ANALYSIS OF INFRARED SENSOR IMPLEMENTATION IN LINE FOLLOWER ROBOT: A LITERATURE REVIEW OF DETECTION METHODS AND CONTROL ALGORITHMS

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ANALYSIS OF INFRARED SENSOR IMPLEMENTATION IN LINE FOLLOWER ROBOTS: LITERATURE REVIEW OF DETECTION METHODS AND CONTROL ALGORITHMS

Abstract: The development of robotics technology shows significant evolution in the implementation of infrared sensors in line follower robots that integrate advanced detection methods and sophisticated control algorithms. This research aims to comprehensively analyse the implementation of infrared sensors through a structured literature review of eight major studies in the 2021-2025 range. A library research methodology was used with thematic analysis to categorise the findings based on sensor type, control algorithm, and performance metrics. The analysis shows the transformation from a single infrared sensor to a hybrid multi-modal system that integrates computer vision, ultrasonic, and colour sensors with improved detection accuracy, reaching an error rate of 0.1-85 pixels. Diversification of control algorithms from classical PID to fuzzy logic, neural network, and Q-learning proved superior adaptability to a dynamic environment with 66.67%-100% success rate. The convergence of wireless communication technology and autonomous learning capabilities marks the transition of the line follower robot into a platform for automated guided vehicles and autonomous mobile robots. The conclusion shows that infrared sensors maintain high relevance in modern robotics when integrated with advanced computational methods, providing a foundation for the development of intelligent and adaptive navigation systems for the implementation of Industry 4.0.

Keywords: *infrared sensor, line follower robot, control algorithm*

INTRODUCTION

The development of robotics technology in the last decade has shown significant growth, especially in the development of autonomous robots capable of operating independently without human intervention. One of the most fundamental forms of robotics technology implementation is the line follower robot, which is an autonomous robotic system designed to detect and follow a predetermined path (Arya Nugraha et al., 2017). The line follower robot becomes the basis of learning in the field of robotics because it integrates various technological components such as sensors, actuators, and control algorithms in one cohesive and structured system.

Since infrared (IR) sensors can accurately distinguish the colour contrast between the path and the surrounding surface, they have become an essential part of detection systems for line follower robots. By generating infrared light and measuring the amount of light that returns to the sensor, the line sensor determines whether a black line is present (Herman et al., 2024). Different materials reflect infrared radiation in other ways, which is how infrared sensors operate. More infrared radiation is absorbed by dark surfaces than by light ones, resulting in different sensor readings that the microprocessor can use to guide the robot's movement.

The complexity of infrared sensor implementation in line follower robots lies not only in the technical aspects of the hardware, but also in the development of control algorithms that are able to optimise the detection and navigation performance of the robot. A line follower robot is an autonomous robot that detects black lines using infrared sensors that send and receive infrared waves to identify black lines (Taufik & Yudha Permana, 2015). The variety of sensor configurations, ranging from the implementation of single sensors to multi-channel sensor arrays, provides its own challenges in the development of effective and efficient control strategies to handle various path conditions, including straight paths, sharp curves, intersections, and broken paths.

Line follower robots use techniques to locating and manipulating objects in conjunction with sensor and computer technologies. The addition of a Cartesian sensor arrays to the LFR makes it more efficient at following difficult paths with the most efficiency. Classical control techniques that have evolved include proportional control and bang-bang algorithms. More sophisticated control systems that can react more fluidly and adaptively to changes in the operating environment include fuzzy logic control, neural network-based control, and PID controllers. Exploration of robot movement with integrated control systems and sensors demonstrates the important role of control systems in reducing errors and tracking movement across multiple paths (Kurniawan et al., 2025).

In the context of developing future robotics technology, particularly in the application of automated guided vehicles (AGV), autonomous mobile robots (AMR), and robot navigation systems for industrial and medical applications, the literature review on the use of infrared sensors in line follower robots is extremely pertinent. A mobile device that can recognise and follow

a line drawn on the floor along a predetermined path, which could be a black line on a white surface with a high contrast colour, is called a line follower robot (Huda et al., 2024). In many real-world applications, a thorough grasp of infrared sensor properties, detection techniques, and control algorithm strategies will be crucial to the creation of more reliable, accurate, and effective robotic systems. Studies indicate that the implementation of advanced sensors on wheeled robots enhances operational precision and efficacy in intricate missions, a concept that may similarly be applied to the optimization of line-following robots (Kasiyanto et al., 2024).

