design is a Pikachu-themed vehicle that is composed of a base, body, ears, and a tail. Final design challenges were mainly due to the size limitations. Although it was difficult to ensure all parts would fit, the solution was the placement of each part. The Product Development section follows. Assembly involves securing the parts on or below the base, wiring, placing the body over the base, integrating the sensor and LEDs, and inserting the batteries. Manufacturing challenges include the orientation of the 3D print and connecting the wires. The Software Development section is next. The program consists of variables, move/stop/turn functions, and setup and loop functions that initialize the output pins and control the sensor. The videos are a demonstration of the motors working and the robot working with the sensor. Software challenges include determining the motor speeds, ease of the program for the user, and the robot's turning timing and angle. The Prototype Testing section ends the individual reports. The robot's motors work with the sensor as it follows a wall until the wall is 40 centimeters away. Then it will turn 135 degrees to the left or to the right and repeat the process. The robot is safe and durable, but further testing should be done in the future. The robot meets the course's engineering specifications. There were issues with connecting four motors to one H-bridge and figuring out the power source. This was resolved by using two motors and two casters instead. The group recommends sending the robot out to a few people to receive feedback and make adjustments accordingly. Then it will be made available to the public. To conclude, the project generates interest in STEM and provides students with valuable experience to prepare them for their future as engineers.

I. INTRODUCTION

The team aims to create an enriching product that will benefit both the engineers and the students that will interact with the robot. This project will teach the team many fundamental skills such as communication, teamwork, and delegation of work. The project also provides many opportunities for individual learning experiences such as coding, wiring, and 3D design. All of the skills learned during this project will help the team moving forward in their careers in engineering. Additionally, this project will also be introduced to young K-12 students. By making the design of the robot easy to assemble, kid-friendly, and easily recognizable, the team hopes to capture the attention of young people. This project will generate interest and curiosity regarding the fields of STEM and aims to spark light in a new generation of engineers.

Project-based learning is an approach to teaching that encourages students to investigate the solutions to a problem through an engaging project. These projects are collaborative, multidisciplinary, and are focused on the application of knowledge [1]. The curriculum of a course is centered on the project. The project should be realistic rather than school-like and provide students with a feeling of authenticity [2]. Projects help students build their own knowledge, as they are primarily student-driven. The students' management of time and resources in addition to the differentiation of tasks and roles are essential in project-based learning [1]. In the Foundations of Engineering course, students are expected to work in a group of five to design an autonomous robot that will be presented by the end of the semester. Project-based learning can increase motivation, improve teamwork, and allow students to develop problem-solving skills [3]. Students have a deeper understanding of content as they are exposed to real-world applications. Interacting with instructors, teaching assistants, and experienced engineers enhances the learning process. Students from Technion - Israel Institute of Technology who took a project-based learning course stated that it promotes creativity, emphasizes the importance of responsibility, and develops engineering thinking and intuition [3]. Project-based learning is growing rapidly and consists of many supporters despite the push for standardized testing and teacher-directed instruction [2]. Project-based learning provides students with a new, active learning environment that will allow them to gain valuable skills for the real-world.

The core of the technology that will power the robot is an Arduino Uno, which will provide the logic for it. It will take input from devices and supply output to others. Those devices in question are an Ultrasonic sensor which will measure the distance in front of it then send that data to the Arduino, an L298N H-Bridge which will take instructions from the Arduino to power 4 DC motors in a specific fashion so that it will move as we have intended.

II. PROJECT PLAN

PROJECT SCHEDULE

The goal of this project is to create a robot that can run and navigate its environment on its own. The team established a design early on and then moved forward improving and working around the design. The design lead printed the main chassis of the robot early on so that the hardware lead could start working with the final design. This head start gave the team significant breathing room because many design and printing complications were dealt with early on. The software lead led the team recently, as the code of moving the robot has become the last significant piece of material the team needs before having a fully functional design. During the last few weeks, the team has been focusing on implementing proper movement in all four wheels of the design. These are the final steps of the design process, with the final product being ready in the coming weeks.

