Building an Industrial Autonomous Line-Following Robot through the Design and Construction Processes

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Abstract

Line following is among the essential parts of robotics. A black line placed on a surface with a bright color can be followed by an autonomous robot known as a Line Follower Robot (LFR). It is designed to move and follow the line automatically. With the help of a set of optical sensors, the robot can find the line and help itself stay on it. With its five sensors, it can move with accuracy and adaptability. DC gear motors are used to steer the robot's wheels. The Arduino Uno board is used to create and test algorithms that control the speed of the motor and drive the robot so that it can easily follow a line. This work aims to build the algorithm and manage how the robot moves by optimizing the operating parameters to make the robot work better. It is suitable for use as an industrial automated equipment transporter.

Keywords
LFR, Robotics, Autonomous, Arduino, IR Sensor, Motor Controller and AGV.

1. Introduction
Most industries now use crane systems to transport packages or goods from one location to another. Sometimes, lifting heavy loads during that time might result in the breaking of lifting equipment and harm to the packages. Using a line follower robot is the way forward to solve this problem. A Line Follower Robot (LFR) is a robot that can move independently and follow a line drawn on the surface. The path may seem like a dark line against a light background (Jha et al. 2016). When a sensor finds a line and the robot moves along it, the system is simple and works well. The driver continually adjusts the vehicle's trajectory in response to sensor feedback. Black surfaces take in the lightest. The white surfaces reflect the most, and black characters reflect the least. So, to find the line, use this feature of the light. An infrared sensor or an LDR (light-dependent resistor) is used to find the light. In this project, the digital infrared sensor is used for its superior precision.

The inbuilt op-amp comparator receives the output from the sensor, which detects the IR light reflected from the surface. Positioning the sensor over a white background causes the light to be reflected off the receiver. But when placed on a black background, the sensor doesn't see any reflection of the source light. The sensor measures the strength of the reflected light. The output from the sensor is sent to the microcontroller. It then tells the controller how to run the motor. Based on what the sensor says, the Arduino Uno is set up to move the robot forward, turn to the right or left, and stop. The motor controller receives the Arduino's output. In this case, we need to use a motor controller because the signal from an Arduino isn't strong enough to run the motor, and we need to be able to spin the motors in both directions. Here, we employ an L293D motor controller, a dual-h bridge motor controller that is good for driving two direct-current motors. (Mr. X. 2021).

1.1. Objectives
This project aims to build an autonomous line-follower robot that can carry the load, follow a path, and reach its destination. The following sub-objects have been completed under this project to achieve the aims:

- To develop a line follower robot model looks for a black line on a surface by using a color that stands out from the surface.
- To be able to turn in various directions to follow the line of the line follower robot model.
- To determine the load-carrying capacity of the line follower robot model.

2. Literature Review

The Line Following Robot, an element of the AGV (Automated Guided Vehicle), is a rudimentary autonomous robot that can identify and follow the path of a drawn line on the surface (Kaiser et al., 2014). This sort of robot have been developing for some time. However, the fundamental idea has never changed (Huy 2022). Additionally, contests involving line-following robots are often conducted to inspire to learn more about them (Hasan et al. 2013). These robots use infrared photons to determine the color of a line. Additionally, it constructs its course along that line. (Chowdhury et al. 2017)

Engineers have improved the robot's functions while it works on its own to make it more reliable for practical use in many fields. The sensor values that a line-following robot receives determine how it operates. The sensor values results in the best outcome. It is crucial to comprehend the sensor data and additional information in detail. It is important tobuild a functioning model of line-following robot but also performed data analysis. On the basis on which the robot makes choices (Gao et al. 2015),

The essential part of a line-following robot is route planning. Because it is fully autonomous, it must take action depending on the route. The majority of robots can travel in a straight or circular course. In cases when it has several possible routes to follow, each of which is distinct in form, it is crucial to let it make the selection (Kahe 2007).

A practical investigation has been conducted to include this in the preliminary design. With each passing day, our advanced society moves closer to fully automated labor to eliminate needless human involvement in simple tasks and focus on more meaningful tasks in an atmosphere of increased pleasure and satisfaction. To reduce the amount of human work, they made a robot that not only follows a line but can also detect three ways around obstacles while following a black line (Zaman et al. 2016).

