EXECUTIVE SUMMARY

Group 7

December 1, 2021

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LINE
-FOLLOWING
ROBOT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The team identified a plan to follow through the semester that included a fixed schedule and continuous meetings to meet all requirements of this project. First, CAD designs were developed and evaluated with the purpose of choosing the best prototype that could meet the important metrics of customer requirements. Subsequently, the team started 3D-printing parts, assembling and aligning them with the leading candidate design, and improving it accordingly until a final design was decided upon. Taking into consideration engineering specifications, customer needs and targeted values for this project, the final prototype was designed. A total of 81 parts were used to complete the prototype, including a top case, a chassis, and electronic and hardware components. The main components used for the basic functionality of the product were an Arduino microprocessor, an H-Bridge, 2 IR Sensors, a Breadboard, 2 TT Motors and 22 Jumper Wires. A casewise Arduino code was created to allow the robot to follow a line, where the input of two sensors was used to determine the output of the H-Bridge. This H-Bridge determined the direction the wheels would turn, so, in tandem with the sensors, the robot would navigate itself over a line. The line follower arduino robot worked as expected and was tested for safety, quality and durability. The product's final weight was right around 1.5 pounds, and the dimensions of the product were 6 inches in length, width, and height. It traveled at a speed of less than 1 mile per hour and required 4 AA Batteries to function.

I. INTRODUCTION

The motivation to complete this project was the team's goal to educate young children about robotics and engineering as a whole by providing a cheap, appealing, reliable and safe product that teachers and parents could adopt in their classes and homes. As such, the aim was to introduce school children to hands-on engineering activities at an early age, in order to allow them to start developing skills that they will need in their bright engineering futures, while fostering their creative and artistic skills with the opportunity of playing a role in the development of their own robot design. The result of the project was the creation of a long-standing impact on the children and their families by giving them an unique opportunity and possibly their first interaction with a robot and learning how it works. Furthermore, it is expected that the project will aid children in getting to assemble their first robot and potentially spark their interest in STEM and engineering as a whole. On a personal perspective, the completion of this project impacted the team by improving creativity, time-management and problem-solving skills.

The approach for this project was based on project-based learning. Three articles regarding PBL and their impact were researched to provide further context on its benefits and effects on education. The first article by Moti Frank, Ilana Lavy and David Elata titled "Implementing the Project-Based Learning Approach in an Academic Engineering Course" discussed the process of developing a PBL course and analysed the opinions and stances of freshmen students taking part in an experimental mechanical engineering course. According to the article, the first step to PBL was constructivism which is a principle that states that human beings learn through experience and by making mistakes. As such these type of courses must implement discussions, engagement, and an opportunity for students to analyze and reflect upon their work, with the teacher serving as a moderator. This method has proved to help students improve their critical thinking and has given students who regularly do great an opportunity to improve their grades. The experiment performed in the article with freshmen students helped prove this as students felt the course allowed them to solve problems they had never thought of before. It also challenged their intuition and made them feel more familiar with their major [1]. Conversely, the article "Integrating Project-based Learning throughout the Undergraduate Engineering Curriculum" referred to the tools required to prepare global engineers for the challenges of the 21st century. Consequently, the paper described four strategies to be used along with Project Based-Learning in order to fulfill that objective and provide the students with the possibility of investigating technical challenges on their own. The first strategy was teamwork, which applied cooperative learning, a technique that has proved to be more effective than self-learning. According to Peter Senge, the principles of this strategy are group learning, systems learning and a common vision. The second strategy was systems thinking which referred to focusing on patterns and how different things relate to one another rather than just analyzing a single thing on its own. Dual Tetrahedron Approach was the third strategy. It was about finding balance between the social, economic and environmental aspects of the course to allow engineers to apply critical thinking and self-learning. Finally, there was walking the talk, which was about doing everything to accomplish the set objective. This is essential to PBL as to provide the best experience for students and teachers to succeed [2]. On the other hand, a study published in the American Educational Science Journal during the year 2011 by Clarice Wirkala detailed the effectiveness of PBL in K-12 students. The data from this study was collected by having sixth graders from different backgrounds, ethnicities and academic standings take two different courses, one with a PBL approach and the other with the typical learning method. The results showed that students who did PBL learning were more likely to apply the information they learned in a real world scenario and had better skills at retaining information for a longer time. Surprisingly, the PBL learning method allowed students to learn concepts better than traditional learning. This could possibly be related to practical explanations making comprehending a concept simpler. When compared to adults, PBL learning method seemed to have a greater effect on the K-12 students than on adults, as it empowered their creative skills and got them to take advantage of their curiosity and willingness to explore new things [3].

