DESN1000
Redback Autonomous Car
Term 3
Final Report

Team 7 (Carrl7)

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Executive summary

Carrl7 is a team that proposes a design for the Redback Autonomous Vehicle Project. The project is based on the DARPA and urban challenge which have existed for years and sparked the autonomous nature of car race competitions. The proposed device is designed to be able to safely navigate through the lanes autonomously without any human intervention for 3 laps in under 5 minutes while following the constraints provided by the client.

The project has spanned over 8 weeks of design phases and multiple stages of trial and error, the team Carrl7 has developed a model that has to tackle the obstacles. The first feature is IR sensors which act as the main tool for navigation as they allow the device to detect black lines. However, the IR sensors could not function properly under direct sunlight. The lipo Battery was the power source chosen for our design with the appropriate current and voltage for our system. Lastly, a lane-following algorithm developed for an arduino system was used to detect lines and turn when necessary.

This design managed to run 3 complete laps in a row without any human intervention in 3 minutes and 33 seconds. Even though it did not qualify for the race, the device still functions as intended. However, this was not the optimal design for a lane-following device as seen by competition results and there was room for further development and improvement. The first improvement that could be worked on is making a thinner wheel to make it lighter but also with a large enough radius to still be power-resourceful and provide sufficient speed. With less weight, another set of IR sensors could be added to further increase the accuracy of the device's positioning. Lastly, the code itself could be worked on further to make use of the additional speed and IR sensors to create smoother turns and a faster device that stays within the lanes and satisfies all constraints. These improvements will allow the device to run smoother, faster, and ultimately better to finish the track in a shorter time.

Contribution Statement

Name	Contribution
Cecilia	Final Design, Editing, Formatting, Proofing
Franklin	Executive summary, Editing, Formatting
Lachlan	Conclusion and recommendations
Aneesa	Final Competition, Editing, Formatting, Proofing
Rishi	Introduction
Rahul	Final Design

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Introduction

Within the realm of innovation, the Redback Autonomous Racecar project crafted by the Carrl7 team stands as a testament to the fusion of cutting-edge engineering and autonomous technology. This report serves as a post-competition evaluation, offering a thorough examination of our quest to engineer a self-driving vehicle capable of autonomously navigating designated lanes.

Our primary objective was crystal clear: create an autonomous, lane-following device that shall cost less than $100, weigh less than 500g, and measure less than 250 mm in all directions. The device's design should be innovative and aesthetic. The device itself should be reliable and speed should be optimized. Finally, the device should be able to safely complete 3 laps of the competition track within 5 minutes and not cross any black lines. The collaborative efforts of the members spanning electrical, computing, and manufacturing was pivotal in advancing the project and making it into a fully functioning model.

Reflecting on Our Endeavor

The core of our vehicle's functionality relied on infrared sensors, effective at detecting colour variation. However, their sensitivity to interference, particularly under direct sunlight, posed a notable challenge. Through tackling a series of problems throughout our construction insufficient time was left to code posing a further challenge.

Despite the inability to complete the criteria before the race portion of the competition, our vehicle showcased considerable ability by autonomously and successfully completing three laps in 3 minutes and 33 seconds in our final test, highlighting various avenues for refinement.

Envisioning Progress

Reflecting upon the performance, our team charted a course for refinement. Key strategies encompass exploring the integration of slimmer, lighter wheels to enhance maneuverability and efficiency. Additionally, plans for software optimisation aim to improve precision in navigation, and use of more sensors to facilitate faster speed and accuracy in travel through the lanes.

Final Design

During the process of generating a final design, frequent tests were run and conducted which exposed problems in the vehicle that were not otherwise established. These problems ranged from small to large and showed how important seemingly small adjustments could have drastic impacts on the vehicle's performance. As a result, there was a large emphasis on re-evaluation and research done on the problems to remodel and improve the vehicle.

Model 1

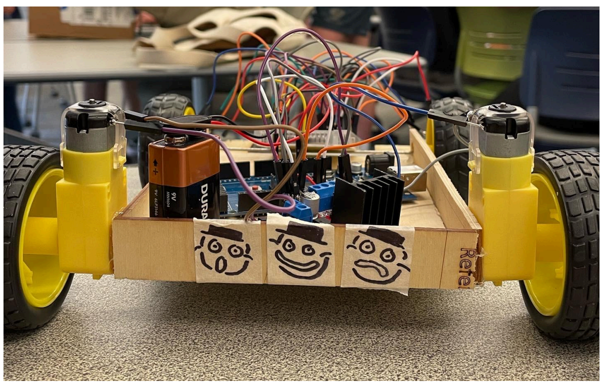


Figure 1. The model used during compliance testing

Features:
- 4 x rubber medium-sized wheels
- 1 x 9v battery
- 1 x battery snap
- 1 x Arduino Board
- 2 x motors
- 2 x phototransistors
- 2 x white LEDs
- 3 mm plywood

Model 1 was used during compliance testing with its main features consisting of a wooden base, rubber wheels, white leds and ir phototransistors. The wooden base was built as a slim rectangular box with dimensions 170 mm by 120 mm by 20 mm from 3mm plywood. It was built as a temporary base strong enough to support the electrical components of the vehicle. The main focus of this model was its ability to move and whether the vehicle would be able to complete a lap of track.