BILL OF MATERIALS

Table 1: Bill of Materials.

Material	Amount	Total Cost ($)
Arduino	1	4.27
2/pack of wheels	1	3.32
Sensor	1	3.40
Female-to-Male wire	23	5.75
Battery	4	4.00
2/ pack DC Motors	1	1.80
Motor Controller	1	1.50
LEDs	2	0.20
Photo resistor	2	0.16
PLA Filament	205 g	4.00

Total Cost: $ 28.40

The total cost of this design is just under the $30 limit that has been set by the project specifications. The design itself is simple and uses only a few expensive materials. The most expensive materials came from the use of four wheels and four motors. While it was possible to create a design that implemented only two motors, the team decided that the four-motor design would be easier to build and operate.

STRENGTHS AND WEAKNESSES

The team’s communication has been one of its greatest strengths. The team established a Discord group chat during the first team meeting, and it has been used consistently during the design process. When one member has a question regarding the design, the team always answers or finds a solution the best of their ability. This has made the design process a full team effort. One of the team’s biggest weaknesses is promptness. There have been multiple times where the team has not started a group assignment until hours before it is due. While the team has always completed the work on time, it is very possible that the quality of work has been affected because of this. Overall, the project has gone smoothly, and the team's effective communication has served as a solid foundation for the design process.

III. PROTOTYPE DESIGN

ENGINEERING SPECIFICATIONS

Table 2: Engineering Specifications.

Engineering Specifications	
Cost	$28.40
Number of 3D Printed Parts	5
Dimensions of Base	5.5’’ x 4.5’’ x 0.5’’
Dimensions of Body	5.5’’ x 4.5’’ x 2.5’’
Dimensions of Ears	1’’ x 1.2’’ x 1.6’’
Dimensions of Tail	3.5’’ x 2.4’’ x 0.3’’
Dimensions of Robot Assembled	7’’ x 6.7’’ x 6.3’’
Estimated Weight	3 pounds
Power/Voltage Requirements	6 Volts
Turn Angle	135
Distance	40 cm
Speed	30 cm/s
Time to Assemble the Robot	4-6 minutes

The engineering specifications were developed with the group’s customer needs and project objectives in mind. The total cost of the robot is $28.40. The design consists of 5 printed parts that can be combined into three STL files. The dimensions of the assembled robot are 7’’ x 6.7’’ x 6.3’’. In its disassembled state, it will fit in a 6’’ x 6’’ x 6’’ box. The estimated weight of the robot is 3 pounds. The voltage required to power the robot is 6 volts, as 4 AA batteries are used. The turn angle of the robot is 135 degrees, and the distance of the robot’s ultrasonic sensor is 40 centimeters. To elaborate, the robot will be following a wall. It will move towards the wall until the wall is 40 centimeters away. Then it will turn 135 degrees to the left or to the right and repeat its role as a follower. The speed of the robot is 30 centimeters per second. The time needed to assemble the robot is approximately 4-6 minutes.