3. Methods

3.1 Basic Operation

The primary function of LFR is to use optical sensors installed on its forward ends to detect the line position. A 5-bit digital IR sensor was employed to create a high-performance and better resilience sensing mechanism. A steering system is also necessary for the steering robot's tracking. Additionally, two-wheel motion-controlling motors are employed in this operation. If the robot senses no black line, it will spin in a circle until it finds the line.

3.2 Block Diagram

First, a setup is described to create a line follower that combines 5-bit digital infrared sensors (IR) with an Arduino Uno R3 connected through the L293D motor controller. In this case, we implemented a schematic diagram. The interconnection for the construction of the line follower, which follows a black line against a light background, is shown in Figure 1.

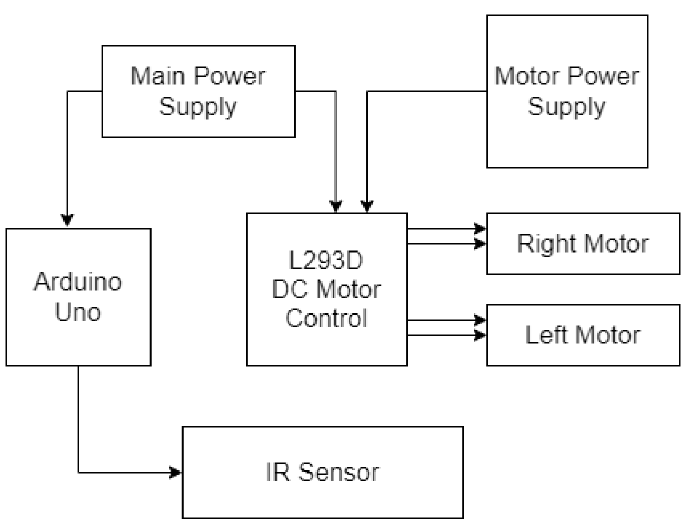

Figure 1. Line Following Robot Block Diagram

3.3 Flow Chart

The line-following robot's system is created using a flowchart as shown in Figure 2, which shows how it moves along the predetermined line. This flowchart shows the procedure and choices the robot takes throughout its course. The sensor system and the sluggish procedure of the line follower robot are its mainstays. The robot was developed so that it could get to where it needed to go faster and work more quickly and effectively.

3.4 Arduino Working Logic

The microcontroller receives five sensor signals (A4–A0) from the Arduino Uno to determine what to perform. In Table 1 below, is shown an explanation of every input as well as its purpose.

Table 1. Working Logic for Arduino

INPUT					ACTION
A0	A1	A2	A3	A4	
0	0	0	0	0	Go Forward
1	0	0	0	0	Move right
1	1	0	0	0	Turn right
1	1	1	0	1	Sharp turn Right
0	0	0	0	1	Move left
0	0	0	1	1	Turn left
0	0	1	1	1	Stop
0	0	0	0	0	Move circularly Until track is detected

