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Design and Implementation of the Line Following Robot with Odometer

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Abstract

Line follower robot constitutes one of the very crucial characteristics of robotics. A robotic system is the intelligent system that can follow whether it's a black-on-white contrasting colored surface or vice versa. The code is programmed in such a way that the robot runs automatically in alignment with the line. The robot designates the line with the help of optical sensor arrays, which enables it to keep its course. The ensemble of four sensors provides accurate and adaptable movement. The wheels on the machine are governed by the rotation of DC motors having gear box. The Atmega32-based Arduino device is utilized to operate and incorporate algorithms that govern motor rotational speed, enabling the device to commute all along the line flawlessly. The objective of this research is to apply the line-following algorithms and regulate the robot's direction and move through proper calibration of the control factors, resulting in better results. Also, an added LCD module is added to indicate by visualizing the trip distance of the system. The system can be used as a load carrier in factories, industries, etc.

Keywords: Line following robot, arduino, IR optical Sensor, odometer

1. Introduction

A system that is capable to abide by a predefined route represented by the line is called as a line-following robot. The route might also additionally be a black line on a white floor or vice versa [1]. An easy but powerful system that is moved through perceiving a line and repositioning the robot to remain on the path, at the same time continuously adjusting incorrect actions making use of the feedback from the sensors. It is appropriate to be used in vehicles, automation structures in industries, navigational purposes, and different solutions. Among the maximum critical factors of robotics automation, is the robot capability of line following, which is an automatic machine that can sense either a grey or white line on a

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divergent coloured on the surface on which it travels [2]. It is constructed to commute automatically and has the capacity to run according to the plotted path.

The project's applications include everything from individual domestic appliances to control and automation elements of heavy enterprises. Humans are intellectual natural machines, but they have significant efficiency and reliability limitations. Robots have been created to probably partly replace human manpower dependency. The project is intended to perform a similar function.

The basic functionalities of the LFR system are as follows:

- The optical sensors are equipped on the rear end of the robot to grasp line position. An optical sensor, which is composed of an IR-LED and a photodiode, has been used for this. This leads to a sensing method with a high resolution and reliability.
- This task is achieved using two DC motors that regulate wheel motion.
- The whole framework must have an LCD screen frame that reveals the distance it moves.
- When no black surface is sensed, the motor drives in a circular motion unless a path is found.

1.1 Problem Statement

Carriers are needed in the industrial sector to move goods from one place to other, that are generally situated in separate areas or separate blocks. Wagons or forklifts with man driven equipment are conventionally used. The objective of the research is to standardize this segment by using carts to abide the black surface, rather than laying railway tracks, which is both expensive and time-consuming. Also, the odometer display the distance it has travelled, and based on that one can know the overall health of the robot i.e., how much charge it has consumed, and how much it can travel. Also, the calibre of the battery or power source can be determined accordingly. Moreover, it provides an aesthetic look to the product.

2. Related Works

Pakdaman M. and Sanaatitan M.S. [3], designed the robot ‘TABAR’ for the competition to follow the line. The brain of the system, Microcontroller ATmega16 with LDR (Light Dependent Resistor), and optical sensors were used. Oswal S. and Saravankumar

D. [4] utilized proximity sensors in order to avoid the collision and sensors in order to visualize the tracking line. The prototype was simulated with the help of Autodesk and the compilation of the system was done by Coppeliasim. The study tried to prove the importance of the application of the system in a manufacturing industry, which can move a distance of 10 meters in 8 seconds.

Omer G., Murat T. and Dogan O, [5] highlighted the need for advanced technology and innovative technology in order to reform public transport, since the growing number of passengers proportionally increases the number of routine services, which enhances the probability of accidents. The integration of technology of "computer-controlled line follower robots in public transport", was proposed as the solution to the problem.

The above-proposed solutions are mostly in software-based simulation with limited capacity, there is no mechanism for the return of the robot if it lost its path anyway. Also, there is a lack of mathematical explanation for taking sharp turns, the variable speed controller, and the odometer for the trip length measurement. The important feature of the odometer which is the base for the calibration of the device is also missing.