FINAL CANDIDATE DESIGN

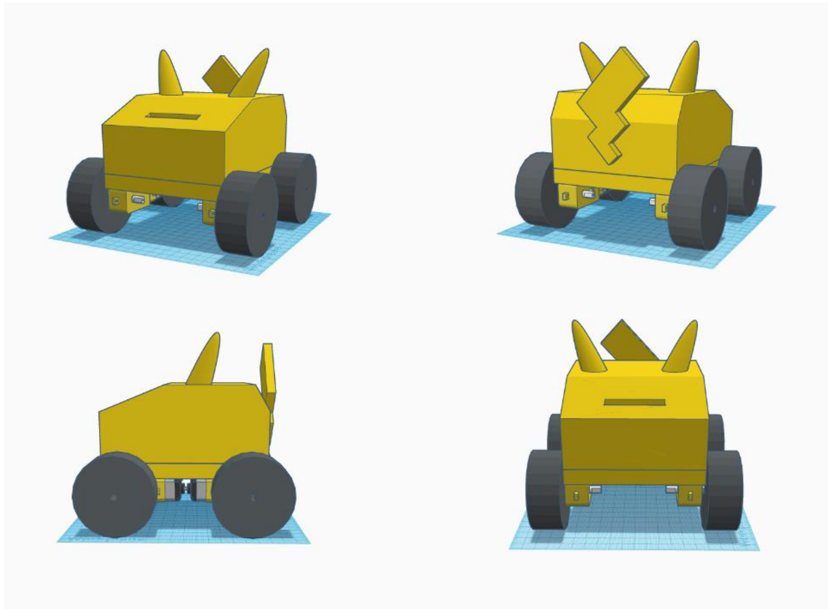


Figure 1: Final candidate design viewed from the front, back, and the side.

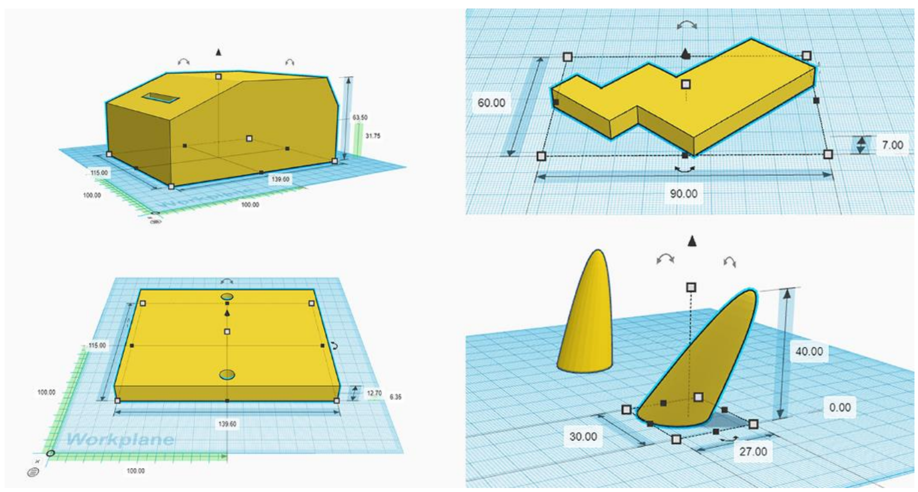


Figure 2: The final candidate design's 3D printed parts.

The final candidate design is a Pikachu-themed vehicle. It is made up of a base, body, ears, and a tail. The design is entirely 3D printed. Each part is within the 3D printer's dimensions of 5'' x 5'' x 5''. They were printed with 2 shells and 15% infill. The base is 5.5'' x 4.5'' x 0.5''. There are two holes in the base. They are on the middle left and the middle right of the base to provide better access to the wires. The diameter of each hole is 0.4 inches. The body is 5.5'' x 4.5'' x 2.5''. It is hollow, but features a flat area on the bottom towards the front and the back to attach it to the base. There is also a rectangular hole in the body for the sensor. This hole is 1.8'' x 0.5''. The ears are 1'' x 1.2'' x 1.6'' and they are glued on top of the body. The tail is 3.5'' x 2.4'' x 0.3'' and it is glued at the back of the body. The Arduino UNO R3 and the L298N H-Bridge are placed on the base. They are secured with electric tape. The motors, wheels, casters, and battery pack are placed below the base. They are secured with glue. The body covers the base and is secured with Velcro. To make the design more visually appealing, a face and extra colors are added with paper, tape, and marker. This includes Pikachu's red cheeks, black tips on the ears, and brown highlights on the tail.