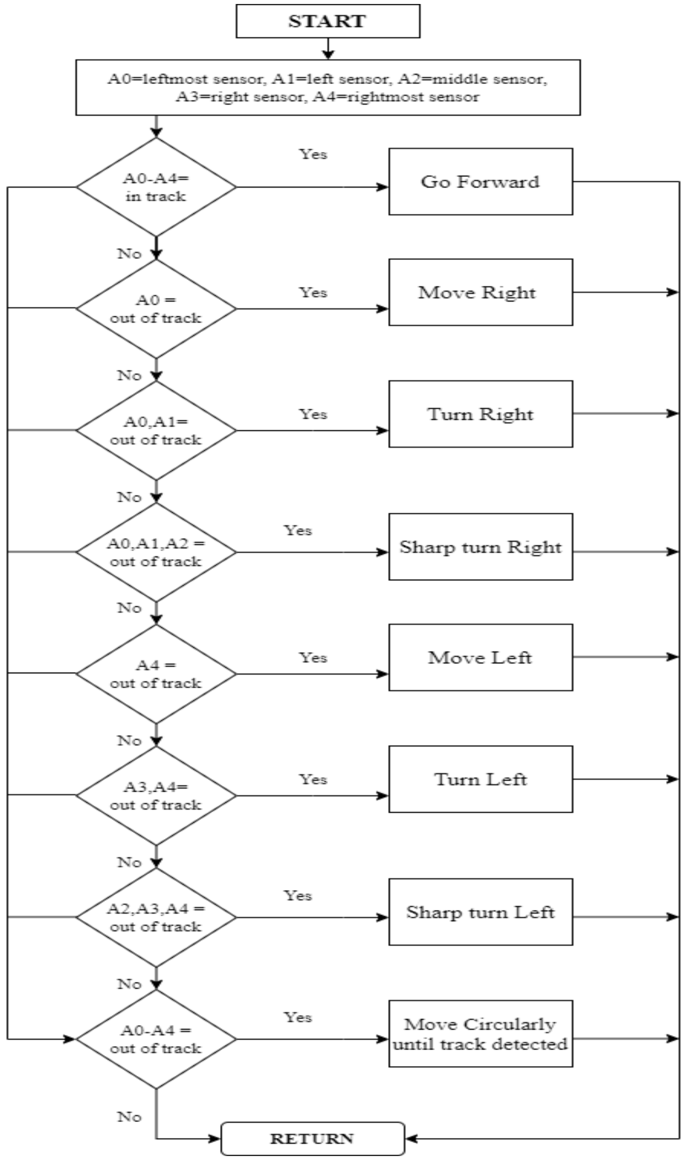

Figure 2. Flowchart of the line following Process

3.5 Hardware Required

The necessary hardware is classified as follows:

3.5.1 Arduino UNO

The ATmega328P is the foundation for the Arduino UNO microcontroller board. It has six analog pins, a ceramic resonator, 14 digital input/output pins (6 of which may be used for pulse-width modulation output), one USB connection, a power connector, an In-Circuit Serial Programming header, and a restart switch. It includes everything needed to support the microcontroller (Robu 2021). To begin, power it with an AC-to-DC adaptor or battery, or link it to a computer through USB.

3.5.2 Digital IR sensor array

The ATmega328P is the foundation for the Arduino UNO microcontroller board. It has six analog pins, a ceramic resonator, 14 digital input/output pins (six of which may be used for pulse-width modulation output), one USB connection, a power connector, an In-Circuit Serial Programming header, and a restart switch. It includes everything needed to support the microcontroller (Robu 2021). To begin, power it with an AC-to-DC adaptor or battery, or link it to a computer through USB.

3.5.3 Battery Operated motors
The BO (Battery Operated) gearing motor provides adequate torque and rotational speed at low voltages. After being powered by a single Li-Ion battery, the motor can reach speeds of up to 150 RPM (Roboticsbd 2022). This motor is considered excellent for lightweight robots. It is generally utilized for lightweight operations. Torque and RPM options are available.

3.5.4 Motor Driver (L293D)
In motor control ICs, the L293D is widely recognized as a top choice. As the name suggests, it is often used to provide power for motors. Two DC gear motors may be run off of a single L293D IC, with each motor's position controlled independently (Lastminuteengineers 2022). The supply voltage may range from 4.5V to 7V, while the motor voltage can go from 4.5V to 36V. The motor's highest peak current is 1.2A, although its maximum continuous current is 600mA.

3.5.5 Power supply
To supply power to the whole circuit to move the robot quickly. Lithium polymer batteries are popular due to their high energy density, long lifespan, and low cost. Experts agree that lithium polymer batteries are the best option (RAVPower 2017). There are many features of lithium polymer batteries. These standard features include a high temperature discharge, a good internal impedance, and a high rate of discharge.

3.5.6 Jumper wires
Jumper wires are basic cables having connector pins on both ends that may be used to join two spots without the need for soldering (HEMMINGS 2018). Employing jumper wires with either a breadboard or a piece of experimental equipment allows quick circuit changes.

3.6 Programming and Simulation
The microcontroller's programming decides which outputs to produce in response to which inputs. A code set is developed and compiled into a ".hex" file and burnt inside the Arduino 1.65. Fritzing software is also used to simulate the output.

3.7 Mechanical Design
PVC Board is chosen for the robot's chassis because of its high load capacity and lightweight (Meghmani 2019).

4. Result and discussion
DC motors are the easiest to regulate. Two signals are used by one DC motor to operate. The needed orientation may be changed by switching the polarity of the power source across it. By adjusting the voltage throughout the motor, speed may be changed. The DC motor lacks sufficient torque to operate the robot correctly. Therefore, the DC gear motor is used to boost the DC motor's torque at the expense of speed to overcome the issue (Daware 2021).