The final product for the project was a line-following robot which employed sensors to follow a black line. For this reason the core technology used to complete the project consisted of electronic and software components. As for the electronic part, a pair of IR Sensors which consist of two diodes that act as the transmitter and the receiver were used. They were in charge of detecting the black line on the floor through the use of IR light. An Arduino UNO was used as well, it acted as the microprocessor and was the one executing the code to control the H-bridge and the TT Motors. This allowed the wheels to spin according to the input from the sensors which in turn made the robot move forward and turn right or left based on the position of the robot in respect to the black line. As for the software part, the Arduino IDE was employed to develop and compile a functional code that allowed the components to perform these tasks. Additionally, CAD software was used for the planning and creation of 3D-Printable parts that served as the chassis and case for the design of the robot.

II. PROJECT PLAN

PLANS AND SCHEDULE

Once assigned the task to be delivered at the end of the semester, the team's first goal was to identify a plan to follow throughout the semester. As a result, along with all members it was decided to create a schedule that would serve as a guideline to accomplish the project on time. The plan was to do a first meeting during the fourth week of classes (September 15), during which the CAD model for the design would be decided and improved upon. This led to the selection of the car as the design to use for our project. Then on October 2, a second meeting was done to create the first version of the robot's control system. It was successful and gave an understanding on how to advance with the software and hardware areas. From October 11 through October 17, the team met at the DFX Lab to work on the design for the chassis and the top case along with the development of the first functional prototype. The connections and the code worked as expected, providing the group with their first working version of the robot. Afterwards, on October 22 the team 3D-printed the parts for the chassis and the brackets, allowing to improve the first test prototype with a design closer to what is expected in the end. Later on, the team met on October 30 and November 8 to improve details on the assembly of the robot with the use of screws and nuts to provide a more secure fit to the parts. The team met on November 17 to 3D-print the top case of the robot, paint it, decorate with stickers and install it to the final setup of the robot. As such the robot was completed during Week 13 of classes.

BILL OF MATERIALS

With low-cost being one of the fundamental objectives the team was attempting to accomplish, optimizing and cost reduction were essential to the construction of the robot. In consequence, it was crucial to reduce the quantity of materials needed and the weight of the 3D-printed parts so that customers had the opportunity of easily affording our product. For this reason, the idea of using 2 H-Bridges and 4 TT motors was scrapped in favor of saving costs. The total cost of the prototype is $x.xx with some of the essential parts like the arduino going for $4.27, the IR Sensors $3.26, the breadboard $0.24 (taking into account it was cut into 6 pieces), and the H-bridge and the TT Motors for $1.50 and $1.80 respectively (see Table 1 for complete breakdown on costs).

Table 1: Bill of materials and total cost of final prototype in USD

Material	**Cost**
Arduino	$4.27
Breadboard	$0.24
IR Sensor x2	$3.26
H-Bridge	$1.50
TT Motor x2	$1.80
Motor Wheel x2	$3.32
Universal Wheel x2	$1.66
Long L-Brackets x2	$0.08
Short L-Bracket x1	$0.03
Screw x 40	$0.65
Jumper Wire x 28	$1.00

Battery Pack	$2.00
Chassis	$0.82
Top Case	$4.07
LED x2	$0.20
Total Cost	**$24.90**

STRENGTHS AND WEAKNESSES

In general, the team seemed to have very good team ethics and high performance. In the meetings hosted so far, members appeared to communicate well with each other. This helped to efficiently work on tasks and keep track of our progress. Each member seemed to agree with the goals and aims established and there existed a clear plan to achieve these goals. Through every task done, all members contributed their fair share of the workload and supported each other. However, there existed some weaknesses that were perceived as the team progressed on the project, which the team tried to address. The team got distracted relatively easily. Although getting along well is a plus while working with any group, it seemed to have led to getting easily side-tracked. Additionally, the team planned too much to complete in each meeting. Therefore, meetings ended up lasting much longer than intended, and in most of the cases it became relatively impossible to get as much done as it was originally expected. Another thing to note, is that across the different assignments, the group noticed a difficulty understanding what each member was tasked to do causing confusions and delays at the moment of delivering an assignment. Overall, the strengths detailed were essential to the completion of the project, the great communication that existed among the members facilitated teamwork and as a result it allowed the team to complete some of the tasks quicker than expected and provide a final prototype to feel proud about.

III. PROTOTYPE DESIGN

ENGINEERING SPECIFICATIONS

The engineering specifications for the final prototype design included different metrics and target values that the team was able to achieve. This prototype had a low cost of $25 so that it could be easily accessible by most and not be an impediment for children to learn about STEM. In addition, the maximum dimensions of this prototype were 6”x6”x6” for a more convenient transport. A 3D printer utilizing PLA plastic was used for the case, chassis, and brackets; and all other parts were purchased. The assembly of this prototype should take a child around 5 minutes to complete using the instructions. This robot consisted of 76 purchased parts and 5 3D-printed parts with 20% of infill each. This project took around 60 days to elaborate and complete.