As seen in Figure 1, the white leds and IR phototransistors are located at the front of the vehicle. They have been placed lower to the ground to reduce the distance between the track and sensor with the intention of the positioning being the most efficient for sensing light variation on the track. The problem however arises from the sensitivity of the IR phototransistors which had caused varying input ranges. Ultimately, when the vehicle was placed on the track the vehicle could not accurately detect the changes in colour which caused the vehicle to veer off-track.

Changes leading up to the final competition

IR Sensors

Initially, a pair of Phototransistors and LEDs were used to construct an IR sensor but the input values received from these sensors were never in a fixed range. Hence, they could not be calibrated to our use. These were replaced by a pair of line tracing IR sensors which immediately fixed this issue.

Battery

Changes to the battery were made switching from a 9V battery to an 11-volt lipo battery. The main challenges faced with using a 9V battery was that there wasn't enough supplied current which caused the vehicle to slow down after each lap. The lipo however, was a better alternative as it held a greater amount of voltage while providing enough current and could be easily recharged but it was way heavier than the 9V battery.

Arduino

Problems that arose during tests were due to faulty Arduinos which led to the replacement of two Arduinos. The first faulty Arduino occurred due to the ports being broken. This meant that there was an open circuit with no connection to any of the materials in the system. The second faulty Arduino had a technical issue with being unable to connect to an external device to receive the code.

Fuse

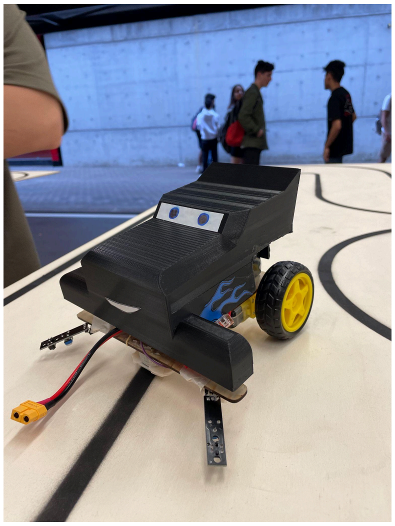
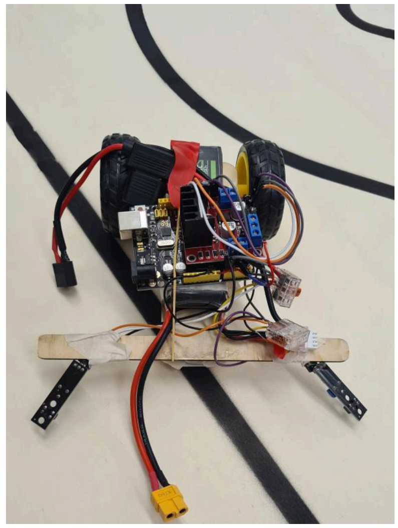
A fuse explosion occurred due to a short circuit. Having moved wires around this caused a wire to be exposed making it susceptible to touching other wires. This caused a new node in the system which produced a short circuit and damaged the fuse. And so, a replacement of the fuse was necessary in order to prevent any accidents.

Code

The sensors (Phototransistors and LEDs) were calibrated by reading the analog input values shown. As the device was placed on the track, the range of tested input values were then put into if statements, commanding the device to move in particular directions according to the input value range. The directions were set by different combinations of motor pin values as 0 and pwmDutyCycle for 4 motor pins. For Model 1, the pwmDutyCycle value was set to a constant value of 150 after testing with different values for the power supplied by a 9v Battery.

Model 2: (Final model)

Model 2 was used during final competition with its main features consisting of a three wheel system, smaller size and aesthetic appeal. Compared to Model 1, a three wheeled system was used as it allowed accurate steering which showed better performance when covering straight distances. It also helped reduce the overall weight of the vehicle in order to fit the 500 grams requirement. The aesthetic of appeal of the model draws inspiration from the movie ‘Cars’ with its prominent features being its eyes, smile and added flames on the sides of the car.