3. Proposed Work

The block diagram in fig.1 demonstrates the "Line Following Robot" (LFR). The Arduino Uno supports the program's brain as well as the robot's crucial constituent. The following are the major features of the hardware:

- Arduino Uno
- The IR-LED with a photodiode
- The LM324 comparator IC
- The DC motor driver IC (L293D)
- DC motors with the gearbox
- Connectors to link various boards to make a single functional gadget
- As a proximity sensor, a set of IR-LEDs and a phototransistor are utilized in the configuration of a tachometer.

Each hardware component is tested separately for its features before being fully integrated into a single platform. This assisted the unit's testing process.

Proteus® software is utilized for circuit simulation. The Arduino 1.65 ® is utilized for programming and uploading the sketch.

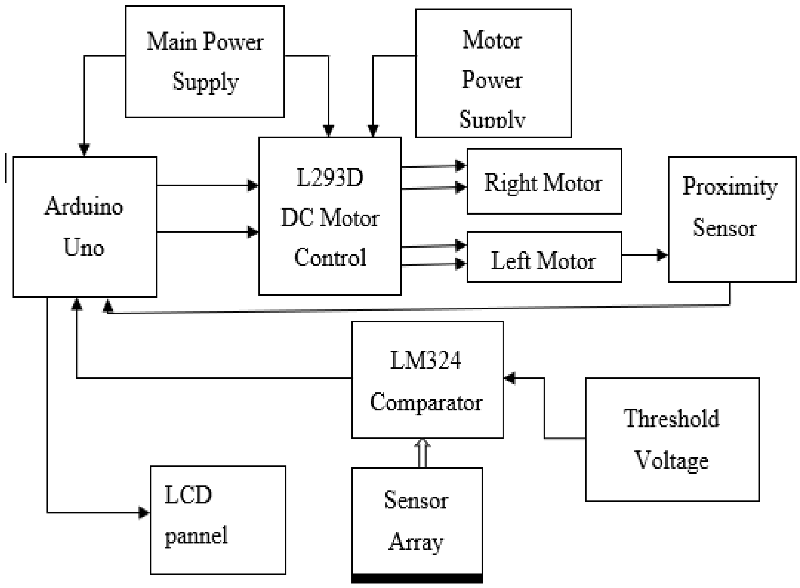

Figure 1. Block diagram of the line following robot

3.1 Programming and Simulation

The programming code is compiled and is burned into the microcontroller, which acts as the brain of the system, trying to decide the outcomes for a particular input set. The program is compiled in Ardunio API "Arduino® 1.65" [6], which interacts with Arduino through the USB interface and the resultant "hex" is uploaded to the simulation in Proteus as well.

The idea behind Arduino's process is to process the sensor's input feedback with the help of the code burned to it and facilitate output processing signal to the microcontroller, which then directs it to move the motor in a way that tends to produce the expected movement.

The differential steering mechanism is used to move the robot. The system's rear wheel is attached with a separate motor, while the front castor wheel is free to move. To move in a straight line, both motors are given the same voltage. To manage a turn with varying sharpness, the motor on the required side of the turn is maintained at a lower potential difference, so that the system achieves the required level of steering [7]. The diagram below depicts the logic that has been implemented.

