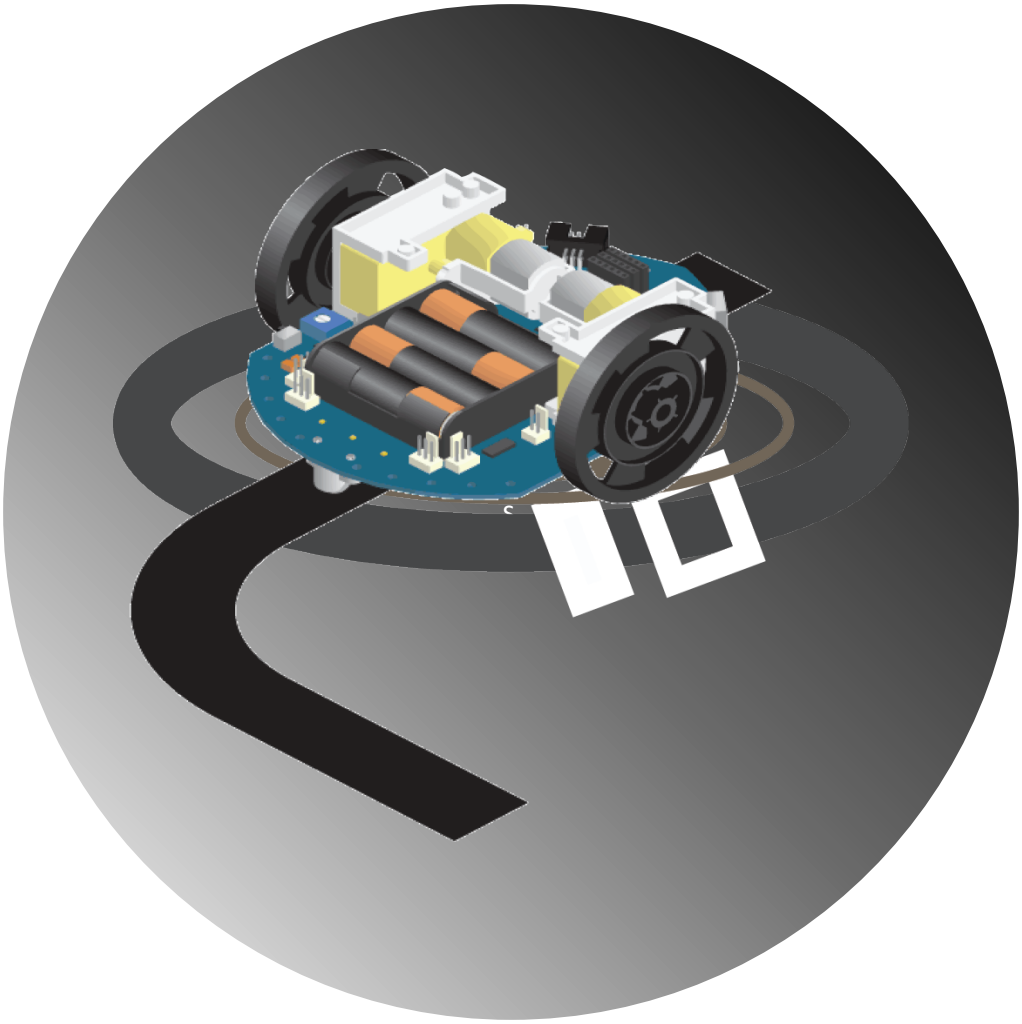
LINE FOLLOWING ROBOT

BY JITEN AYLANI & RITWIK TEMBURNI



TEJ4M0

DECEMBER 10, 2018

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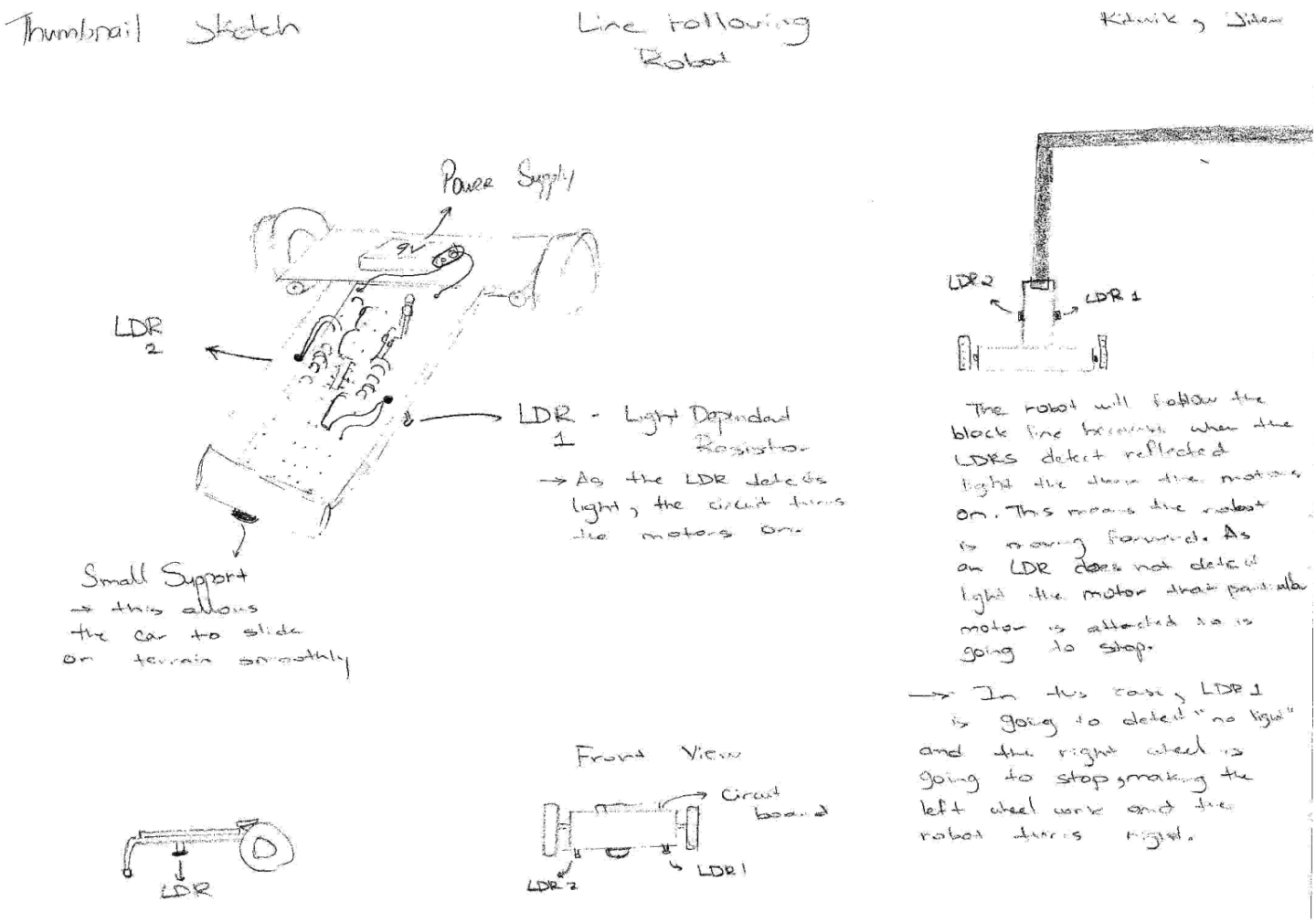
Parts List