4.1 Mathematical Interpretation
Pr = Torque (T) * Rotational Speed (ω), is the formula for calculating rotational power (Pr).

$$\Gamma = Pr/\omega$$

For a constant electrical input, Pr is constant in a DC motor.
As a result, torque (T) is inversely proportional to speed (ω) (Vedantu 2022).

$$\Gamma + 1/\omega$$

4.2Speed Control
By modulating the voltage across the motor through the enable pin of the L293D, the speed of the dc motor may be adjusted using just an Arduino for control. As a result, velocity drops as well. Both the velocity and the direction may be adjusted using the command.

4.3 Load Carrying Capacity
The carrying capacity of the line follower robot is increased by putting a load of up to 1400 grams on the model robot. Table 2 shows the distribution of load and the robot's performance. The results show that the model robot can carry 1000 gm easily. Figure 3 shows the arrangement of observing the performance of the LFR for different types of load carrying condition.

Table 2. Robot load capacity

Load	Can Carry?
No load to 1000 gram	Yes
1000+ gram	Failed to carry

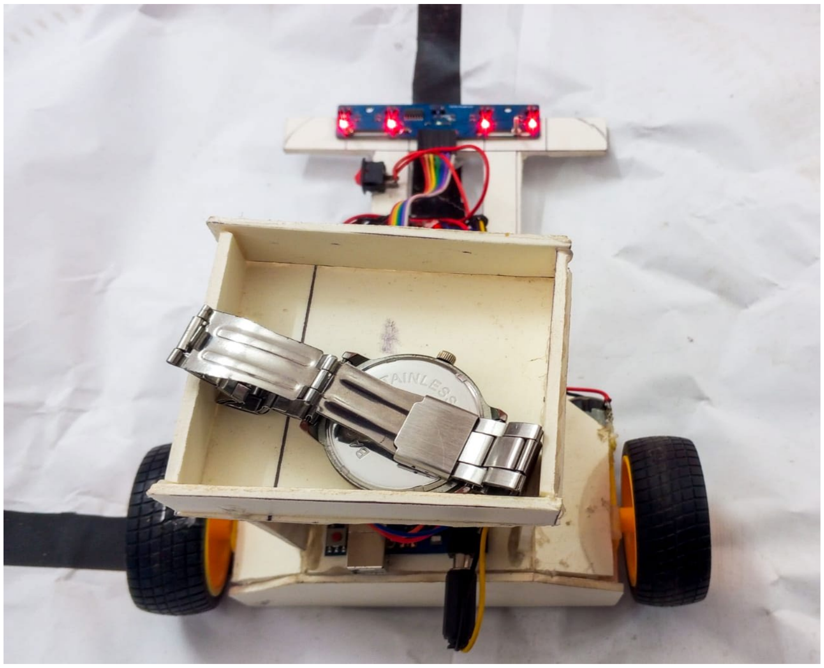

Figure 3. The robot carrying the load

4.4 Determination of speed

The speed of the line follower robot is also determined when the robot successfully carries an object. Table 3 shows the speed of the robot in a straight line. The maximum speed of 2.19 km/h is found at zero load conditions..

Table 3. Load carrying capacity of the robot

Load	Speed
No Load	2.19 Km/h
150 gram	2.16 Km/h
300 gram	2.08 Km/h
600 gram	1.98 Km/h
1000 gram	1.87 Km/h
1200 gram	Fail to carry

5. Conclusion

The line follower robot is an autonomous vehicle with the capability to detect its route and move to adjust its position in the direction of the line, allowing it to keep on track. This project involves the construction of a 200-gram line-following robot integrated with an infrared sensor and programmed to follow a black line on a white background. The maximum rpm of this electromechanical robot is 150 while operating under no load and plane conditions, and its dimensions are 20 by 25 centimeters. At a speed of 24.2 cm/s, the machine has the lowest turning radius of 100mm. If the robot wanders off track, it can figure out where things went wrong. Building a line-following robot required the team to coordinate their efforts, share information, and increase their knowledge of electrical and mechanical components and how they interact with the programming language in the model robot featuring adaptability for numerous settings and how it is intended to perform. There were several paths, yet the robot could recognize the line, follow the route, and carry a weight of up to 1000 grams. Thus, the goal of developing an autonomous load-carrying line-following robot has been accomplished.

6. Future Work

The team's initial project was the line follower robot, and they concluded that the project might need some upgrading. In the future, a CCD camera can be introduced with this line follower robot so that image processing and artificial intelligence can also be added for better performance. In addition, the color sensor will also be used so that better recognition and precise tracking of the path can be achieved.

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