DESIGN CHALLENGES

The final candidate design was chosen by using a weighted benefit analysis table. The group decided that the Pikachu design addresses the group's customer needs and the project objectives the best. However, the process of making the design functional came with many challenges. To begin with, the initial design resembled a hatchback car. This design was more aesthetic than the current design. It required a base with room for the motors and a frame that fits perfectly over the base. Figuring out the dimensions for the frame and how it was going to be attached to the base was difficult. Another issue was it left little space for the hardware, as each part had to be within 5'' x 5'' x 5''. A solution was to slice the parts, make them bigger, and glue them together. Ultimately, it was still not large enough to enclose the parts while staying within the 6'' x 6'' x 6'' objective. The design was too complex, so it was modified to be the current, final design. The new design had its own challenges despite being simpler. In order to avoid overhang issues, the ears were adjusted to be more upright, and the body had to be printed upside down with supports. Furthermore, the group did not know where the sensor should be placed, as it could not hang out of the hole freely. They decided that the front of the body would be the most viable spot. To continue, the group originally planned for the battery pack to be attached to the inner top of the body. This made the wiring difficult, so it was moved to the bottom of the base. Another problem was keeping the hardware stable on the base. Anti-static tape was the solution. Additionally, the group had to find a place where the LED lights could go. They decided that the sensor hole could be utilized.

IV. PRODUCT DEVELOPMENT

PARTS AND COMPONENTS

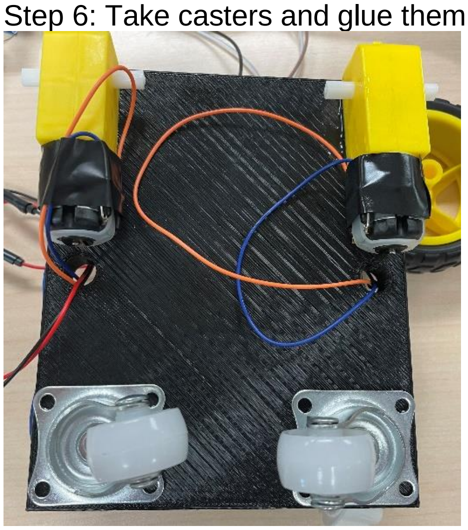
Table 3: Prototype parts and components.

Components	Amount
Arduino Uno	1
Wheels	2
Sensor	1
Female-to-Male wire	23
Battery Pack	1
Motors	2
Motor Controller	1
Casters	2
LED lights	2
220 Resistor	2
3D Printed parts	5

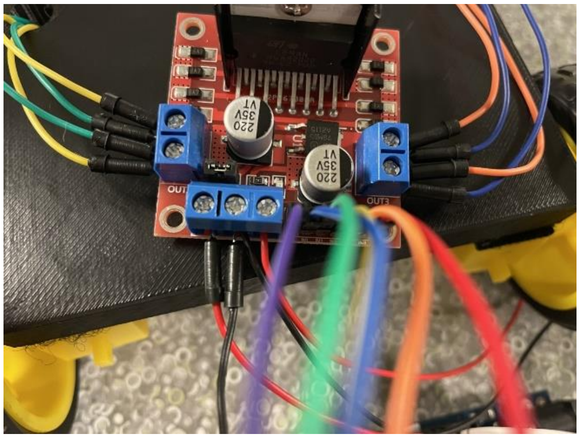
When building the robot, the components in the table were all used. The Motor Controller, or also called h-bridge was connected to the four motors using wires, and one wheel was connected to each motor. The Motor Controller was connected to the Arduino and to the Battery Pack, power went to the Motor Controller then to the Arduino board. The Sensor was connected to the Arduino board, and the 3D printed parts were the base where all the other components are attached to, the body that covers the components, and other design parts for the robot.