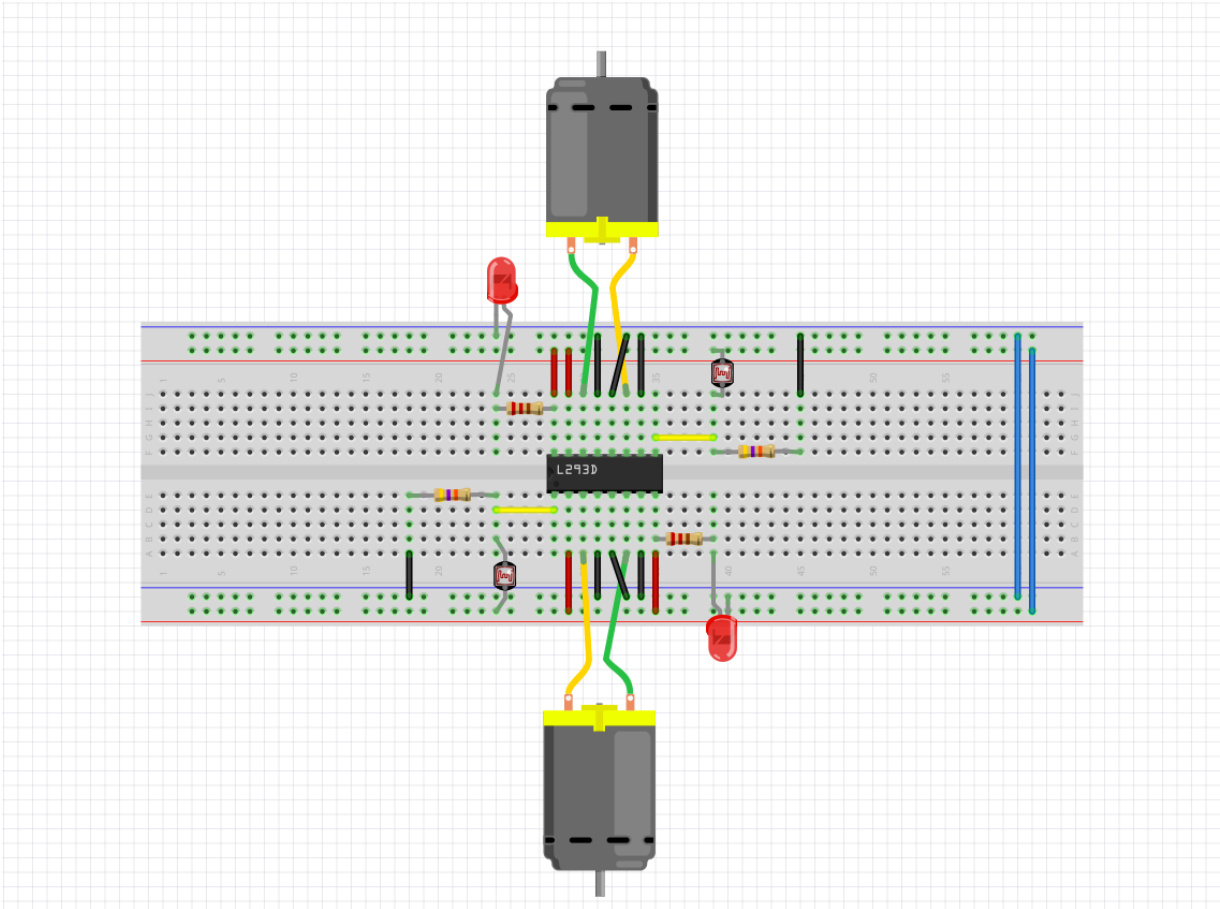
1. Cardboard
2. DC Motors x2
3. Wheels x2
4. Wires
5. Connector x1
6. 9V Battery x1
7. Breadboard x1
8. L293D x1
9. LDRs x2
10. LEDs x2
11. 220Ω Resistor x2
12. 47kΩ Resistor x2
13. Smooth Rolling Ball x1