 Figure 2.1 Front view of final design)	 Figure 2.2 Inside compartment of the final design	Features: - 3mm Plywood - 1 x Arduino - 2 x medium-sized rubber wheels - 1 x bearing ball transfer wheel - 2 IR sensors - 3D printed PLA cover - 1 x 11-volt lipo battery - 1 x fuse

Code

As the Phototransistors and LEDs were replaced by line tracing IR Sensors, the input was now digitally read as HIGH and LOW values, which was put into if statements for direction commands. The battery was switched from 9v to a 11v lipo and the pwmDutyCycle had to be reduced to accommodate the extra power. Testing with various values led to a value of 30 to be the most stable option. Speed needed to be increased while still maintaining the precision during turns and hence speed was made variable with pwmDutyCycle value set to 32 for Forward direction and 30 for left and right.

```
// Determine the direction based on the sensor readings
char currentDirection = 'x';

if (sensorValue1 == LOW && sensorValue2 == LOW) {
  currentDirection = 'f'; // Move forward
  pwmDutyCycle = 32;
  analogWrite(leftMotorLogicPin1, pwmDutyCycle);
  analogWrite(leftMotorLogicPin2, 0);
  analogWrite(rightMotorLogicPin1, pwmDutyCycle);
  analogWrite(rightMotorLogicPin2, 0);
} else if (sensorValue1 == HIGH && sensorValue2 == LOW) {
  currentDirection = 'l'; // Turn left
  pwmDutyCycle = 30;
  analogWrite(leftMotorLogicPin1, 0);
  analogWrite(leftMotorLogicPin2, pwmDutyCycle);
  analogWrite(rightMotorLogicPin1, pwmDutyCycle);
  analogWrite(rightMotorLogicPin2, 0);
} else if (sensorValue1 == LOW && sensorValue2 == HIGH) {
  currentDirection = 'r'; // Turn right
  pwmDutyCycle = 30;
  analogWrite(leftMotorLogicPin1, pwmDutyCycle);
  analogWrite(leftMotorLogicPin2, 0);
  analogWrite(rightMotorLogicPin1, 0);
  analogWrite(rightMotorLogicPin2, pwmDutyCycle);
} else {
  currentDirection = 'x'; // Stop
  analogWrite(leftMotorLogicPin1, 0);
  analogWrite(leftMotorLogicPin2, 0);
  analogWrite(rightMotorLogicPin1, 0);
  analogWrite(rightMotorLogicPin2, 0);
}
```

Figure 3. Depicts the code snippet for variable speed used in Model 2

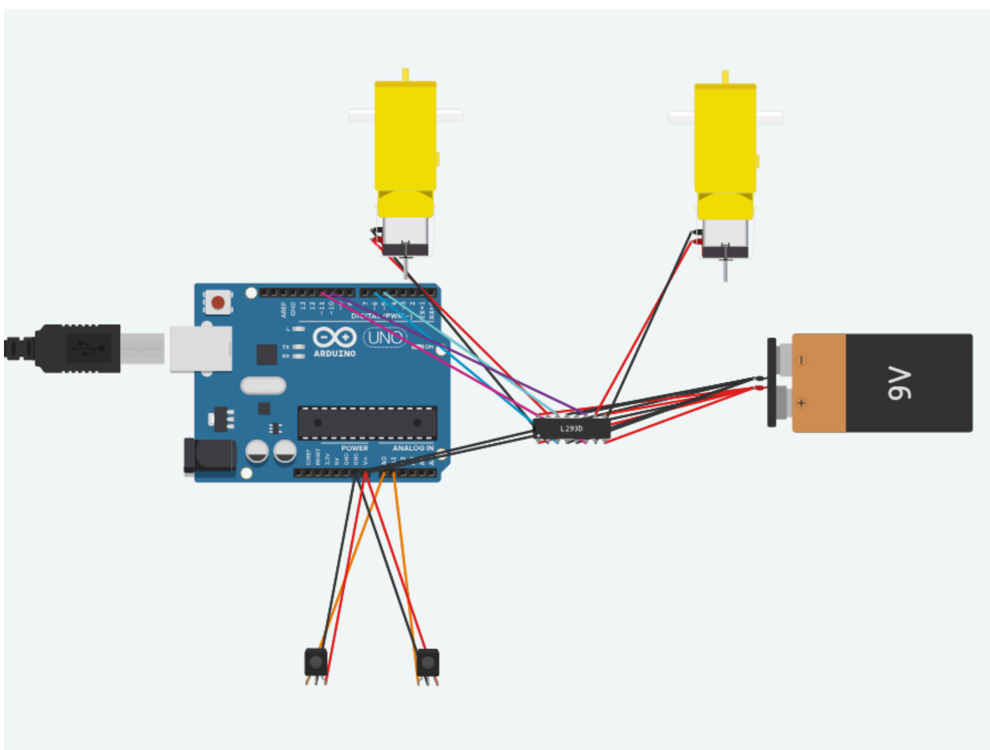


Figure 4. Depicts the electrical circuit used throughout the models. It was used to supply current through to the arduino and motors. With changes made to the power source and motor controller.