FINAL DESIGN

The final candidate design consisted of the representation of the character of the movie Cars, Lightning McQueen. A total of 81 parts were used to complete this design. The parts of the robot included a 6”x6”x3.5" top case, a 3D-printed 6”x6” chassis and 3 L-brackets made of PLA plastic. Additionally, an Arduino microprocessor, 1 H-Bridge, 2 IR Sensors, a Breadboard, 2 TT Motors and 22 Jumper Wires with standard measurements were used. For simplicity, a grid of 17x17 holes was used to measure and mark the position of the holes that were going to be used. This gave a total of 27 holes. See Figure 1 for an overview on the final CAD Design.

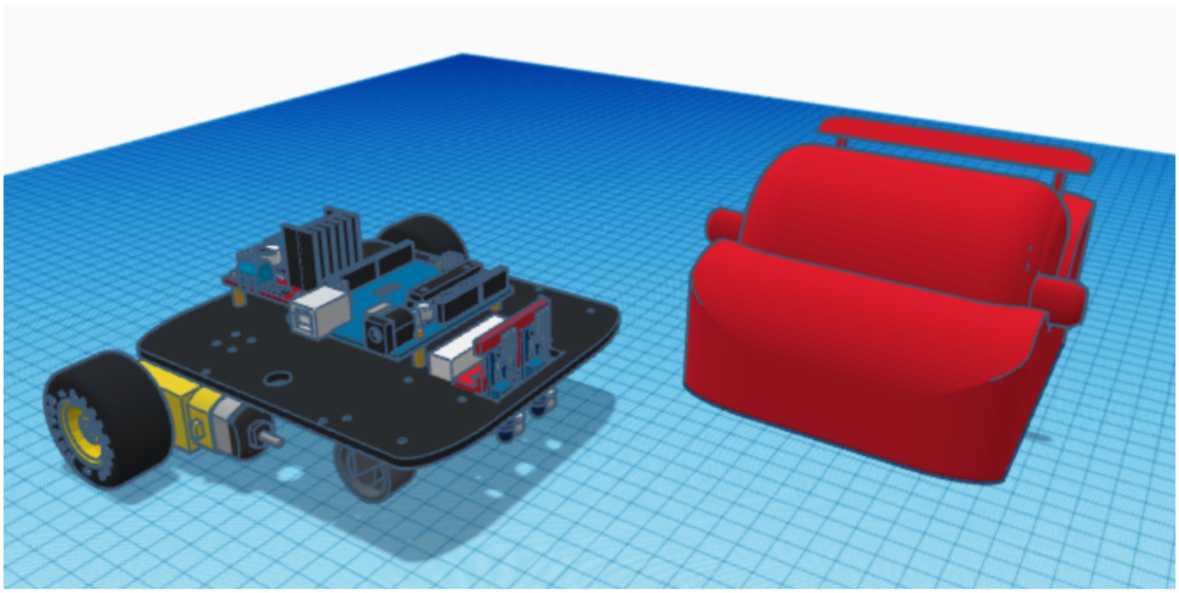

Figure 1: Final CAD design of prototype, including top case, chassis, components and screw holes.

DESIGN CHALLENGES

The design process involved several issues the team had to address before proceeding with the project. Initially, the measure of the chassis that was planned to be used did not fit all the hardware materials of the robot. As such, a new chassis had to be redesigned and 3D-printed. After all the components were placed in the new chassis, the team encountered a problem when trying to insert the screws since some of the parts were not able to fit into the holes of the initial grid. These issues were easily solved by updating our CAD design, based on the problems that were found to ensure the final prototype was in optimal conditions.

IV. PRODUCT DEVELOPMENT

LIST OF MATERIALS

The development of the final prototype of the product involved the use of electronic, hardware and 3D-printed materials in order to make the robot fulfill its purpose and ensure the specifications and needs detailed in section III were properly met. The main components used for the basic functionality of the product were the Arduino microprocessor, 1 H-Bridge, 2 IR Sensors, a Breadboard, 2 TT Motors and 22 Jumper Wires (See Table 1 for a complete list of components). The aforementioned parts made up the control system of the robot with each of them managing a different purpose. The Arduino was the microcontroller in charge of managing and controlling the rest of the electric components based on a software algorithm meant to make the robot follow a line. The IR Sensors acted as the eyes of the robot, providing input on obstacles around them and as the color black goes undetected, it made for a perfect element to make the robot follow a line. The breadboard connected everything together and distributed energy from the batteries to all components. Finally, the H-Bridge controlled the movement of the TT Motors, based on the instructions from the microprocessor.