PROTOYPE ASSEMBLY

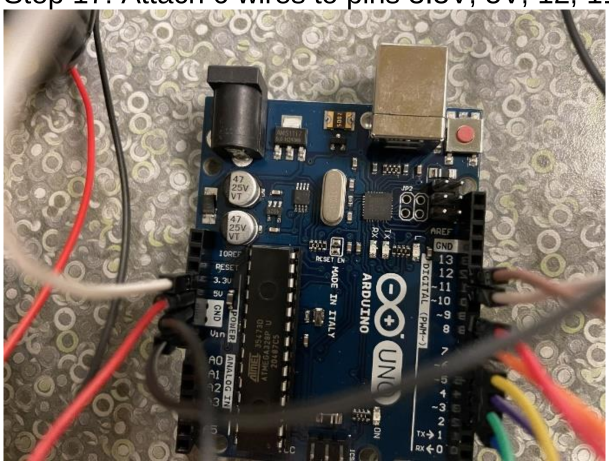
Step 1: Attach wires to the copper ends at the top of each motor and wrap with tape.
Step 2: Attach one wheel to each motor, on the opposite side of the wires.
Step 3: Glue the motors to the front 2 corners at the bottom of the base, have the wheels stick outside of the base
Step 4: Take any wires on the left side of the base and pass them through the left hole to the top of the base.
Step 5: Repeat Step 4, but on the right side of the base with the right hole
Step 6: Take casters and glue them to the bottom back 2 corners of the base



Step 7: Using electrical tape, tape down the Arduino Board and the H-Bridge on the top of the base, have the Arduino be placed on the front side of the base and the H-Bridge on the back
Step 8: Take the wires on the left side of the base and attach one wire to the OUT 4 pin on the H-Bridge and attach the other wire to the OUT 3 pin
Step 9: Take the wires on the right side of the base and attach one wire to the OUT 1 pin on the H-Bridge and attach the other wire to the OUT 2 pin
Step 10: Attach 6 wires on the Arduino Board on pin 4-9
Step 11: Take wire attached to pin 6, attach it to pin ENA on the H-Bridge
Step 12: Take wire attached to pin 4, attach it to pin IN1 on the H-Bridge
Step 13: Take wire attached to pin 5, attach it to pin IN2 on the H-Bridge
Step 14: Take wire attached to pin 7, attach it to pin IN3 on the H-Bridge
Step 15: Take wire attached to pin 8, attach it to pin IN4 on the H-Bridge
Step 16: Take wire attached to pin 9, attach it to pin ENB on the H-Bridge



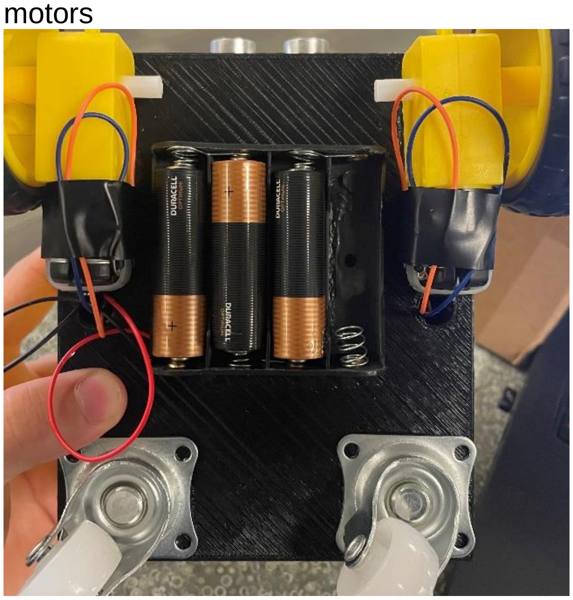
Step 17: Attach 6 wires to pins 3.3V, 5V, 12, 11, and 2 wires to GND