Manufacturing Changes

To achieve an aesthetic design, 3D-printed covers were manufactured to be placed over interior electrical components. In total there were three main models that consisted of a common slicked back appearance resembling shapes used for modern commercial cars. All covers were created on solidworks using filets, extrusions and extruded cuts and as well being printed using black PLA filament that was inexpensive and lightweight.

 Figure 5.1 Side view of the 3D printed cover  Figure 5.2 Back view of the 3D printed cover	 Figure 5.3 Bottom-side view of the 3D printed cover	 Figure 5.4 Close-up of drilled holes into the 3D printed cover

Design 1

For design 1, problems occurred with the size and functionality. The size contributed to a mass of 149 grams for the vehicle that exceeded 500 grams and the cover had also been printed without pre-designed holes which meant there was no appropriate way of attaching the axles of the wheels. To fix this, holes of 10mm wide were drilled in (refer to figure (5.4)) however the hole created lacked a clean finish due to the structural composition of the 3D printed covers being printed by layers. This was an issue as it took away from the aesthetic appeal of the cover.

Figure 6.1 Side view of 3D printed cover

Figure 6.2 Bottom-side view of 3D printed cover

Figure 6.3
Back View of 3D printed cover

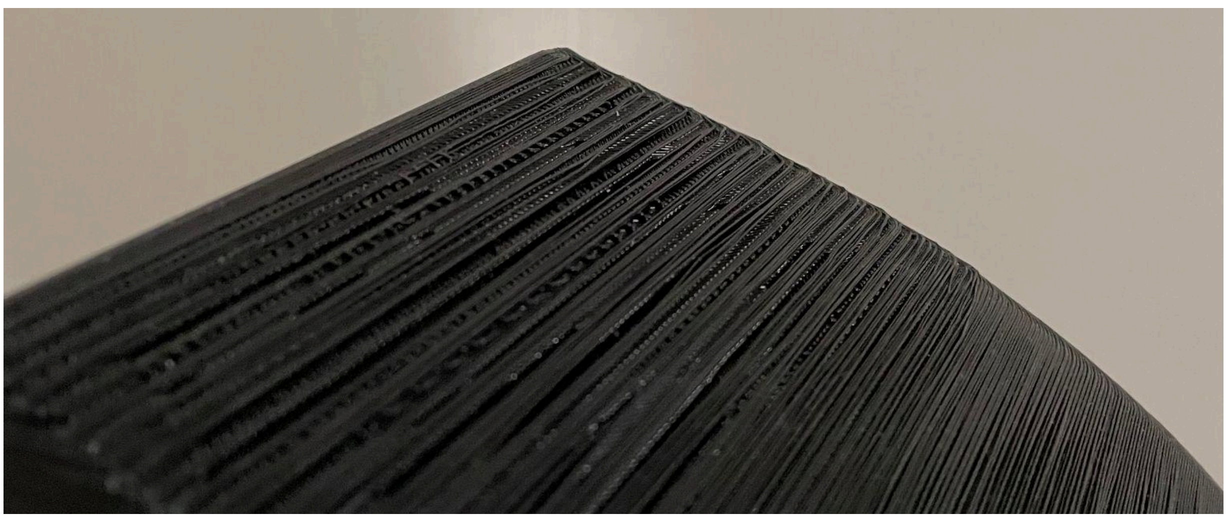


Figure 6.4
Close up view of the top of the 3D printed cover

Design 2

Design 2 was designed with the intention of contributing less weight. To achieve this the design had a shorter length and height. No holes were implemented in the design as it was concluded that with the wheels attached underneath the base, the cover would be easier to attach on and off to fix any electrical wiring issues. However, with a change in batteries, the cover was now too short and was unable to accommodate the lipo battery.