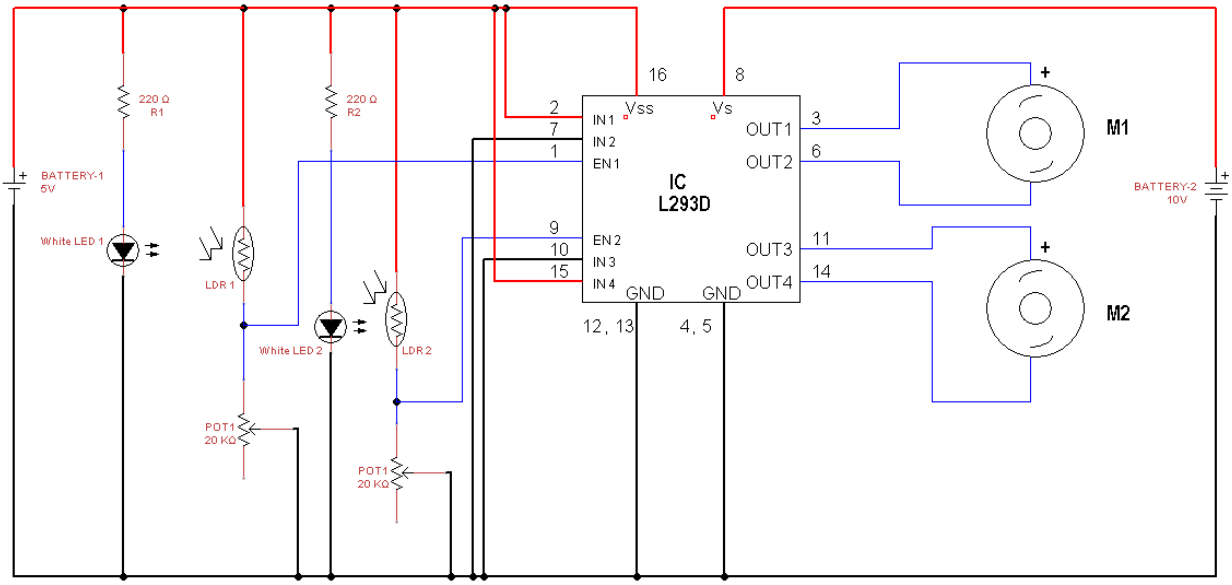
Thumbnail Sketch



Our rough thumbnail sketches simply indicate the overall look of our car and its function tied in with the electronics. Our goal was to ensure the function of our circuit was consistent before constructing the final project so as to avoid any potential repairs, diagnoses or tests later. We wanted our car to serve its purpose by also transporting its own essential components, almost like an organism. The car was designed to have two platforms: one for carrying the 9V battery, and one for carrying the breadboard with the main circuit. This platform-based design allows for easy access to the electronics but also maintains the streamlined design we wanted. The sensors responsible for the line-following function were hidden from view not only for protection purposes, but also for the 'mystery' of the car's methodology. If the sensors were hidden underneath the car, it would seem as if the car was sentient and was following a line unaided. The use of light-dependent resistors also ties in with the autonomy of the vehicle. An autonomous vehicle would serve its purpose and increase efficiency.

