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Design and Implementation of a Low-Cost 8051-Based White Line Follower Robot Using IR Sensor Array and Embedded C Programming

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ABSTRACT:
Background: Line follower is a smart autonomous robot that detects or follows a white line embedded in the ground. Infrared sensors are used to detect these lines. Typically speaking, the area unit of the infrared sensors is used to locate the path that the robot must follow.
Results: The robot movement is automatic and can be used for applications of long distances. The device proposed is extremely useful in commercial, medical, rescue and military operations. It can be used in industrial automated equipment carriers, small household applications, tour guides in museums, etc.
Conclusion: We have implemented the algorithm and controlled the movement of the robot by proper tuning of the control parameters using 8051 microcontroller and embedded C programming and thus achieved better performance. Using motor driver IC and BO (Battery operated) motor has been used for proper functioning of the robot.

Keywords: White Line Follower, 8051 Microcontroller, IR Sensor, Embedded C, Robotics

1. Introduction

The Line Following Robot is an autonomous robot that detects a path and follows it with the help of an IR sensor attached to the robot. Autonomous robots are those that can perform a task with a high degree of autonomy, which is particularly desirable in fields such as space exploration, cleaning floors, mowing lawn, and wastewater treatment. Modern industrial robots must manage variations in item position, orientation, and task requirements while operating autonomously in controlled environments. Applications in the actual world get more complex as a result of this un-certainty. Therefore, improving a robot's perception, adaptability, and performance in dynamic en-vironments such as industrial, terrestrial, underwater, aerial, and space domains is a major area of robotics study.

The path can be either a Blackline drawn over a white surface or vice versa, thus avoiding any detection error. Line follower robot also consists of an obstacle sensor that detects any obstacle in front of the Robot thus avoiding any unnecessary accidents.

Nature and Scope of the problem: Classical line following robot is slow in response to the error and will easily leave its track that drawn on the floor. This problem will cause the motion of the robot to be not smooth. Although the line following robot can follow the black lines, its motion still needs to be improved. The design and development of an autonomous line tracking robot is a very complicated task. There are many aspects that should be considered such as mechanical system, electrical circuit and microcontroller programming. All these aspects need to be fully integrated between each other so that, the autonomous robot can be perfectly functional to achieve the tasks provided. Furthermore, there are many types of microcontrollers, sensor device and dc motors in the market. Each of them has difference specifications, capability and functions. The biggest obstacle is to program the microcontroller based on the information

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gathered from the robot's line sensors. For line sensor case, its information is based on the rate of reflected light that have been detected by detector. In different environment or brightness of area, the rate of light detected by detector is fully different. So, the strong programming languages knowledge is needed to synchronize environment changes with the program in the microcontroller.

2. Objective

We have developed a robotic vehicle that follows a specific path. A pair of photo sensors comprising IR transmitter and photo diode is interfaced to the controller to detect the specified path for its movement. Two DC motors are interfaced to the microcontroller through a motor driver IC. It operates by sensing the path and transmits the signal to 8051 Microcontroller which then decides to make any changes (if needed) in the directions or speeds of the robot according to the inputs received and sends the control signal to the line follower robot according to the program written in it and drives motors as desired. Objective of this research work is to design and develop an autonomous line tracking robot which must be capable of following a line, taking various degrees of turns, must be insensitive to environmental factors such as lighting and noise and must allow calibration of the line's darkness threshold.

3. Methodology

Robot captures the line position with optical sensors mounted at front end of the robot. For this a combination of IR-LED and Photodiode called an IR Sensor has been used. The steering mechanism for tracking has been achieved by two motors which governs the wheel motion. All the data is processed by 8051 microcontroller and accordingly decision will be made.

3.1. IR Sensors

An infrared sensor is an electronic device that can measure the heat emitted from the object as well as detects the motion. The emitter is an IR LED (Light Emitting Diode) and the detector is a photodiode that is sensitive to same wavelength as that emitted by the IR LED. When IR light falls on the photodi-ode, the

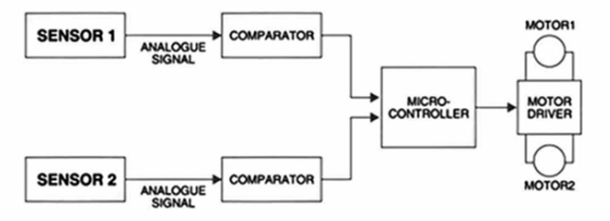


Figure 1: Block Diagram

resistances and hence the output voltages will change in proportion to the magnitude of the IR light received.