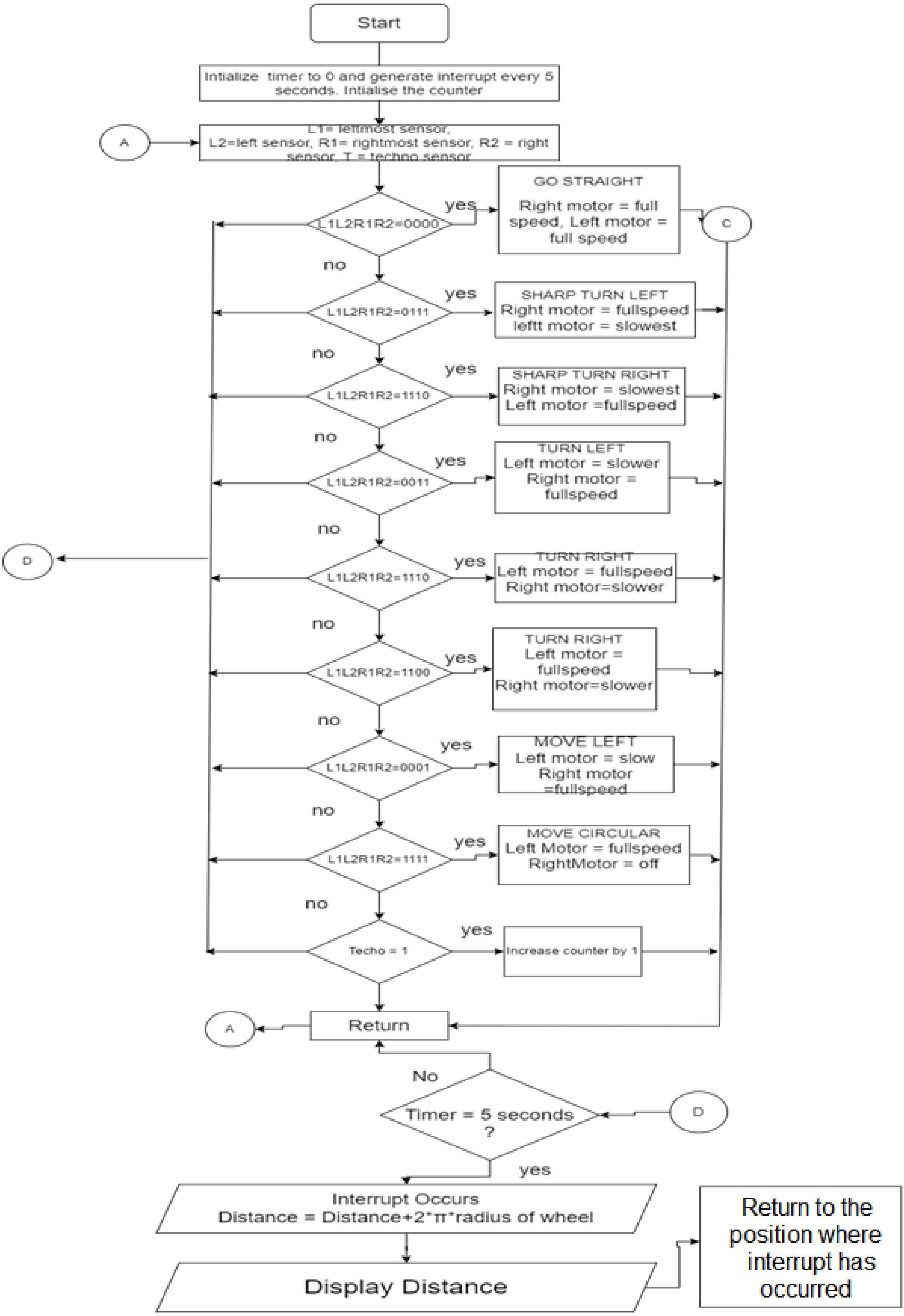

Figure 2. System overview for line follower robot and odometer

4. Results and Discussion

At the different stages of the process of designing and constructing the LFR, the mathematical analysis for the kinematics of the robot is represented mathematically. DC motors are controlled by the IC L293D, which analyses the Pulse Width Modulation (PWM) signal generated by the Arduino. The PWM signal directs the IC to fluctuate voltage to slow or fasten the robot. The voltage polarity is used for the back-and-forth motion of the robot. The DC gear motor is utilized in the project since the normal DC motor is not able to generate enough torque. The gearbox increases the torque with a trade-off to the speed.

4.1 Speed Control

The rotational speed of the motor is controlled by IC L93D which processes the PWM signal generated by the Arduino. The mathematical expression is shown below.