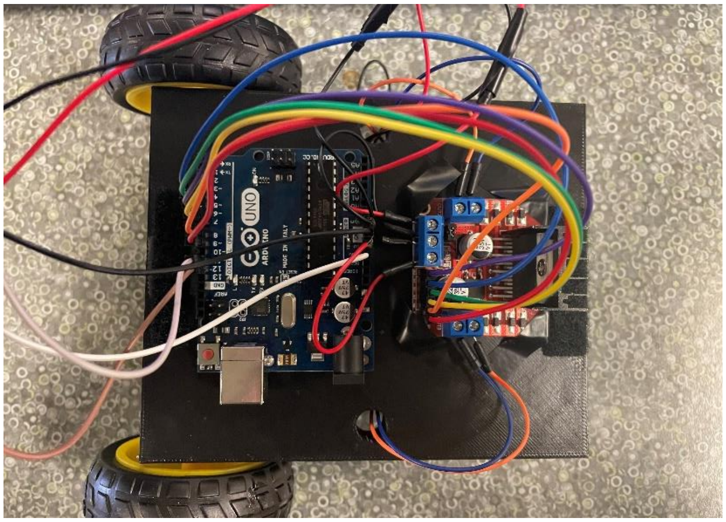
Step 18: Take wire attached to 5V on the Arduino Board and attach it to the 5V pin on the H-Bridge

Step 19: Take one wire attached to GND on the Arduino Board and attach it to the middle power pin on the H-Bridge

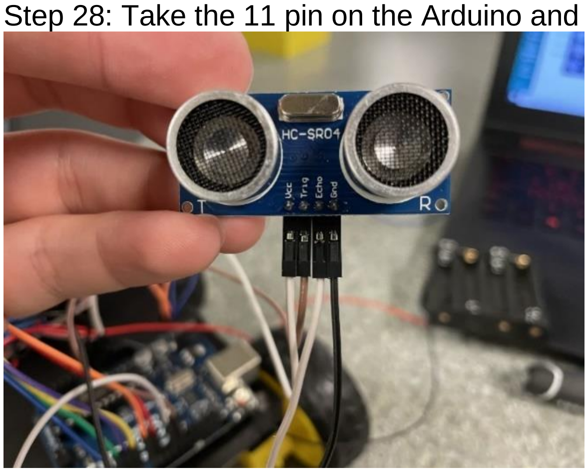
Step 20: Take one Battery Pack and glue it to the bottom of the base, between all the motors



Step 21: Take the black wire of the Battery Pack and connect it to the ground pin on the H-Bridge
Step 22: Take the red wire of the Battery Pack and connect it to the 12 V pin on the H-Bridge



Step 23: Attach Velcro to the bottom of the 3D printed Body and on the top of the base
Step 24: Take wires attached to 3.3V, 11, 12, and the 2 GND on the Arduino Board and slide them through the whole on the 3D printed body.
Step 25: Take Sensor and attach the GND wire on the Arduino to the Gnd pin
Step 26: Take the 3.3V pin on the Arduino and attach it to the Vcc pin on the Sensor
Step 27: Take the 12 pin on the Arduino and attach it to the Trig pin on the Sensor
Step 28: Take the 11 pin on the Arduino and attach it to the Echo pin on the Sensor



Step 29: Tape the Sensor to the very front of the body

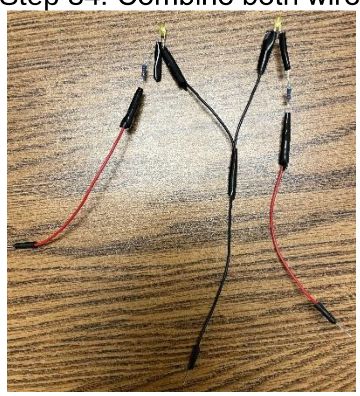
Step 30: Take an LED and tie a 220 resistor on the positive end of the LED, then wrap it with electrical tape

Step 31: Repeat Step 35 with the second LED and resistor

Step 32: Tie a wire to the negative side of the LED and wrap it with electrical tape, with both LED's

Step 33: Tie a wire to the other side of the resistor and wrap with electrical tape, with both resistors