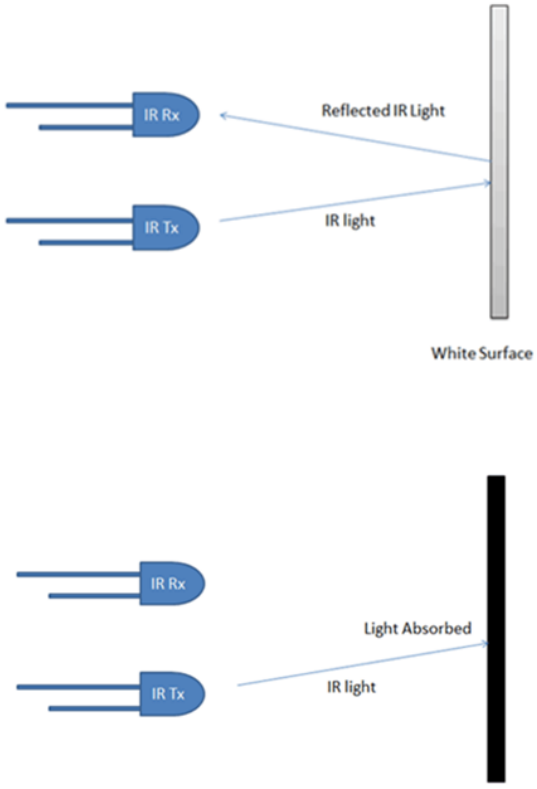


Figure 2: Working of IR Sensor

3.2. 8051 Microcontroller Development board

An 8051 Development Board is a circuit board designed to facilitate the programming, testing, and de-velopment of projects. It's a versatile platform that includes components like AT89S52 Chip, Power Supply, and Programming Interfaces, allowing users to experiment with microcontroller peripherals and build various applications. The AT89S52 is an 8-bit microcontroller based on the industry standard 8051 architecture. It features 8KB of in-system programmable (ISP) Flash memory, 256 bytes of internal RAM, and 32 programmable I/O lines. The AT89S52 is widely

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used in various embedded applications due to its low power consumption, high performance, and flexible programming capabilities.



Figure 3: 8051 development board

3.3. L293D Motor Driver

A motor driver is an integrated circuit chip which is usually used to control motors in autonomous ro-bots. It is a current enhancing device. The most used motor driver ICs are from the L293 series such as L293D, L293NE, etc. These ICs are designed to control 2 DC motors simultaneously. The L293D is de-signed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V.

3.4. BO Motor

BO MOTOR is known as Battery Operated Motor. Motor is a device that converts any form of energy into mechanical energy or imparts motion. In constructing a robot, motor usually plays an important role by giving movement to the robot. In general, motor operating with effect of conductor with current and the permanent magnetic field. The conductor with current usually producing magnetic field that will react with the magnetic field produces by the permanent magnetic field to make the motor rotate.

3.5. Lithium -Ion Battery

A lithium-ion (Li-ion) battery is an advanced battery technology that uses lithium ions as a key compo-nent of its electrochemistry. During a discharge cycle, lithium atoms in the anode are ionized and sepa-rated from their electrons. The lithium ions move from the anode and pass through the electrolyte until they reach the cathode, where they recombine with their electrons and electrically neutralize. The lith-ium ions are small enough to be able to move through a micro-permeable separator between the anode and cathode.

Li ion batteries can have a very high voltage and charge storage per unit mass and unit volume. Com-pared to the other high-quality rechargeable bat-tery technologies (nickel-cadmium or nickel-metal-hydride), Li-ion batteries have several advantages. They have one of the highest energy densities of any battery technology today (100-265 W-h/kg or 250-670 W-h/L). In addition, Li-ion battery cells can deliver up to 3.6 Volts, 3 times higher than technologies such as Ni-Cd or Ni-MH. This means that they can deliver large amounts of current for high power applications, which has Li-ion bat-teries are also comparatively low maintenance, and do not require scheduled cycling to maintain their battery life. Li ion batteries have no memory effect, a detrimental process where repeated partial dis-charge/charge cycles can cause a battery to ‘remember’ a lower capacity.

3.6. Design and Implementation

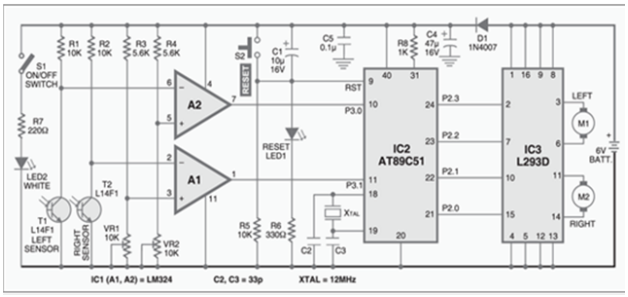


Figure 4: Circuit Diagram

3.7. Working Logic

The microcontroller gets 3 inputs from the sensor circuitry, to the (P1.0–P1.2) of the microcontroller to decide what to do when on the line. Below is the complete description about what each input mean and what needs to be done.