Design 3 (final design)

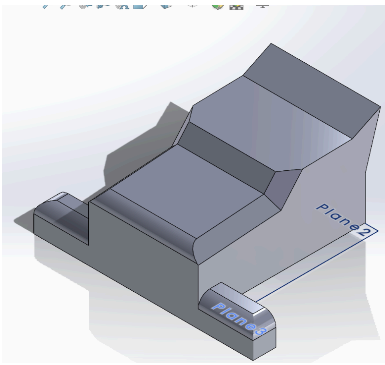


Figure 7.1 Top view of 3D printed cover

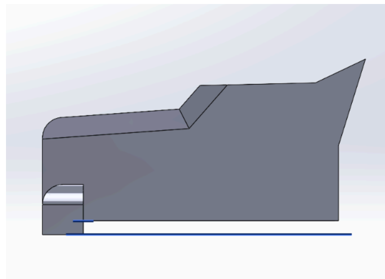


Figure 7.2 Side view of 3D printed cover

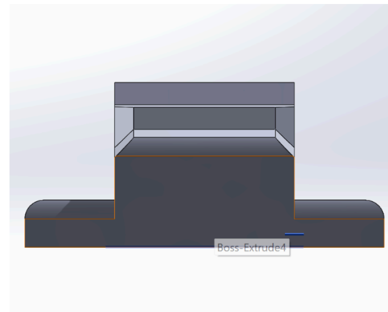


Figure 7.3 Front view of 3D printed cover

Design 3 takes on a different appearance compared to designs 1 and 2. Changes were made to the infill, back and top design. During the process of 3D printing with the previous covers, the curved surface left an uneven and rough finish (refer to figure(6.4)). This is partly due to curved surfaces being a little difficult to print. To address the issue, the newest design is composed of taller slanted shapes and as well as a smaller sized infill of 0.1mm to reduce any unnecessary weight of the cover. Cuts were also made towards the back of the cover to accommodate larger wheels. However, when the cover was printed, it was discovered the cut was not high enough. Due to time constraints, 3D printing another cover was not possible. And so, to create a higher cut, heat was used from the soldering tool to melt the plastic and cut away the excess material with sandpaper also being used to smooth the appearance of the cuts.

Total Cost

no.	Item name	Description	Price per unit/m^2	Quantity	Cost/$
1	Wheels	Plastic Wheel 65 mm	3	2	6
2	Ballpoint wheels	Mini swivel castor wheels 60 Degree Rotating Casters, Bearing Ball Transfer	1.5	1	1.5
3	Arduino uno	Keystudio uno R3	40	1	40
4	Plywood	0.003mm thickness	16.15	20cm^2	0.66
5	Lipo Battery	11.1v Lipo battery	20	1	20
6	3D print	PLA material	-	1	-
7	Hobby Motor	Plastic geared motor	5.75	2	11.5
8	IR sensors	Infra-red line trace sensor module for Arduino projects	5.45	2	10.90
9	wires	Covered Copper wires	0.375	12	4.5
Total cost					95.06

Figure 8. Bill of Materials

Final Competition

Competition results

Within the final competition stages the device was able to successfully complete 3 laps of the course in 3 minutes and 33 seconds with a model that cost $95.56, had a weight of 493gm and measured to be 19 cm by 15 cm by 14 cm satisfying the requirements, however was unable to qualify for the competition round.

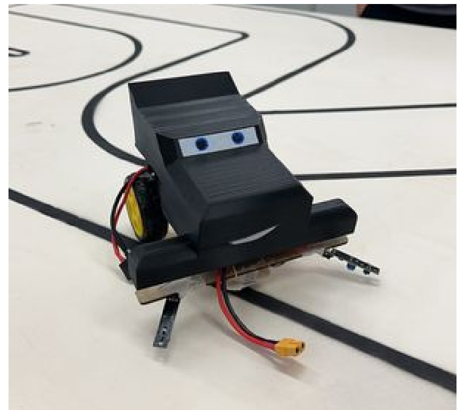


Figure 9 depicts the final model on the racetrack.

Competition performance

Module performance was monitored and noted throughout the competition. The infrared sensors were functional however the adhesive material situated around the infrared sensors made for an unfinished look with the tape noticeable on the exterior of the device. There was difficulty of the sensors to detect the colour change due to the presence of sunlight and the inconsistent colour of the black borderlines on the board. These inconsistencies did lead to unreliability in the infrared sensor.

The motors of the system were functional and the motor controller supplying voltage to the motors was able to supply a variation in voltage and change in terminal voltage supplies to successfully rotate the device and vary speed. The wheels were connected onto the provided adapter, however the wheel were noted to move slightly off axle when power was supplied to the motors. This mainly affected the movement of the device on straight paths and sharp turns.

An exterior cover was 3D printed to conceal the interior however when attached the device did not function as intended with only the left wheel rotating with a faster RPM. It was determined that the exterior placed pressure on wires which led the exposed wires to touch and form a short circuit bypassing one or two of the nodes to the right wheel. Due to this the exterior was not attached for the competition.