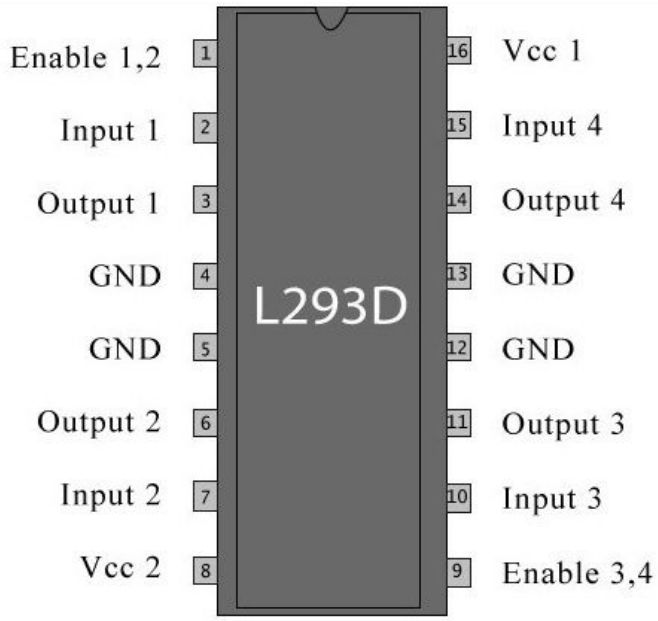
Pictorial & Schematic Drawings



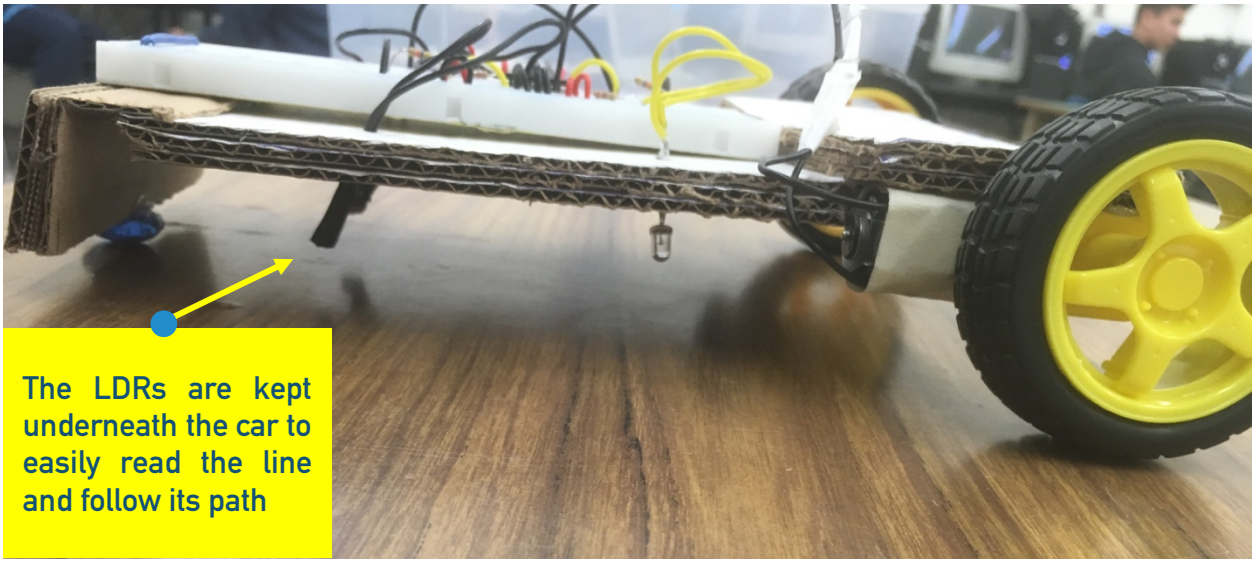


This circuit is very intuitive in its build and has a very symmetrical layout of input-output signals. The main IC chip used, known as a motor driver or a dual H-bridge, was a L293D. This is a 16-pin IC chip that can control two DC motors in different directions. The circuit itself can be thought of as a 'mirror' because of how symmetrical the wiring is. Both motors, LDRs and LEDs were placed in symmetrical configurations. The 16 pins in the chip each have their function that power the motors based off of power supply and any component connected to the enabler pins (Pins 1 & 9).

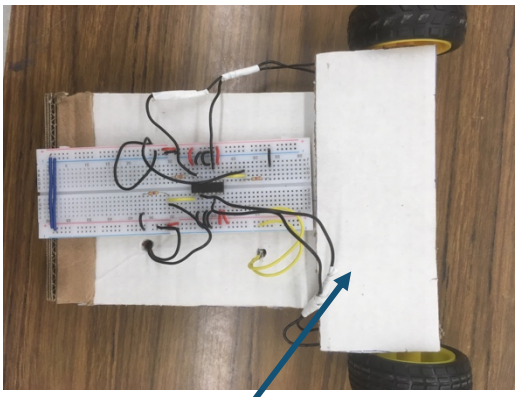
Pins 1 and 9, known as enabler pins, act as 'accessory regions' or pins where extra electronic components can be added that determine the output of the chip based off of the input of the component. For example, the LDRs or light-dependent resistors constantly pick up light and use it as an input of HIGH. If light was obstructed, the film contacts and the semi-conductor tracks, which make up the head of the LDR, would output a LOW value and therefore the motor would also output a LOW value. Pins 2 and 7 act as input pins, where wires would be connected to power. These pins would route to the output pins 3 and 6 that would power the motors. Pins 4 and 5 act as essential ground pins, and, finally, the 8th pin would act as the main power supply, Vcc. The reason the L293D is symmetrical in its electrical wiring is because the 9th, 10th, 11th, 12th, 13th, 14th, 15th and 16th pins all serve the same function.