Table 2: List of materials and quantities for production of the line-following robot

Material	Quantity
H-Bridge	1
Arduino Microprocessor	1
Breadboard	1
IR Sensor	2
Jumper Wire	22
TT Motor	2
Wheel	2
Multi-Directional Wheel	2
Battery Pack	1
Screw	40
Battery	4

6”x6” Base	1
L-Bracket	3
6”x6” Top Case	1
LED	2

ASSEMBLY STEPS AND FABRICATION METHOD

The fabrication method for the final prototype consisted mainly of 3D-printing the chassis, the brackets and the top case. For this, CAD software was utilized to model them along with the parts and the position in which they would be placed in. This allowed to make precise holes as to where each component would go, making assembly much easier to perform and understand. PLA plastic was utilized for the printing of parts due to its inexpensive and environmentally-friendly nature. The parts were printed and structurally tested to ensure they would properly sustain the weight and motion of the robot in an adequate manner. The assembly phase for the robot consisted of two parts: the factory assembly and the user assembly. During factory assembly, the basic components were put into the chassis to make it easier and quicker for the user to assemble the rest of the unit. These phases go as follows:

Factory Assembly:

Figure 2: Chassis base with numbered holes for reference

1. For the front wheels, align the four holes on the multi-directional wheels to holes #1 #2, #9 and #9 and screws and nuts to secure it in place. Repeat the process for the other universal wheel using holes #6, #7, #11 and #12. Use Figure 3 as reference.

Figure 3: Mounting front wheels to the chassis

2. Put the L-Bracket and an IR Sensor Upside-down, align them and screw to the bottom hole of the bracket as in Figure 4. Repeat the same process for the other IR Sensor.

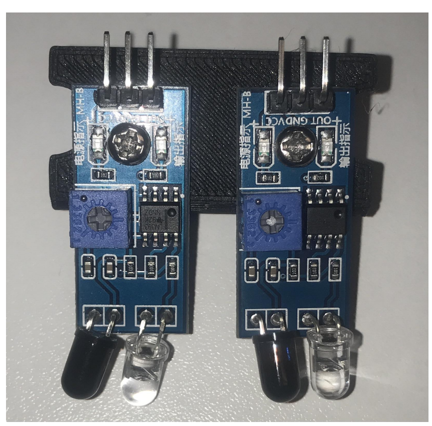

Figure 4: Installation of IR Sensors to the L-Bracket

3. Align the holes on the L bracket for the IR Sensors to holes #3-#5 and use screws to put it into place. They should end up looking like Figure 5.

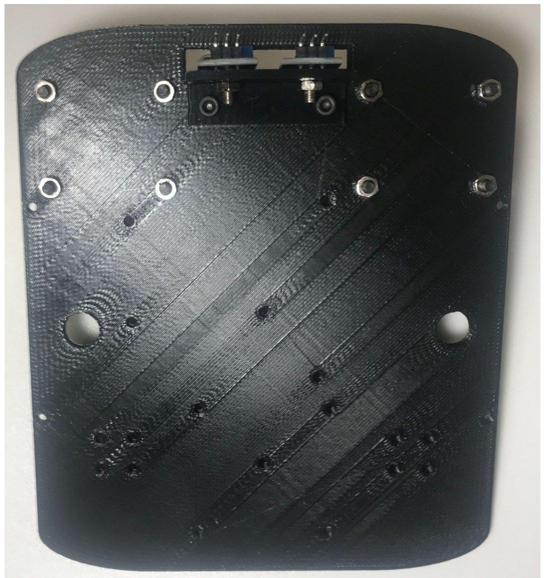

Figure 5: Chassis with added IR Sensors

4. Add screw extenders to holes #10, #13, #15 and #18 of the chassis. Repeat the same process for holes #21, #22, #30 and #31. Use Figure 6 as a reference

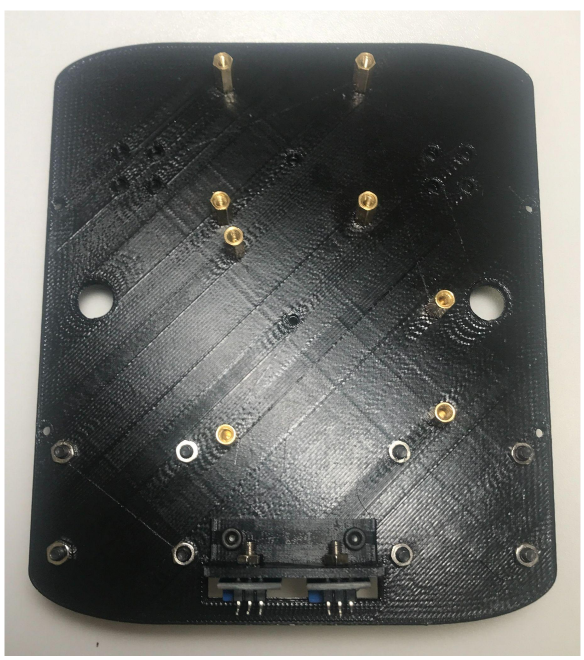

Figure 6: Screw extenders added to chassis

5. Take the Arduino UNO and align the bottom part with holes #10, #13, #15 and #18 from the top. Use M3 screws and nuts to screw it into place. See Figure 7 for reference.