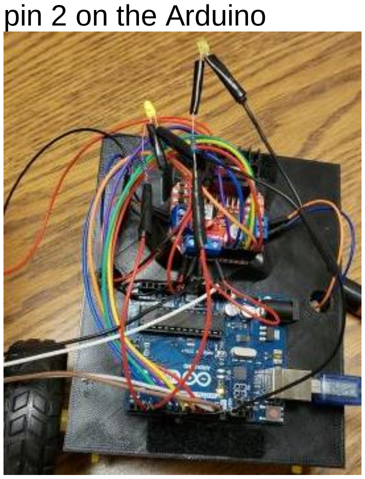
Step 34: Combine both wires attached to the negative side of both LED's



Step 35: Take the wire attached to both negative sides of the LED's and put it in the GND pin in the Arduino

Step 36: Take one of the wires attached to the positive side of one of the LED's and put it in pin 3 on the Arduino

Step 37: Take the other wire, on the other positive side of the second LED and put it in pin 2 on the Arduino



Step 38: Take the LED that is attached to pin 3 and put it through the hole in the body, and have it sticking out on the left side of the Robot
Step 39: Take the LED that is attached to pin 2 and put it through the hole in the body, and have it sticking out on the right side of the Robot
Step 40: Tape the LED down to the top of the body

Step 41: Take the Body and put it over the base of the robot
Step 42: Put batteries in the Battery Pack

MANUFACTURING CHALLENGES

First, when 3D printing the body of the robot, it had to be printed upside down, because the inside of the body is hollow and wouldn't print right side up. On the front of the body, where the whole for the sensor will be, this part was difficult to print, so this part of the body isn't smooth. Once, assembling the robot, it was difficult to figure out how all four motors would be connected to the Motor Controller and how the Motor Controller and the Arduino Board would be powered. Then with some research, the four motors could be connected to the one Motor Controller and then the Battery Pack could be connected to the Motor Controller first, then wires from the Motor Controller could be connected to the Arduino Board could power it.

V. SOFTWARE DEVELOPMENT

PROGRAMMING CODES

The rationale behind the robot's program is for all complex elements and functions to be prewritten. Then, the user will write a few simple lines of code to make the robot work. This will make programming easy for the user to understand. The first 12 lines initialize numerous variables that are needed for the robot's function, like pin numbers and distance values. Next, there are functions that are written out: move, stop, and turn. These functions operate as they are named, where move makes the motors push the robot forwards, stop stops the robot, and turn makes the robot turn to the left or the right. Afterwards, the setup and loop functions are written, which setup initializing the output pins that are used in the program. These portions of the program reference a guide created by Arduino [4]. Next is the loop function, which first sets the pin going to the ultrasonic sensor to high for 10 microseconds, then sets it back to low. Next, it assigns variable "duration_us" to the value returned by library function pulseIn, sending it the values of the pin for the sensor's echo and HIGH. Then the variable "distance_cm" is assigned the value of duration_us multiplied by 0.017. Finally, the section that the user will write themselves, which makes calls to the previous functions. The first line they will write sets up an if statement which executes if variable distance_cm is above 30 centimeters. The code that executes calls function forward(), moving the robot forwards and activates both LEDs. The else statement after the if calls functions stop() then turn(). Turning turns on the LED corresponding to which direction it will turn. The direction it turns alternates between left and right each time it turns. Finally, a delay of 500 (half a second) is called for the ultrasonic sensor's delay.

FABRICATION VIDEOS

The first video of the robot is a demonstration of an electric DC motor working with an Arduino and an H-Bridge. The video demonstrates that an Arduino can make a motor turn forwards and backwards (Motor Test). The second video is of the robot prototype with an Arduino, an H-Bridge, two DC motors, and the ultrasonic sensor working together. This video shows the ultrasonic sensor causing the motors to stop when something is in front of it, which is a crucial part of the robot's programming (Sensor and Motor Test).