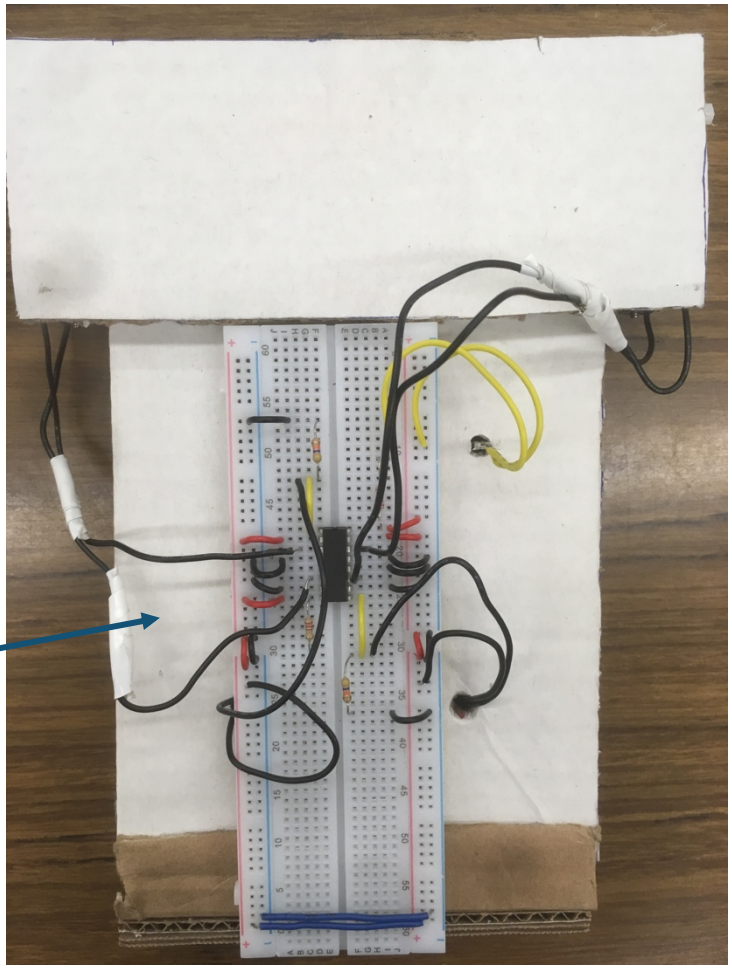
Construction of Circuit & Car



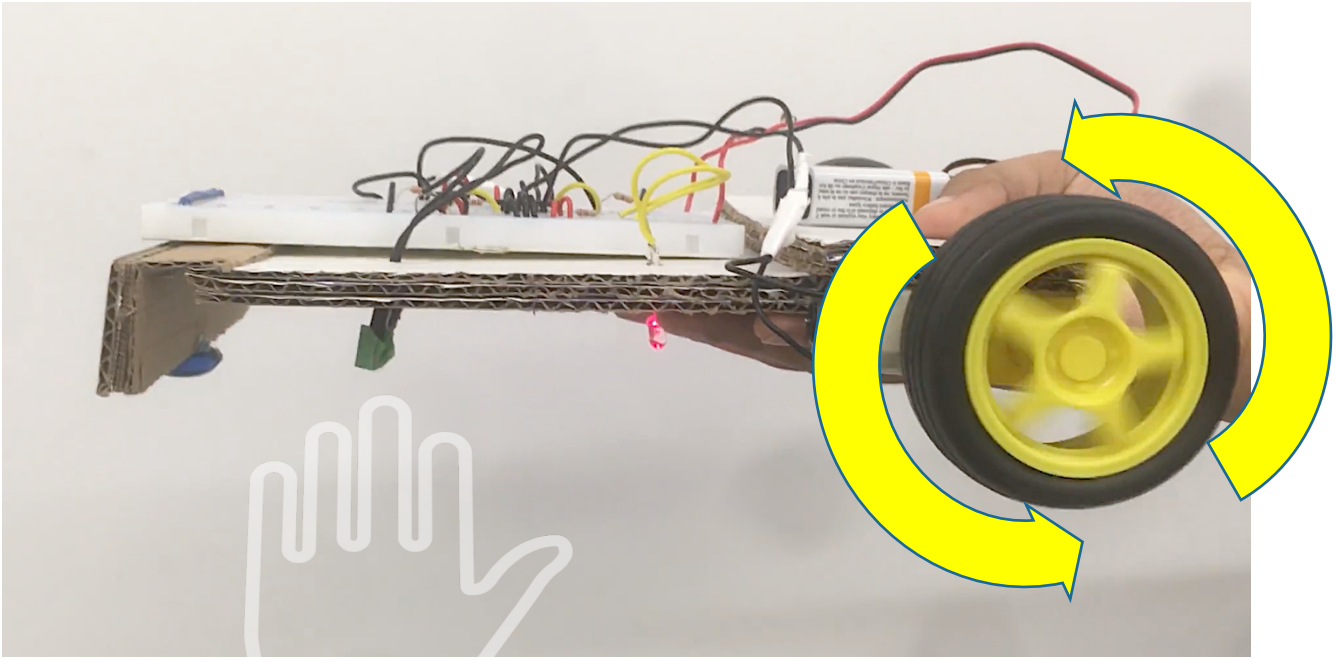
The LDRs are kept underneath the car to easily read the line and follow its path