In the initial run of our performance test, the device was seen to not respond to the line and continued on a straight trajectory. This occurred due to wires in the system coming loose and was corrected upon the second run of our performance test. In the second test run, the device successfully completed the 3 laps. The infrared sensors were able to detect the colour difference between the board in an artificially lit room, however there was a delay in response which was due to the time delay between the code and motor controller in response to the change in code which was not accounted for prior. This is what led to decreasing the speed of the device to accommodate for this delay in response from the sensors and system.
The turns of the device were also very acute which due to the time delay in sensor response was further reason to slow the speed to successfully complete the 3 laps. The axle of the wheels also factored into the poor execution of these turns. The placement of the sensors however did lead to a smoother run of the path by the device as with the sensors placed in close proximity to the line were able to follow the path rather than haphazardly move on the track.

Overall there were a considerable amount of failures and successes of the device through the design, construction and final phase.

The infrared sensors were unresponsive to colour changes in bright light. This meant the device was unsuccessful in a well lit room or under sunlight. Further analysis of reviews and research could have prevented this as the team could have purchased different sensors. However the decision to purchase the infrared sensors was based on the time sensitivity of the project and cost of goods. If infrared sensors responsive in all settings were able to be purchased locally and were cost effective this may have affected the teams decision of sensor purchase.

Motor controller pins were difficult to connect as they protruded from the device rather than allow for a wire to be placed inside the device. This led to the team soldering wires onto the ports, however these ports were in close proximity and created a possibility of short circuits due to exposed wires touching. Electrical tape could have been an option to prevent this from occurring, However, as during the construction this system was not a priority it was overlooked. The chip of the motor controller was also later found to have slow processing, However as the motor controller was already purchased and buying another would cause further delays in build it was worked around.

The cover, while did deliver aesthetic appeal, was not functional when the device was running. This was due to delays in the team's last 3D print. The failure of the team's updated outer shell led to the prior print to be used. Constant changes to the base and the need to fit weight requirements led to this situation.

Code was another aspect that had not been fleshed out, with constant changes to the system the code was unable to be improved upon till the day and this led to a simple algorithm used for our final design. This also led to the speed having to be decreased to allow for the device to complete 3 laps as turning angles had not been calculated and a slower speed was needed for the device to stay within the tracks.

Further problems occurred with the arduino which also led to delays. The original arduino Vin and Ground ports were unstable and not connected to the system forming an open circuit. As power was unable to be supplied to the arduino the code could not be applied to the system and a new arduino was purchased. Problems also arose with the second arduino, with the arduino unable to connect to the laptop and therefore code unable to be adapted. A change of code was required as the voltage supplied at Vin had changed from 9v to 11.1v as the lipo battery was now used. This led to the purchase of a new arduino an hour before the competition. Initial use of the 11.1v lipo battery in our initial prototypes would have ceased the need to purchase a new arduino on the day.

Overall with many failing systems, the device was pulled together in the last moments to have a system that was able to function and complete the 3 laps successfully.

Competition reflection

Alterations

Design alterations could have been made to further enhance the performance of the device. The wires used were rigid near the end and were not compatible for connecting with the motor driver or infrared sensors. This required modifications of the wires we had and thus these were trimmed, cut and soldered to fit with the parts we obtained. However the soldering of items meant removal of the wires was difficult and due to the proximity of ports crossing of bare wires could lead to short circuits or wrong voltages through nodes in our model. An alteration in the next iteration to correct this issue would be to purchase a variety of wires that would be compatible for each connection. Another would be to strip wires closer to only allow for the connected portion to be attached.

Research was not thoroughly completed on the range of motor drivers, the one purchased by the team contained a slower processing chip than others available on the market. The effect of this decision impacted the delay in turns and impacted the speed of our final design. If more research was completed and motor drivers were easily accessible locally a different motor driver could have been purchased which would allow for the device's speed to be increased.

Construction of a prototype starting within week 6 and 7, along with the multitude of problem faced throughout the construction, this timeframe was insufficient to fully construct an autonomous lane following device. As problems with the items purchased and incompatibility of parts were not factored in the timeframe, this ultimately led to insufficient time to develop upon the code to enhance the speed and movement of the device. Starting the build time earlier would have provided more time to develop the code and tackle problems.

The infrared sensors were unable to function in sunlight, to correct this a cover could be added to the next iteration to block light from all directions to allow for the sensors to work in all lightings. Additions of further infrared sensors would also allow for further enhancements in the code as based upon a multitude of sensors a distance formula can be adapted and incorporated into the code to factor into the variable speed of the device and based on the devices distance from the center of the path. The formula which would be based on the Steering value being proportional to some positive value for K times the distance from the line and the rate of change in speed based upon the derivative of the equation.

Limitations

The final design including all alterations would still have limitations. The arduino has a byte capacity and if the device required a significant amount of code this capacity could limit the ability to enhance the code. Infrared sensors are limited in the range of colour that can be detected and under different colour spectrums may not be able to detect a line. The sensors also would not be able to pick up on minor changes in colour and a different sensor would have to be used. If the line was made smaller the range of detection the sensors could pick up would be decreased and cause further errors and a different system or sensor would be required.