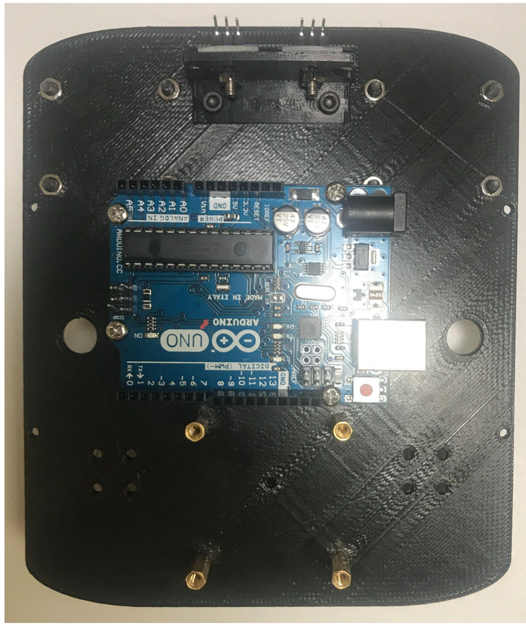

Figure 7: Arduino UNO screwed into the base

6. Align the H-Bridge with holes #21, #22, #30 and #31. Use screws and nuts to tighten it in place. Figure 8 depicts the final result.

Figure 8: Installation of H-Bridge through holes #21, #22, #30 and #31

7. Using screws and nuts, fix the TT motors to the L-brackets by aligning the two holes on the bracket to the ones on the motors. Review Figure 9 for guidance.

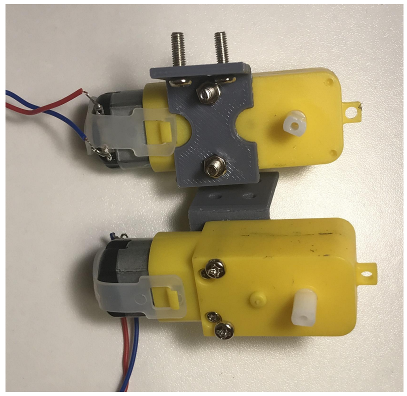

Figure 9: Fitting the TT Motors to the L-Brackets

8. Screw the first back motor into place by aligning the holes on the top of the bracket to holes #19 and #26 from the bottom. Repeat the same step for the second back motor using holes #24 and #28 as in Figure 10.

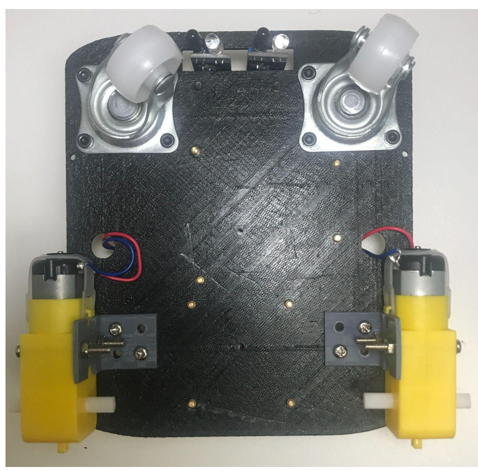

Figure 10: Placement of back TT motors on the chassis

9. Align battery pack from the bottom with holes #16 and #27 and insert screws from the bottom. Tighten it up using a pair of nuts and a screwdriver. Feed the cables through holes #14 and #17. Figure 11 depicts how it should end up looking like.

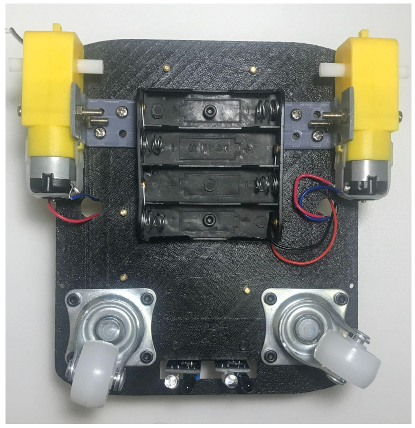

Figure 11: Battery pack added to chassis of the robot

10. Take the breadboard and remove the piece of paper on the bottom to uncover the adhesive layer. Place the breadboard in between the arduino and IR Sensors as in Figure 12.