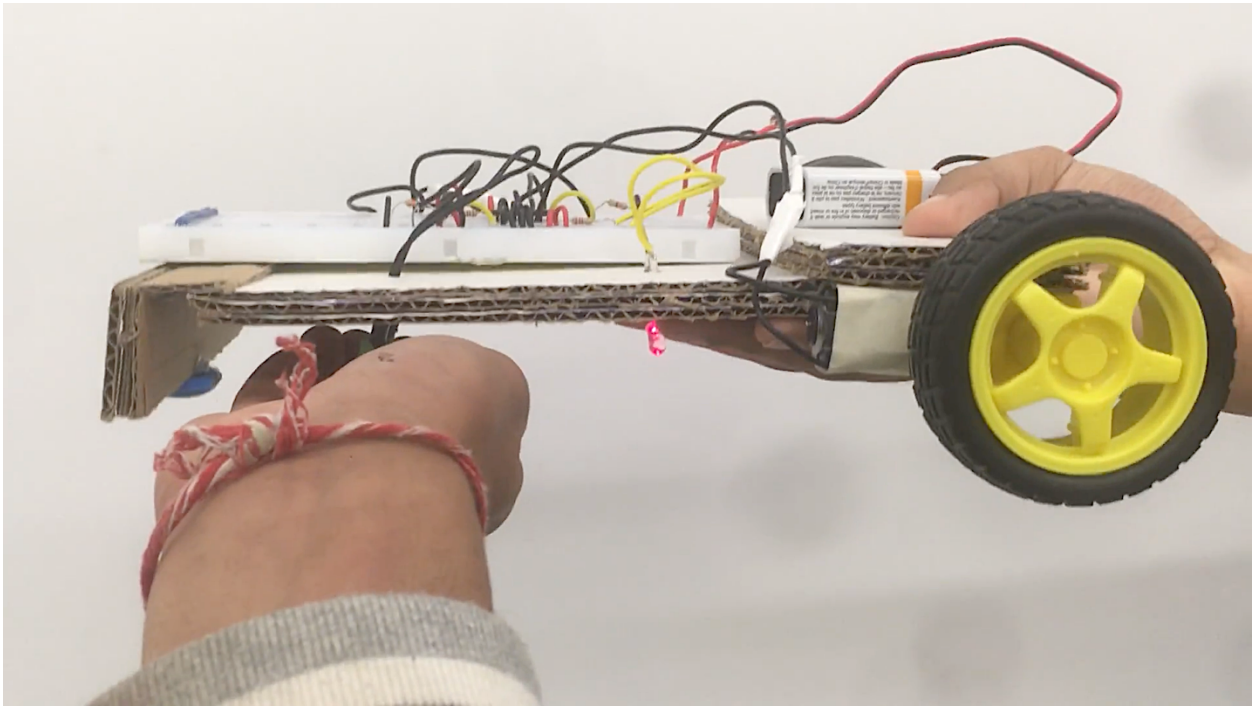
The line-following car has an elevated platform just for the 9V battery to hold



The main platform on the line-following car holds the breadboard and also has holes for the LDR wires



The LDR is picking up ambient light which is why the motor is running and the wheel is turning



If the LDR doesn't detect any light, it outputs a LOW value which stops the motor

SPICE

S

Situation or Scenario

Understanding the change to autonomy in industry sectors, we wanted to create a product that could fulfill transportation and warehouse-based needs for businesses. Our car, known simply as a 'line following car', can follow a black line with the use of light dependent resistors. Although this may seem like a trivial function, our product should fulfill a very basic need for warehouses, storage spaces and the like; the line-following function should allow it to safely maneuver through a field and avoid obstacles.

If the line-following robot can follow a line, it essentially travels to its destination by itself. The applications for this technology include transportation, storage and delivery. Right now, there are businesses that require efficient, micro-manageable technology that performs a vital function for their business, which is listed as its applications. If autonomous line-following vehicles were implemented into businesses, it could provide huge benefits to businesses such as resource-saving, efficiency and faster response times.

Line-following robots also possess the potential to cut costs from mistakes. If these robots were programmed to follow instructions without human error impeding, then businesses will have essentially saved money.

P

Problems & Possibilities

Design Brief: "To design a small prototype robot that can assist in carrying lightweight objects to its destination by following a given black line."

Requirements:

- The toy must be able to fit into your shoebox (when it is empty). All electronic components must be concealed by your toy, but allow access into the toy for servicing (i.e. changing the battery)
- A full-sized breadboard must be used to make your connections. All connections must be completed neatly and properly colour coded
- All components are to be built neatly onto the breadboard, but the LED/MOTOR (output) can be placed anywhere on the toy. The circuit will be powered by a 9V battery
- A report must be submitted at the end of the project, complete with a peer and self-evaluation. The students will mark themselves and their partner using the accompanying rubric and will include a paragraph that justifies how your mark was determined. There must also include a chart on how the work was divided (Activity Log)

Limitations:

- Listed components can only be used
- Limited tools and equipment in the classroom can be used
- The project must be completed in the classroom within the time limit

1

Investigation & Ideas

Key Questions:

1. How to let LDRs detect concentrated light and not pick up on the ambient light of the LEDs?
2. How to allow the car to move on its own without letting the friction of the ground stop it?
3. How to implement an ultrasonic sensor into the front-facing position if it needs to be connected by rows in the circuit?
4. Could infrared sensors be implemented into the circuit?
5. Where should the placement of the LDR be?
6. How would you support the vehicle without it tipping over?

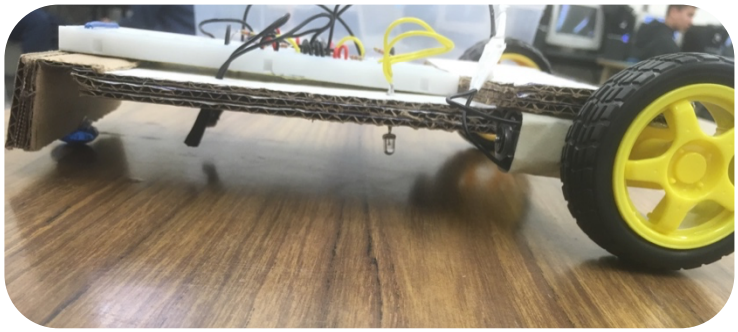
Ideas:

1. Using electrical tape, the LDRs were funneled around the head of the component to let maximum light enter and allow the LDR to only pick up the light from the ground rather than from the LED
2. The initial plan was to use a metal caster ball. However, the plan fell through when we realized that the caster ball couldn't be properly inserted onto the front of the vehicle with the current design. So, we decided to use a small, smooth marble that could easily be glued on and still function as a multi-rotational wheel on the front.
3. Due to time-constraints, the ultrasonic circuit was scrapped. The idea of the ultrasonic circuit was to allow the vehicle to have a 'safety measure' if an obstruction was detected. Using a comparator circuit consisting of transistors in a Schmitt-trigger, an ultrasonic range finder could be applied to the main circuit to allow the vehicle to be able to detect obstacles in its path and stop all functions.
4. The use of infrared sensors was the initial plan paired with photodiodes and operational-amplifiers however we switched to light-dependent resistors because of the lack of photodiodes in our resources and the unreliable nature of op-amps
5. Initially, the placement of the LDR's were designed to be at the front of the vehicle due to easier replacement. However, tests showed that the LDRs being placed at the front gave them latency issues and also pre-maturely detecting the presence of a black line. This meant that even if light was shone at the light dependent resistor, the motor would remain off. The change to putting the LDRs in the middle of the vehicle, right underneath, was to allow the LDR to not be affected by any ambient light and ensure accuracy in the processing of the LDR.
6. The line-following car was constructed with clear, precise measurements based off the size of the breadboard, the battery and the size of the wheels. Having the front cardboard piece of the car to be slightly off the ground to ensure the marble and the wheels would both be leveled was the most calculative step we took towards the integrity of the car

C

Choose & Create

To ensure that every part of our project could be put together in a streamlined, compact design, we decided to create a car design that has 'platforms' or cardboard pieces that hold the power supply, the main circuit and also hold the motors. We also took into account the friction the car may experience while moving and how that could hinder the turning of the wheel. So, we decided to use a smooth marble and glue to the front of the car and let it slide.



E

Evaluation

When completing the project, the beginning was simple and easily understandable to follow using the schematic. After working on the project for some weeks, issues and problems reaped setbacks. The original idea was to create two IR sensors that would be in control of the motor on each side. The IR sensor required the use of a Photodiode which was unavailable. This resulted in replacing the Photodiodes with Light Dependent Resistors instead. The LDR's would be connected to the enabler pins with motors as the output. One of the encounters with a problem that took a while to detect and solve was the problem in which the row of the breadboard was not correctly functioning. This was known when the motor did not work while being plugged into the correct row but working when it touched the "legs" of the L293D IC Chip. The circuit was fully functional, but this was known without creating the "Black Line Test Course". After making the course, the project was not satisfactory as it would follow the line during a straight path but not during turns (the vehicle would slightly twitch in the direction of the course). At first, the problem seemed to be the delay in the LDRs providing the input to the motors. But when the trial recordings were reviewed, the thickness of the line had to be doubled. The reason for this is because the LDRs either had too little time to detect the black line (Which could be solved by slowing down the motors) or the line wasn't thick enough to be fully recognized. Once the line was thickened, the LDRs were able to detect the line and the car was able to follow the angled turn.

Activity Log

Date	Work Done	Hours
20, Nov, 2018	Ritwik – Researched circuit schematics and components Jiten – Designed the car and researched parts needed	1h45m
21, Nov, 2018	Ritwik – Started building circuit and researched circuit concepts Jiten – Gathered materials and electrical components	1h20m
22, Nov, 2018	Ritwik – Finished circuit Jiten – Brought cardboard, measured and cut up pieces for the car	1h15m
23, Nov, 2018	Ritwik – Built circuit (Circuit was not working properly) Jiten – Soldered new motors with wires (Fixed stalling motor)	1h15m
26, Nov, 2018	Ritwik – Diagnosed and fixed wiring problem in circuit (Short wires) Jiten – Built breadboard-support and battery-support portions of car	2h30m
27, Nov, 2018	Ritwik – Connected LDR components and tested motor output Jiten – Helped with motor output testing (Test was successful)	1h15m
28, Nov, 2018	Ritwik – Rebuilt and rearranged circuit (Circuit stopped working) Jiten – Finished overall car build	2h15m*
29, Nov, 2018	Ritwik – Tested circuit to see if it worked (Stopped working) Jiten – Re-soldered motors (Fixed another motor for delay issues)	1h25m
30, Nov, 2018	Ritwik – Re-wired circuit and replaced L293D chip (Circuit worked) Jiten – Tested batteries for usability	1h15m
3, Dec, 2018	Ritwik – Fixed circuit and wired breadboard to car (Tested LDRs) Jiten – Helped with construction and LDR testing (Test successful)	1h15m
4, Dec, 2018	Ritwik – Started building ultrasonic circuit Jiten – Replaced motors and soldered wires	1h15m
5, Dec, 2018	Ritwik – Researched ultrasonic circuit and built special wiring for it Jiten – Put together original circuit and car together and tested	1h50m
6, Dec, 2018	Ritwik – Fixed original circuit's LDRs and replaced faulty components Jiten – Helped fix circuit	1h15m
7, Dec, 2018	Ritwik – Ran diagnostic tests for circuit (Fixed wiring) Jiten – Helped fix circuit and built slide-marble part for car	1h15m
10, Dec, 2018	Ritwik – Fixed circuit Jiten – Finished ultrasonic circuit	1h15m
11, Dec, 2018	Ritwik – Tested ultrasonic circuit, stopped working Jiten – Tested original circuit (LDRs and components were working)	1h30m
12, Dec, 2018	Ritwik – Ultrasonic circuit was scrapped due to time constraints Jiten – Constructed car into one piece	1h15m
14, Dec, 2018	Ritwik – Installed LDR wires through car for line detection Jiten – Helped soldered LDR external wires and LED wires	2h*