The final device would also not work for uneven surfaces, with change in height of the sensors from the surface affecting the input for the sensors and the device not accommodating with the appropriate wheels or body to move along an uneven path. The weight restrictions imposed on the device also limit the structure and material.

Design Performance

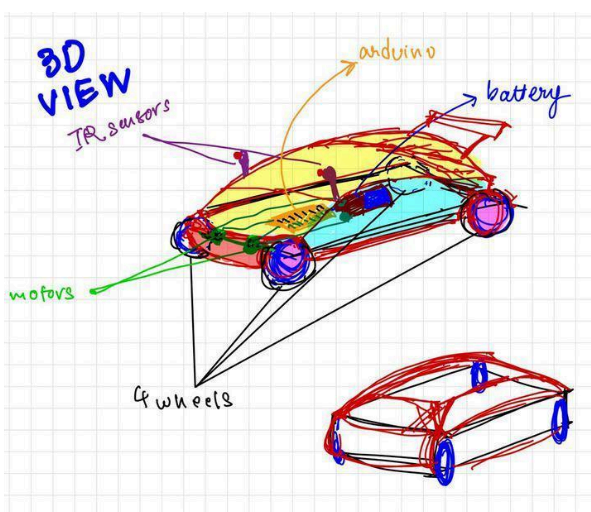


Figure 10. Depicts early prior prototype design

The design proposal as seen in Figure 10 was the design used to construct our prototype and model for the compliance testing. However after the compliance testing and further tests it was found the proposed design did not function as desired. The device used the two back wheels to rotate and turn which led to the front two wheels obstructing turns and becoming a hindrance to the movement of the device. This realisation led to our final design modal seen in figure 9.

If the design in figure 10 was used the wheels paired with our method of turning through change in speed and direction rather than direction of the front wheels would have continued to cause issues in the movement of the device. The placement of the sensors would have been another issue as with infrared sensors they must be placed close to the object planned to detect for. The infrared sensors on the design are positioned to face out and upwards. The sensors would therefore not be able to detect colours on the track from this range and make the sensors ineffective. The design above would most likely be overweight if the 11.1 lipo battery was used with the model as the final mode just came under the weight constraint by less than 10 grams and did not include a full base or fourth wheel. The length of the model above would have also caused the back wheels to go outside the path, ultimately disqualifying the device.

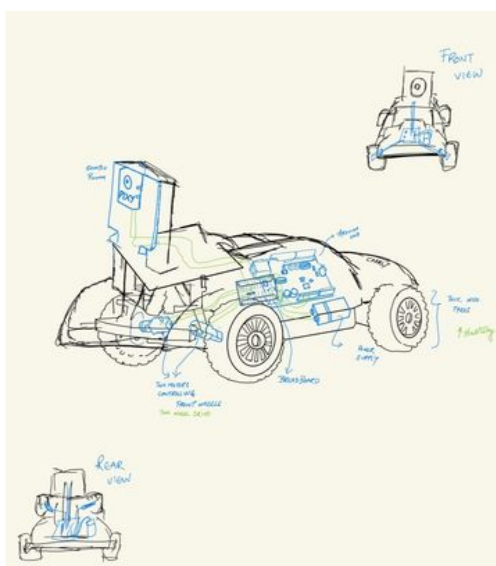


Figure 11. Depicts early design sketch

The device in Figure 11 would function with a Pixy cam, as no one in the team has worked with a Pixy cam, there would be difficulty with coding and wiring the system. The placement of the pixy cam at the back may also affect the input received as the device may have an obstructed view and not function optimally. The use of four wheels again would have provided the same issues as with our previous design and the overall bulky shape of the device would have meant the device ran overweight if used with an 11.1v lipo battery.

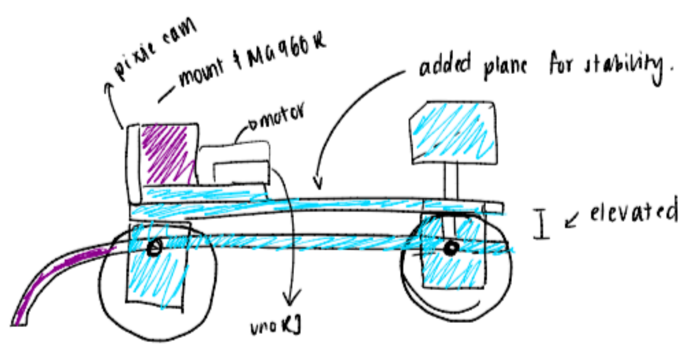


Figure 12. depicts early design sketches

The design in figure 12 has a pixie cam, however the pixie cam is situated at the front which means it would have a clear view of the track. The above design also uses four wheels however is front wheel motored and as a front wheel motored system was untested it is difficult to determine if this would work for a four wheel design. Aesthetically this design would have performed poorly with no outer shell and bulky design, however it may have been able to function but would have needed further adjustment to run as desired with possible changes to the back wheels to become rotatable and addition of a lightweight exterior.