Calculation:

$$\mathrm{T} = \frac{1}{T}\int_0^{Ton} V dT$$

$$\mathrm{T} = \frac{1}{T}\int_0^{Ton} 12 dT$$

$$T = 12\frac{Ton}{T}$$

$$T = 12 \times \rho$$

In the above equation, the PWM signal is controlled by the value of ρ, duty cycle; so, the duty cycle alternation affects the amplitude of the PWM control pulse, which manipulates the DC voltage fed to motors that control their speed. Arduino-dedicated pins are capable of generating PWM. At different duty cycles, the RPM of the motor is measured under no load conditions.

Table 1. Study of the correlation of PWM on the motor's RPM

Duty cycle (ρ)	PD across Motor	Revolution per Minute
0	0 v	0
1/4	3.5 v	16
1/2	6.5 v	30
3/4	9 v	44
100%	12.5	59

4.2 Digital RPM Meter

A digital Revolution per Minute (RPM) counter is a device for measuring the rotational speed, which is programmed to digitally count the number of revolutions made by the object in a circular motion. The same approach is implemented in Tachometer. The set of "IR led and photodiode" is utilized for counting the number of revolutions made. The system is programmed to update the distance calculated every 6 seconds, that is 10 times per minute. In this case, the built-in revolution counter is used as a tachometer, which was tried in the lab under all environments with a standard tachometer as a reference.

Table 2. Comparative analysis of a benchmark and a built odometer sensor

Voltage Across Motor	Revolution per Minute (Lab Tachometer)	Revolution per Minute (Built odometer sensor)	Error in percentage
3 v	71	76	6.26%
6v	123	131	9.31%
9v	181	175	6.65%
12v	256	233	10.41%
15v	331	283	12.39%

4.3 Mechanical Design

The efficient manoeuvring of any automobile system is dependent upon the differential steering mechanism, and this design is based on the same concept. Here, a pair of wheels is positioned on a single-axis line, which is power-driven and controlled independently. It provides steering and driving. The castor wheel acts as a passive wheel used for support and is mounted at the front. The robot moves in a linear path if both driving wheels rotate at the same speed. If one wheel rotates quicker while another is slower, the robot will take a curved path. The robot pivots if the wheel moves in the opposite direction to each other [8]. The chassis platform of the built system is made of a composite of epoxy glass which in lighter in weight but has more load-bearing capacity. The radius of a vehicle's turning radius is the vehicle's minimum U-turn (i.e., round turn). The phrase 'turning radius' is an analytical term used to represent the curvature of the path in technical usage.

Calculation:

The robot car's approx length is 17.2 cm, which is the least radius turn that it can shift dramatically. At the max value of $\sin\omega$, which is 1, the value of the turn radius comes to $1/2\ L = 0.0872$ m.

Speed of the vehicle is the most crucial point in deciding whether it can take a turn in a smooth manner or not. As an outcome, the correlation between the radius turn and the speed of the building system must be assessed.

Radius turn (r) = 10cm.

Velocity (V) = ?

Friction coefficient (μ) = 0.08 [9, 10] [rubber and paper]

$V = \sqrt{\mu r g}$

$= \sqrt{0.08 \times 8.75 \times 9.81}$

= 0.26 m/s, which is attained at the speed of 84 rpm.

So, the path should be constructed in such a way that the turning's radius in the path shouldn't be less than 0.1 cm.