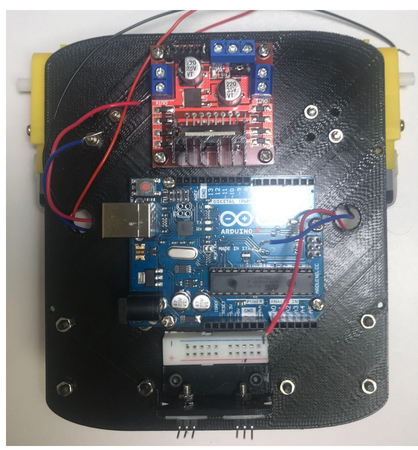

Figure 12: Guidance on adding Breadboard to the robot

11. Connect wires from pin 5,6, 9 and 10 of the arduino to IN1-4 of the H-bridge. Add wires from 12V and GND of the H-Bridge to the positive and negative of the breadboard respectively, Then, connect the motors to the sides of the H-bridge. Afterwards add wires from the IR Sensors to pins 3 and 12 of the arduino. Consequently, connect the positive end of the LED lights to pins 2 and 12 of the arduino. Finally connect the remaining wires from the positive and negative end of the IR sensors and battery pack to the breadboard's respective positive and negative ends as shown in figure 13.

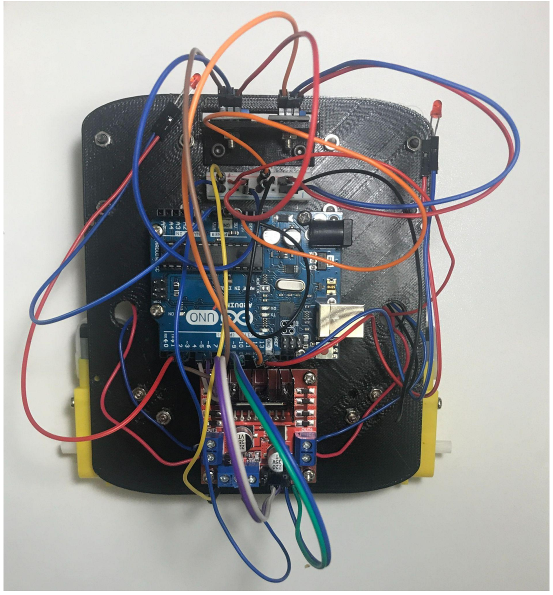

Figure 13: Wiring of final prototype

User Assembly:

1. Take the two wheels and align them with the white part of the TT Motors. Once this is done press to insert them to the motors. Use Figure 14 as reference.

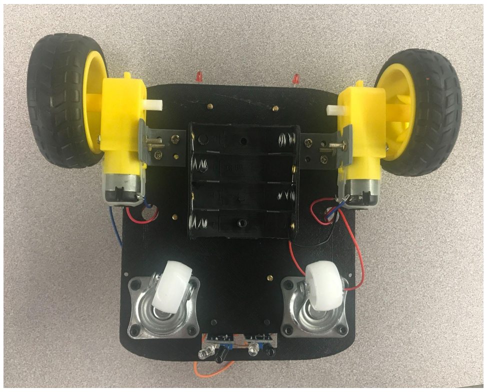

Figure 14: Insertion of wheels to the TT Motors.

2. Insert 4AA batteries to the battery pack on the bottom of the chassis. See Figure 15 for help.

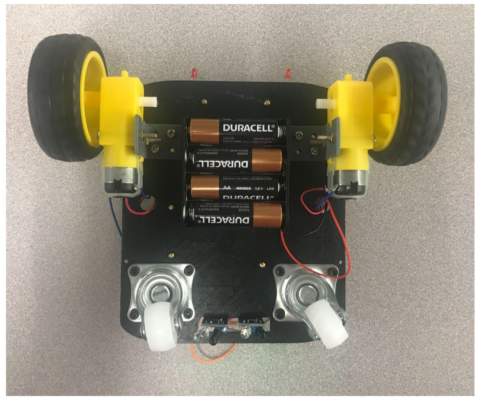

Figure 15: Installing batteries to the robot

3. Decorate the top piece of the car using the provided stickers. Figure 16 shows an example on how to do so.

Figure 16: Decorating top piece with stickers

4. Using the four screws provided, take the car-shaped top piece and align them with the four remaining holes (A-D) in the chassis. Screw the base securely to finish the assembly of the robot. Figure 17 shows the final result.

Figure 17: Completed robot assembly

PRINTING CHALLENGES

As previously mentioned, 3D-Printed parts were used for the mounting brackets, the chassis, and the top case. While 3D-printing has been a revolutionary invention and has opened up new opportunities for creation, it is important to note there’s still some limitations as to what can be done with it. Due to the fact that our car-shaped top piece was a bit large in size, it was difficult for it to be properly printed. As a result, the piece had to be modified to reduce printing time and make the process more reliable. On the other hand, the L-brackets initially printed were flimsy and prone to break during regular use, this made them unreliable and affected the overall durability of the product. In consequence the brackets had to be re-engineered making them slightly thicker and adding round edges to them which turned out to be a success as the resulting pieces were structurally tougher resulting in a lower probability of them breaking apart. Besides 3D-Printing, some contact issues were found with some of the jumper wires, therefore all wires had to be thoroughly tested to determine whether they worked correctly so they could be used for the final prototype. Finally, another issue spotted during the hardware assembly was getting all the components to fit together. While it was possible to get everything snugly, it would mean sacrificing reliability and safety. This meant it was necessary to reduce the amount of components used, hence it was decided to go from the originally planned 2 h-bridges, 4 TT motors and 2 battery packs to only 1 H-bridge, 2 tt motors and 1 battery pack.