18, Dec, 2018	Ritwik – Tested final car on line-track (90° degree and 45° turn) Jiten – Diagnosed and fixed issues with latency	2h15m*

**Extra time taken in-class after period*

Total	30h35m

Peer & Self Evaluation

Self-Evaluation

Ritwik –
Jiten –

Categories	Level 4 (80-100%)	Level 3 (70-79%)	Level 2 (60-69%)	Level 1 (50-59%)
Design and Plan	Excellent sketches, accurate pictorial & schematic drawing. Toy resembles drawing or can account why it does not	Neat sketches, correct placement of components in drawing	Some requirements met or exceeded.	Few requirements met or exceeded.
T/I	9-10	7 – 8	6	5
Construction.	Very good show of workmanship, safe use of tools & equipment at all times. TOY is durable and will withstand most forces. Electronics are integrated seamlessly	Most requirements met or exceeded.	Some requirements met or exceeded.	Few requirements met or exceeded.
App	12-15	11-10	8-9	6-7

Technical skills in circuit building and circuit design and neatness.	Student is able to use hardware at or above expected level. Final product is neat and tidy and methodically placed. Circuit is difficult, and/or many new pieces used	Meets requirements discussed in class. Circuit is somewhat difficult to build.	Some requirements met or exceeded. Circuit is not very difficult, or no new electronics used	Few requirements met or exceeded. Circuit is not difficult to build at all.
App	12 – 15	11-10	8 - 9	7
Evaluation Report	Good evaluation. Complete description of strengths and weaknesses. Peer and self-Evaluation complete and insightful. Schematics are correct	Meets requirements discussed in class	Some requirements met or exceeded.	Few requirements met or exceeded.
Comm	9-10	7-8	5-6	4

Jiten's Self-Evaluation Justification

I believe I deserve this mark because of my dedication and hard work put into this assignment. I am proud of myself and my partner for working on this project with a minimal amount of assistance. Also, working on the L293D circuit which was a fairly new concept to us as it was a Dual H-bridge integrated circuit. This project allowed me to use my critical thinking skills in order to detect and diagnose problems with our circuit. One of the problems that I detected and later diagnosed was when the right motor of the circuit was not functioning. After checking the problem, I concluded that the particular row of the circuit was not functioning. This was known when the motor worked when attached to the "legs" of the IC chip. The problem was later diagnosed by moving the circuit 4 rows down, which later solved the issue. Overall, I put in my knowledge and effort in completing what needs to be done with my own time like staying after school multiple times. In conclusion, I firmly believe I deserve this mark because of all the new things I learned and implemented while working on this project.

Ritwik's Self-Evaluation Justification

This project truly changed my outlook and approach towards problems that exceed my limitations. Before this project, I felt like I didn't anything about electronics from a hardware perspective. And that doesn't mean I know everything there is to know about computer engineering, but I definitely feel like I've broadened my knowledge and my research has allowed me to understand important key concepts of IC chips like the L293D and electronic components such as the light-dependent resistor. I did immense research to understand how a line-following car worked, especially without the use of a microprocessor, microcontroller, Arduino or even an operational-amplifier. This project allowed me to use my creativity to, almost, 'make-shift' a line-following car without using complex hardware and programming. I put in a lot of work and extra time to make sure this circuit was efficient, organized and, most importantly, functional. I definitely could not do this without my partner, Jiten, whom I worked with very well. We were able to collaborate in a seamless way and allow each of our ideas to be expressed into the final product. I believe the mark I evaluated myself with is completely accurate because it reflects my hard-work, dedication and improvement in application for this course.

Peer-Evaluation

Categories	Level 4 (80-100%)	Level 3 (70-79%)	Level 2 (60-69%)	Level 1 (50-59%)
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Jiten's Peer Evaluation Justification

I believe Ritwik deserves this mark and one of the reasons being the amount of work he did and the effort he put into completing the project. Ritwik was completely dedicated to what needed to be done, and he never said "No" to any new ideas or suggestions provided. He assisted and corrected me when I was wrong and helped me understand the concept of the circuit better. Ritwik used his knowledge and research to make the project better every day. If there was a problem, he would try finding the solution for it instead of asking for assistance. In conclusion, I believe Ritwik deserves this mark because of his work and the knowledge he took away from working on this project.

Ritwik's Peer Evaluation Justification

Jiten has been a valuable partner throughout this project's development. At every bump on the road, Jiten would be the one who would always say, "Let's figure out why this isn't working." And most of the time, he would be the one to fix the problem. For example, when the circuit faced one of its biggest malfunctions: An entire row not conducting power, Jiten was the one to figure out to move the circuit on the breadboard around to make it work. He one fixed a DC motor, that wasn't turning but was seemingly working, by opening it up and reassembling the gears in the motor itself to make the pegs rotate. Jiten, although not wholly contributing to the construction of the circuit, was able to diagnose and repair parts of the circuit, its electronic components all while designing and constructing the chassis of the car.

Rubrics

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