Team Performance

Overall the team's performance through the course was collaborative and cooperative with everyone participating in meetings and throughout the entire design and build process. In the planning stages online meetings over teams were coordinated at a time suitable for all individuals and group discussion was interactive and.

Our group however delayed on purchasing materials for the proposed design which led to delays in the build. The delay also affected our build process with a shift to the proposed schedule in our gantt chart.

Meetings were planned for each assignment and to discuss the design of the project with over 10 meetings organised through teams with these occurring on a weekly to fortnightly basis on Tuesday and Thursday evenings.

There was insufficient time to work on trial and testing our device with the abundance of problems faced in the construction stages. However with this the team managed to come together within the leadup to the competition to work on the project for over 5 hours each week from week 6 to work on the construction. These times mainly constituted of the allocated DESN1000 class times and included times throughout the week where possible.

Delegations of components were mainly distributed by streams learnt through the course, with slight variation to the roles based upon skills and which sections individuals desired to work on. In the construction phase the electrical was delegated to Aneesa, code to Rahul and build of the device to Rishi, Cecilia and Franklin, Lachlan. However everyone contributed to the discussion and expenses for the device. Allocation of roles could have been better distributed however as no formal discussion was made on the topic of roles in the construction phase they were not specifically delegated which should have been a part of the process before the build stage.

Conclusions and Recommendations

The Carrl7 team's design solution for the Redback Autonomous Vehicle project demonstrates the team's ability to face technical challenges. Many challenges were encountered in dealing with infrared sensors, including the unstable response of the sensors under sunlight and the wire connections of the sensors becoming unresponsive. However, the team managed to successfully identify and solve each problem faced through an iterative process of testing and design. Several modifications and improvements were made throughout the construction phase to produce a model for the final competition. Although there were issues with the final design, which included insufficient time to optimize the code due to the problems along the way, the adaptability, and flexibility shown by the team allowed them to resolve multiple faulty systems at the last minute and give a viable final product. The success of the project was due in large part to the collaboration and teamwork amongst the team members, as well as the judicious use of limited time and resource allocation. The working principle of team 7's vehicle is the use of infrared properties to determine the difference between different coloured surfaces. The infrared tracking sensor uses the strength of the infrared reflection signal received by the infrared receiver head to determine whether the vehicle is in close proximity to a black line and then determines the state of the vehicle's running position.

Recommendations for Future Projects

Battery Specifications and Details

The performance enhancement of using a battery that supplies greater power in a design can be understood in terms of power transfer and efficiency. A battery with higher voltage and current can deliver more power. As both voltage and current are proportional to power increasing both supplies more power. This provides more power to the automated cart. Using a higher voltage battery also protects the battery better and extends its life. This is because less current is consumed for the same power requirement. Higher voltage at a lower current reduces the heat generated in the system and increases the efficiency of the battery. Typically batteries convert a portion of their energy into heat, which reduces the life of other electronic components in the vehicle. The less heat converted protects the electronic components. If given the opportunity to change aspects of our design, the first iteration of the teams design would have included the lipo battery that supplied 11.1 volts as the current provided by a singular 9 volt battery was insufficient for the system. Furthermore, the build process would have been started earlier along with the ordering of materials to factor in for delays in delivery and unexpected problems.

Compare the impact of changing weight on the project

The team faced weight constrictions as specified by the client and found the easiest areas to reduce weight were in the base and the cover. This allowed our design to come underweight. If provided more time another adaptation would be to custom make wheels to fit with our model that could be thinner and lighter and allow for an overall lighter model that would allow for the cover and base to have more weight and therefore be more structurally sound.

An easily accessible location for purchasing materials for the team was Jaycar, Jaycar's staff have an in-depth knowledge of the electronics and automotive field. Jaycar group can provide expert advice on different sensors and help people choose the one that best suits the project needs. Moreover, Jaycar's employees are very enthusiastic and have a great service attitude.

Recommendations to the client

To the client it is recommended to increase the weight restraints to allow for more room for aesthetic and design as well as to accommodate for the battery. It is also recommended to provide a list of suppliers of parts since this is a key to the project and poor parts can lead to a poor design and execution of the final project.

References

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