SOFTWARE CHALLENGES

Challenges that were faced in the development of this program included determining the proper speeds to set for the wheels' motors going forwards and backwards so that they match, as those speeds vary depending on direction of rotation. Another issue was considering how to have a user easily write the program, and determining what the user should have to do to make the robot function, and what they would learn from this experience. The last issue, similar to the issue with the motor speed, was determining the time to have the robot turn to the left and right, so that the robot turns at an adequate angle for it to function.

VI. PROTOTYPE TESTING

PROTOTYPE PERFORMANCE

All four motors are working with the sensor and the robot follows a wall. It moves towards a wall until the wall is 40 cm away, then turns 135 degrees to the right and moves again towards a wall until it is once again 40 cm away. Then, it will turn 135 degrees to the left and repeat this same process. The robot works safely within the necessary parameters and the quality of the design holds up well. There has not been any real rigorous durability testing conducted, as this would require us to put the robot at risk if for whatever reason it is not capable of withstanding certain forces, this is something that must be tested once fully completed and ready for mass manufacturing but as it stands right now it is fully capable of being put together, driven, and taken apart without any wear or tear at all to the robot which is a good sign in terms of its durability. The testing of durability would be best to be conducted after the robot is presented to the class, as it must be shown capable of working. Durability can be worked on easily between the presentation and mass production.

CERTIFICATION TEST REPORT

Table 4: Prototype specifications.

Net Weight	Dimensions	Max Speed	Assembly Time	Power Required	Sensors
3 lbs	7'' x 6.7'' x 6.3''	255 PWM	4-6 minutes	6 Volts	Ultrasonic sensor

The first specification of the prototype is being able to turn in all directions and follow a person or object based on sensors and programming with the program also able to adjust turning speed and aggressiveness which it is capable of doing based on the code as shown previously. The design must have some sort of novel feature which for this robot is LED lights that have been added to the side of the design. It also must cost less than $30, it costs $28.40 as calculated above, and must be capable of being assembled by an elementary school student in under 7 minutes or by an experienced person within 4 minutes. Lastly, the prototype does fit inside a 6” x 6” x 6” cube when disassembled even though when assembled it is larger than that and it has a 3D-printed enclosure. So, all of the given specifications have been met with this design.

PERFORMANCE ISSUES

When we started putting the prototype together, we encountered issues with connecting all four motors to one h-bridge. We found that we can connect pairs of motors to a single port on the h-bridge, allowing all four motors to rotate together. We also had trouble connecting power to both the h-bridge and Arduino board, but we found that the power can go into the H-bridge and then can relay into the Arduino board. We were also unsure about how to use the sensor with our current design. But we decided that the hole in the body was enough for the sensor to work, as it could stick out in the front. Another issue was figuring out how to secure the Arduino board and H-bridge to the base. Our solution was anti-static tape or velcro. In addition, we did not know where the LED lights could go because our enclosure does not have any holes aside from the sensor hole. To compromise, we placed the lights on the side of the main body of the robot.

VII. RECOMMENDATIONS

The next steps for the project would be to produce a few different robots that are identical to this one to send out to a select few people to test out and get their feedback. With their feedback, the group can make any adjustments or changes to meet what customers want out of the product. Once the final touches are done to the robot, the group can actually start manufacturing the product and make it available to the public. During this mass manufacturing process ads would also be created to help reach more potential customers.

VIII. CONCLUSIONS

The goal of this project is to generate interest in the STEM fields and engineering in particular by creating a robot that is interactive while also having a kid friendly theme of the robot that will draw in grade school kids to want to pursue the project. Project-based learning is a different approach to learning that uses a more “hands on” approach to the process that should really be used more often, with the goal of peaking students interest in actually seeing a project come to life in front of them, keeping them engaged the whole time instead of just hearing about it and writing about it in lectures where students will sometimes lose interest or focus on what’s important. This process gives students good design experience for the future, as well as teaching them valuable teamwork and investigative design skills that are a key part of the engineering field.

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