V. SOFTWARE DEVELOPMENT

PROGRAMMING CODE

```
#define SNR 13
#define SNL 3
#define IN1 5
#define IN2 6
#define IN3 9
#define IN4 10

#define RLED 2
#define LLED 12
int SNSL;
int SNSR;
void setup() {
  // put your setup code here, to run once:
  pinMode(SNL, INPUT);
  pinMode(SNR, INPUT);
  pinMode(RLED, OUTPUT);
  pinMode(LLED, OUTPUT);

  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);

}
```

Figure 15: Variables and pins defined for the code

The first step of our Arduino code was to define variables for the pins that the group used. Since the design includes two sensors and an H-Bridge, one pin was needed for each sensor, and four pins for the H-Bridge. IN1–4 corresponded to the pins for the H-Bridge. Furthermore, the first two pins (IN1-2) of the H-Bridge controlled the left wheel, while the last two (IN 3-4) controlled the right one. Lastly, in this first step of the code, two variables SNSL and SNSR were initialized, with datatype 'int'. These stored the state of the left and right sensors respectively. Lastly, the two back lights of the car were defined as RLED (Right LED) and LLED (Left LED).

Additionally, In this setup portion of the code, it was necessary to assign the mode of each of the pins that were defined previously. The two sensors that were used detected an input from the black line, so both SNL and SNR pins had to be set to Input. All four pins of the H-Bridge controlled the wheels and their direction, so they were all set to output. It should be kept in mind that the first two H-Bridge pins corresponded to the left side of the robot, while the other two to the right side. Similarly, as the LEDs emit light they were set as outputs.

```
void loop() {
  // put your main code here, to run repeatedly:
  SNSL = digitalRead(SNL);
  SNSR = digitalRead(SNR);
  if(SNSL==1 && SNSR==1){
    //STRAIGHT
    digitalWrite(IN2, HIGH);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN1, LOW);
    digitalWrite(IN4, LOW);
    digitalWrite(RLED, LOW);
    digitalWrite(LLED, LOW);


  }
    else if(SNSL==0 && SNSR==0){
    //STOP
    digitalWrite(IN2, LOW);
    digitalWrite(IN4, LOW);
    digitalWrite(IN1, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(RLED, HIGH);
    digitalWrite(LLED, HIGH);
```

Figure 16: Straight and stop functions for the robot

With the first two preliminary steps completed, the construction of the logic of the code began. The design used two downward facing sensors positioned at its front. Depending on the input received from these sensors, the robot drove either straight, turn right, or turn left. This was accomplished by using a nested if statement with different sensor input combinations. If the sensor detected the line, it outputted the number 1, if not, it outputted 0. In this case, if both sensors detected the line, or if both sensors outputted a 1, then the robot would drive straight. To accomplish this, a HIGH signal was outputted to the second pin of each wheel (IN2, IN3). All other pins were set to a LOW signal. On the other hand, If both sensors were not detecting the line, the robot stopped in place. In this case, a LOW signal was simply sent through the H-Bridge to stop all wheels from turning. For the LEDS, they were set to be off when the car is moving straight and be lighted up while it is stopped.

```
  } else if (SNSL==0 && SNSR==1){
    //RIGHT
    digitalWrite(IN2, HIGH);
    digitalWrite(IN4, HIGH);
    digitalWrite(IN1, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(RLED, HIGH);
    digitalWrite(LLED, LOW);

  } else if (SNSL==1 && SNSR==0){
    //LEFT
    digitalWrite(IN1, HIGH);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN4, LOW);
    digitalWrite(RLED, LOW);
    digitalWrite(LLED, HIGH);

  }
}
```

Figure 17: Code to make robot turn right and left

As for turning right and left, if the left sensor is no longer detecting the line, while the right one is, the robot should turn to the right. This was done by having the right wheel spin forward and the left wheel spin backwards. It was achieved by setting IN 2 and IN 4 to HIGH, while having IN 1 and IN 1 at LOW. This causes the right wheels of the robot to turn in the opposite direction, rotating the robot to the right. To the contrary, if the right sensor was no longer detecting the line, while the left one was, the robot would to the left. This was done by inverting the signals sent to the H-Bridge. This caused the left wheels of the robot to turn in the opposite direction, rotating the robot to the left. While the robot turned right, the left LED was set to off while the right one was set to one, the opposite happened when it was turning left.

FABRICATION VIDEO

Video clips of the functioning prototype can be found right below, it demonstrates the combination of hardware, software and design the team has had to go through to deliver a working prototype that can be used by K-12 students and their teachers.