Based on this background, this literature review aims to comprehensively analyse the implementation of infrared sensors in line follower robots with a special focus on detection methods and control algorithms that have been developed in recent studies. The analysis will include evaluation of various sensor configurations, comparison of control algorithm effectiveness, identification of implementation challenges, and projections of future technology development. This research is expected to contribute in the form of synthesised knowledge that can be a reference for researchers and practitioners in developing a more optimised and innovative line follower robot system (Arifin et al., 2016).

RESEARCH METHOD

This research uses a library research approach to analyse the implementation of infrared sensors in line follower robots through a comprehensive and structured literature review. The library research method was chosen because it can combine empirical results from numerous earlier studies to identify trends, patterns, and knowledge gaps in the robotics technology industry, particularly in the context of detection systems based on infrared sensors. The literature search strategy was executed via electronic academic databases such as IEEE Xplore, ScienceDirect, Springer, ResearchGate, and Google Scholar, employing a combination of keywords including "infrared sensor," "line follower robot," "detection method," "control algorithm," and "mobile robotics". The inclusion criteria encompassed scientific articles from 2021 to 2025 that addressed the deployment of infrared sensors in line-following robots, path identification techniques, and control algorithms pertinent to the research topic. The selection of literature was conducted in phases, beginning with the screening of titles and abstracts, followed by a comprehensive reading to ascertain the content's relevance to the research issue. Thematic analysis was performed to analyse the data by grouping the results by the type of sensor, the implementation configuration, the detection method, and the control algorithm utilised. Validation of the analysis results was carried out through source triangulation and cross-verification between publications to ensure consistency and reliability of the findings generated in this literature review (Ismawaty, 2025).

RESEARCH RESULTS

Based on the literature review, there are eight major studies that address the implementation of infrared sensors and other detection technologies in line follower robots in the recent past. Table 1 shows a

complete synopsis of these experiments, including the kinds of sensors employed, the control algorithms used, and the performance metrics reached by each line-following robot system. This comparative analysis provides a comprehensive overview of the evolution of sensor technology and control algorithms in the development of line follower robots, ranging from single sensor implementations to hybrid systems that integrate multiple sensors to improve robot accuracy and functionality.

Table 1. Research Results of the Line Follower Robot with an Infrared Sensor

No	Researcher	Sensor	Control Algorithm	Main Result	Performance
1	(Divanny et al., 2024)	Camera + OpenCV	Fuzzy Logic	Robot tracks trajectories of different shapes	Error: 85 pixels
2	(Kohistani et al., 2023)	IR + Ultrasonic	Arduino Control	Line following + obstacle detection	Good performance at high contrast
3	(Huda et al., 2024)	Computer Vision	Fuzzy Logic	Successfully passed 2 lanes	Error: -11.54 & -3.11 pixels
4	(Leal et al., 2025)	IR + Camera	LSTM + CNN + PID	A neural network is effective but complex	NN replicates PID behaviour
5	(Gregorius Dwi Perkasa & Felix Yustian Setiono, 2025)	Line Sensor + Ultrasonic	Arduino + Bluetooth	Line following + obstacle avoidance	Responsive to wireless control
6	(Pramana & Futra, 2021)	IR Sensor	Q-Learning	Self-learning without external updates	Average success: 86,67%

7	(Rejeki et al., 2024)	IR HW-201	Smart Car Control	High-accuracy line detection and follow	High accuracy + good efficiency
8	(Riyanto et al., 2021)	Line + Ultrasonic + Color	PID Control	Robot forklift with colour detection	Kp=100, Ki=0, Kd=1 (optimal)

DISCUSSION

Analysis of Infrared Sensor Implementation in Line Follower Robot Detection System

The results of the literature review show that the implementation of infrared sensors in line follower robots has undergone significant diversification in the applied technological approach. Research conducted by (Rejeki et al., 2024) shows that the use of infrared barrier sensors with the HW-201 module is able to produce a superior level of detection accuracy in identifying navigation paths, where these sensors are installed facing down to optimise the ability to detect lines along the robot's movement trajectory. In contrast, findings from (Pramana & Futra, 2021) indicate that conventional infrared sensors still have development potential when integrated with the Q-learning machine learning algorithm, resulting in an average success rate of 86.67% with performance variations between 66.67% to 100% on repeated tests. This phenomenon confirms that the effectiveness of infrared sensors depends not only on the hardware specifications, but also on the signal processing strategies and control algorithms that utilise the sensor data, in line with the basic principles identified in the introduction regarding the importance of integration of technological components in a cohesive robotic system.