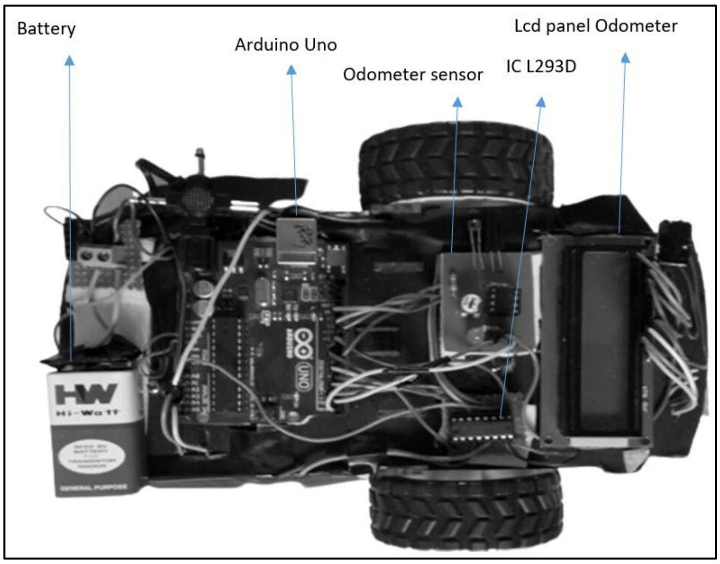

Figure 3. Top view of the built system

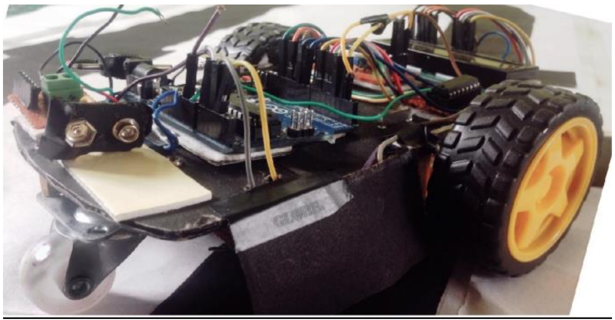

Figure 4. Left view for built System

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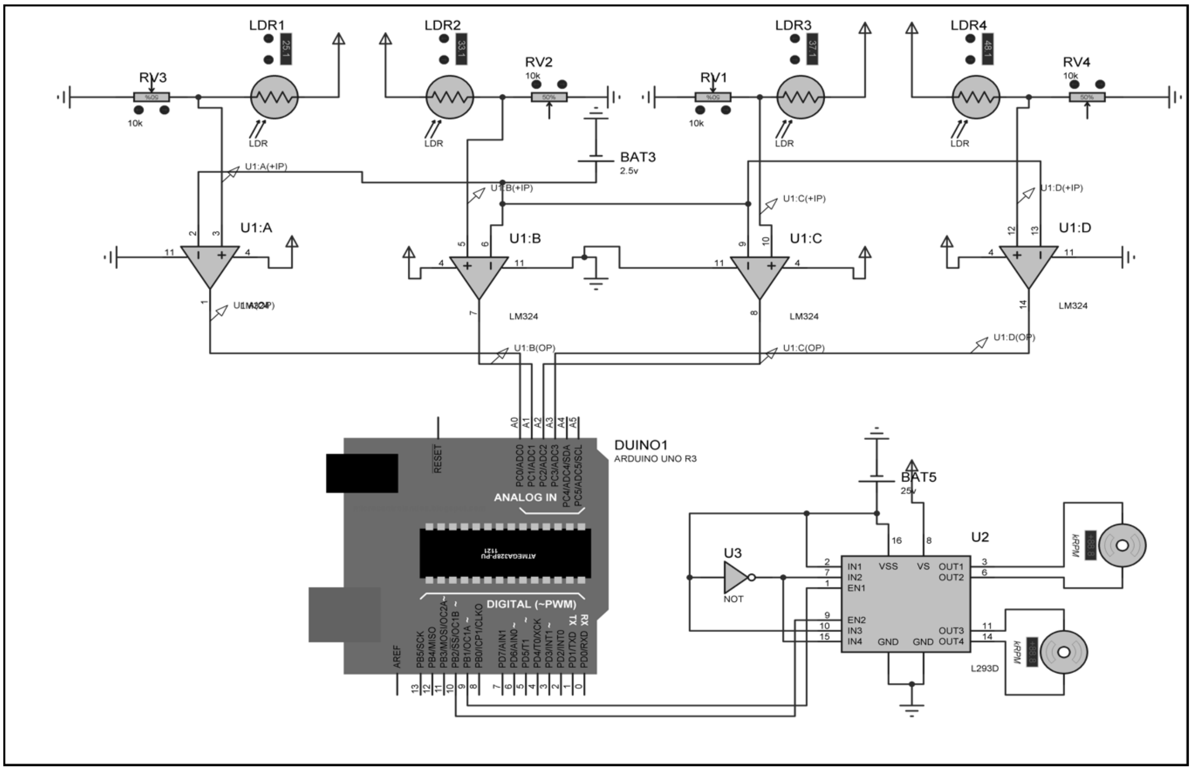