(‘1’= BLACK, ‘0’ = WHITE)

3.8. Hardware implementation

A microcontroller is the brain of the robot, which controls all its functions. It receives input signals from

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Table 1: Decision rules for line-following robot based on IR sensor inputs.

Left IR	Centre IR	Right IR	State	Action
0	0	0	All sensors on white surface	**STOP**
1	0	0	Centre and right sensors on white	Slight right turn
1	1	0	Right sensor on white	Turn right
0	0	1	Centre and left sensors on white	Slight left turn
0	1	1	Left sensor on white	Turn left
1	1	1	All sensors on black surface	**STOP**
1	0	1	Only centre sensor is on white	Move forward

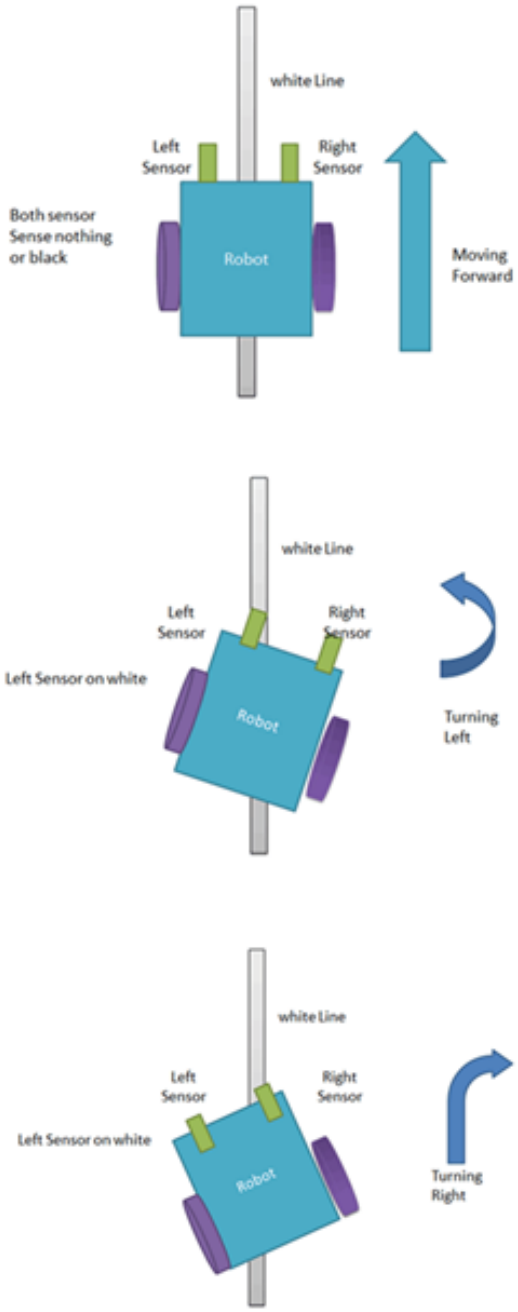


Figure 5: Line following logic

the sensors and generates output signals to the motor driver circuit.