Links: https://youtu.be/J9SMmM1P7cE https://youtu.be/mss4RGwDBiY

SOFTWARE CHALLENGES

Considering that most group members had knowledge of the Arduino IDE and were already skilled in program design, there weren't any major software development challenges encountered. Only aspect worth mentioning is that as in any code, there were some bugs at first so as a result the typical testing and debugging procedures were used to fix any mistakes that were initially made.

VI. PROTOTYPE TESTING

PROTOTYPE PERFORMANCE

After thoroughly testing and analyzing the performance of the test prototype, the results turned out to be particularly exciting, as not only did it manage to perform really well, but at the same time it was able to meet the specifications and requirements the team had in mind without any major compromises. As a result, a robot that fitted inside a 6"x6"x6' box, with a cost less than $30, user-assembly time of less than 5 minutes and which ran on a single battery pack was achieved. As soon as the test prototype met all these requirements and specifications, a final prototype was designed and manufactured along with the team's design and hardware leads to further optimize and ensure the robot would be in the best possible state for children to use.

One of the main goals the team was planning to achieve from the start was ensuring the customer needs for its target audience were properly met as to ensure the product would be perfectly suitable for them. In consequence, part of the testing process focused on analyzing the functionality, safety, quality and durability of the prototype. In the case of functionality, the final prototype managed to follow a black line on the floor without any issues, being able to turn right and left as necessary. As for safety, the design was analyzed closely to inspect any possible hazards small children might run into, the results showed there were no small parts which could cause choking or electrical components left in the open which could shock those using it. In relation to quality and durability, pressure and bend tests were done to each of the printed parts to ensure their reliability, Those that broke too easily were re-designed to improve their durability and while it is still possible to break some of them, it would require a great amount of force for it to happen.

CERTIFICATION TEST REPORT

Considering the outcomes mentioned in the two previous subsections, an official Certification Test Report was developed (See Table 3) to summarize the major findings in terms of the performance of the final robot. The main things to consider is that it weighs around 720 grams, can turn up to a 60 degree angle and requires 4 AA batteries for it to properly function. Overall, this prototype met all the engineering specifications and customer needs.

Table 3: Certification Test Report for Final Prototype

Net weight	720 grams
Dimensions	6”x6”x5”
Maximum speed	200 RPM
Assembly time	5 Min
Power requirements	6V
Type of Sensor	IR sensor
Material	PLA plastic

PERFORMANCE CHALLENGES

As expected, during the first testing prototypes several performance issues were evidenced which had to be addressed before moving on. Most of them turned out to be minor issues which were easy to fix and did not provide any delays to the progress of the project. However, one of the main problems the team stumbled upon during testing were the IR Sensors. Some of the sensors received were faulty and as a result had to be changed. In addition, some of the wiring was incorrect for some of the prototypes leading to the robot turning the opposite way. The major issue however, came from the left sensor being triggered by the right one causing the robot to have problems turning left. This was solved by adjusting the diodes on the IR sensors until eventually they were no longer interfering with one another and the robot was able to successfully turn left.

VII. RECOMMENDATIONS

While the group did its best to deliver the robot on the given timeframe, there were some tasks or ideas that could not be put forth due either to financial requirements or time constraints. In consequence if there were more time and financial resources, the group would recommend the following tasks. Initially, adding a IR Control Device, would be a good idea as it would give children the possibility of picking from two modes, the line-following mode and the user-controlled mode. In the user-controlled mode, children will be able to use a remote control to control the robot's movement, so that they can make it go forwards, backwards or turn right or left. In addition, as part of the aesthetics and movement of the car, 4 wheels and TT motor were required for optimal appearance and performance of the car, but due to lack of financial resources this idea was scaled down to only having 2 wheels and TT motors, so in the future, it could be considered to go back to the original plan as to better capture the perception of a car. Finally, if there were more time, a 9V battery pack and a switch would be added to the product, as they would provide better efficiency and reliability by having an improved power output from the battery that would allow motors to run faster and components to run for longer without having to constantly replace battery packs. 9V Batteries would be easier to install and would not cost anything more than standard AA-batteries.

VIII. CONCLUSIONS

Overall, Group 7 was successful at designing and producing a line-following robot themed after Lightning McQueen. Using the incorporated Arduino, IR Sensors and Motors, the team managed to come up with a functional line-following prototype, which will be able to provide K-12 students with their first hand-on STEM-related experience. As part of the team's commitment to delivering a reliable and durable product, constant tests were done on the robot and its results showed an outstanding performance in all fronts, with the robot being able to thoroughly follow the line at a constant velocity. Although currently, robotic equipment for STEM education is limited and highly-priced, the robot designed by Team 7 provides a perfect alternative which reduces costs, while providing reliability and durability, which will aid in expanding STEM education across teachers and students alike. Our customers will have a very easy time putting together the robot and getting it to run smoothly. The team is eager to begin working on the next-steps to further solidify and implement this prototype as a viable tool for the education of future generations.

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