Figure 5. Circuit diagram of the proposed design

5. Conclusion

The constructed line following robotic system is a dynamic system that can identify its path and move, and alter the robot's posture in accordance to the line in order to stay on course. This research describes a 200gm line follower robotic design that is always projected along a black coloured path on a white surface. The electrotechnical robot has a volume of 192×100×70 mm^3 and a max rpm of 180 under no load and zero friction. At a velocity of 24.2 cm/s, the system's min turning radius is 10 cm. If the robot wanders off the path, it can detect the path again. The Line Following Robot project is the efficient amalgamation of electronics concepts, mechanical design & calculations, and computer programming in one project. Every task has been completed satisfactorily, illustrating the potential of the embedded system. The novel approach in the constructed system is that the system can re-detect the path if it somehow loses its direction, by turning around in a circular motion. Furthermore, the addition of odometer gives the valuable measurement by which other variables can be derived.

References

[1] J. Singh and P. S. Chouhan, "A new approach for line following robot using radius of path curvature and differential drive kinematics," 2017 6th International Conference on

Computer Applications In Electrical Engineering-Recent Advances (CERA), 2017, pp. 497-502, doi: 10.1109/CERA.2017.8343380.

[2] R. Ma, "Line following and beacon tracking robot based on Arduino Mega 2560," 2021 3rd International Symposium on Robotics & Intelligent Manufacturing Technology (ISRIMT), 2021, pp. 32-36, doi: 10.1109/ISRIMT53730.2021.9597071.

[3] M. Pakdaman, . M. M. Sanaatiyan and M. Rezaei, "A line follower robot from design to implementation: Technical issues and problems," in 2nd International Conference on Computer and Automation Engineering (ICCAE),, 2010.

[4] S. Oswal and D. Saravanakumar, "Line following robots on factory floors: Significance and Simulation study using CoppeliaSim," in IOP Conference Series: Materials Science and Engineering, 1012., 2021.

[5] O. Gumus, M. T. Opaloglu and D. Ozcelik, "The Use of Computer Controlled Line Follower Robots in Public Transport," Procedia Computer Science, vol. 102, no. 1877-0509, pp. 202-208, 2016.

[6] J. A. a. H. M. J. Warren, " Arduino Robotics," in Arduino for Robotics, New York, Apress Publication, 2014, pp. 51-83.

[7] K. S. T. K. T. Komonya, "A Method for Autonomous Locomotion of Mobile," Journal of Robotics Society of Japan, vol. 2, no. 31, pp. 222-231, 1984.

[8] Kwok Wai Au and Yangsheng Xu, "Path following of a single wheel robot," Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065), 2000, pp. 2925-2930 vol.3, doi: 10.1109/ROBOT.2000.846472

[9] C. DeArmitt, "23 - Functional Fillers for Plastics," Applied Plastics Engineering Handbook (Second Edition),, vol. 2, no. https://doi.org/10.1016/B978-0-323-39040-8.00023-7., pp. 517-532, 2017.

[10] R. N. Jazar, "Mathematical theory of autodriver for autonomous vehicles," Journal of Vibration and Control, vol. 16, no. 2, pp. 253-279, 2010.

Author's biography

Sujeet Kumar Jha received his bachelor's degree in Electrical and Electronics Engineering specializing in Communication Engineering. He is pursuing his postgraduate degree in the Computer System and Knowledge Engineering at Pulchowk Campus, IOE, TU. His areas of interest are Cellular planning, Embedded Technology, Machine learning, and Big Data.