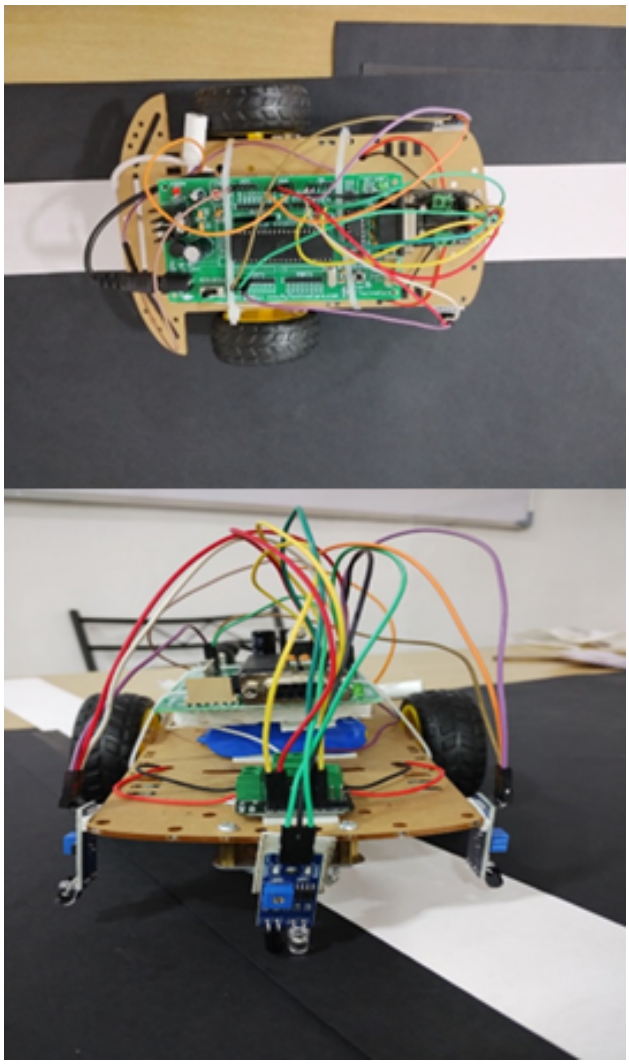


Figure 6: Final product image

A motor driver is an electronic circuit that controls the speed and direction of the motors. Line follower robots usually have two or more DC motors, and the motor driver circuit is responsible for controlling their movements. The most used motor driver is the L293D, which is compatible with many microcontrollers.

Line follower robots use various sensors to detect the line and obstacles. The most used sensors are

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infrared (IR) sensors, which emit and receive IR radiation. The sensors are placed on the underside of the robot, and they detect the contrast between the line and the surface.

A power source is required to power the microcontroller, motor driver, and sensors. The power source can be a battery or a power supply, depending on the requirements of the robot. The chassis is the physical structure of the robot, which holds all the components together. It can be made of plastic or metal, and its shape and size depend on the design requirements. The wheels are attached to the DC motors and enable the robot to move forward and backward. The size and type of wheels depend on the surface on which the robot will be operated.

The differential steering system is implemented to turn the robot. In this system, each back wheel has a dedicated motor while the front caster wheel is free to rotate. To move in a straight line, both the mo-tors are given the same voltage. To manage a turn of differential sharpness, the motor on the side of the turn required is given lesser voltage as level of steering required.

First, connect the motor driver to the microcontroller. Port 2 (P2.0, P2.1, P2.2, P2.3) is used for the inputs of the motor driver. Now, connect the BO Motors to the motor driver.

IR Sensors OUT pin is connected to the Port 1(P1.0, P1.1, P1.2) of the microcontroller.

Connect the Vcc and GND of the Motor Driver and the IR Sensors. Motor Driver is provided with a 12V Vcc and the IR Sensors with 5V Vcc.

Doing all the connections, it's time to upload the code. Connect the development board to the 8051-AVR USB ISP Programmer and open progisp application. Load the .hex file of the code.

4. Results and Discussions

A successful white line follower robot project should demonstrate the robot's ability to autonomously navigate a white line on a black surface. This is achieved using sensors, typically IR sensors, which de-tect the contrast between the line and the surrounding surface.

The robot's control system then processes these sensor inputs to adjust motor speeds, enabling the robot to follow the line.

The Line follower robot is a mobile machine that can detect and follow the line drawn on the floor. Generally, the path is predefined and can be visible like a black line on a white surface with a high con-trasted colour.

This robotic system can provide an alternative to the existing system by replacing skilled labour, which in turn can perform better tasks with accuracy and lower per capita cost.

5. Conclusion

Robots play a vital role in the global economy and in everyday life. Also of concern for robotic re-search is the competitiveness and design of patents in the world's industries according to their type of applications. The need for robotic technology is growing in a wide variety of human applications and applications, especially in the manufacturing, medical, service, defence and consumer industries. This linear robot is an example of an industrial robot. By studying this one can create a linear robot for use in industry.

This robot will be able to manage many assets in a manufacturing system in a shorter amount of time, with higher precision and cheaper cost per unit. The applications of the line follower are lim-ited because it cannot be controlled. The only way to control the line follower is to change the path. Using WIFI module to control the line follower robot will not be helpful because more power will be consumed, so the battery will drain out quickly. Apart from these limitations smart and intelligent line follower robot can be used for long distance applications with a predefined path. This smart and intelligent robot has more benefits because it doesn't consume much power.

Currently, most line follower robots use simple sensors. Future work could explore more advanced sensing technologies, such as LIDAR or computer vision.

Authorship contribution: All the authors have made nearly equal contributions to the research work presented in the manuscript and have approved the

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final version after detailed review. The authors are accountable for the originality, accuracy, and integrity of the work.

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Similarity Index: The authors hereby state that there is no similarity index in the abstract and conclusion, while overall similarity is less than 10%, with individual source contribution is 2% or less.

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