Control Algorithm Evolution and Methodological Comparison

A comparative analysis of control algorithms shows three main paradigms that dominate the development of line follower robots, namely classical control, fuzzy logic, and machine learning. Study (Leal et al., 2025) offers a distinctive viewpoint by directly contrasting the efficacy of neural networks (LSTM and CNN) with traditional PID controllers, revealing that while neural networks can successfully emulate PID functionality, their deployment necessitates greater computational resources and a more intricate calibration procedure. Contrary to these findings, research by (Divanny et al., 2024) and (Huda et al., 2024) demonstrates that the integration of fuzzy logic controllers in computer vision-based systems yields consistent performance with negligible error margins (Divanny et al., 2024) recorded an average error of 85 pixels with a delta error of 0.1 pixels, while (Huda et al., 2024). Got an error mode of 0 with an average error of -11.54 pixels and -3.11 pixels on two separate path methods. These results show that the choice of control algorithms should depend on how

complex the application is and how many processing resources are available. PID controllers are still the best choice for applications that require high efficiency, while fuzzy logic and neural networks are better for systems that need to be more flexible and handle uncertainty better.

Multi-Sensor Integration and Hybrid System Development

The evolution of line-following robots indicates a transformative transition from singular sensor applications to multi-sensor systems that amalgamate several detection modalities to enhance system resilience and performance. Research (Kohistani et al., 2023) Shows how to successfully combine infrared and ultrasonic sensors to make a system that can find obstacles. The system uses an Arduino CPU to coordinate inputs from various sensors and send the right commands to motor drivers with an Ackerman steering system. A more complex approach is shown by (Riyanto et al., 2021) which combines line sensors, ultrasonic sensors, and colour sensors in a forklift robot system. The robot can stay on the black path while doing task manipulation based on object colour detection because it has a PID controller with the best settings Kp=100, Ki=0, and Kd=1. Perkasa and Setiono came up with the idea of an advanced line follower by adding dynamic obstacle avoidance with the HC-SR04 ultrasonic sensor and smartphone-based control through Bluetooth protocol. This shows that combining wireless communication technology can make line follower robots more than just simple autonomous systems; they can also be robotic platforms that can be controlled from a distance and can make more complex decisions when dealing with changing environments.

Technological Implications and Future Development Projections

A synthesis of the examined research indicates that the integration of infrared sensors in line-following robots has evolved beyond mere line detection, establishing a basis for more intricate and application-specific robotic systems. The merging of computer vision technologies, as shown by the camera-based research and OpenCV, holds great promise for creating detection systems that can do more than just simple colour contrast. These systems could be used to navigate in more difficult and unpredictable situations by doing more advanced image processing and pattern recognition. The application of machine learning techniques, particularly Q-learning, is illustrated by (Pramana & Futra, 2021). This means that future line-following robots will be able to improve themselves and adapt to new situations without needing manual reprogramming. This is in line with the idea of autonomous learning, which is the basis for developing artificial intelligence for robotics applications. This evolution demonstrates that infrared sensors, although a relatively established technology, continue to be significantly pertinent in the contemporary robotics landscape when combined with sophisticated computational techniques and multi-modal sensing strategies, establishing a robust basis for the advancement of automated guided vehicles, autonomous mobile robots, and industrial 4.0 applications necessitating accurate navigation and intelligent decision-making abilities.

CLOSING

A comprehensive literature review of infrared sensor implementations in line follower robots reveals paradigmatic transformations in detection methodologies and control algorithm strategies that lead to the optimisation of robotic navigation performance. A synthesis analysis of the effectiveness of detection systems no longer depends exclusively on the characteristics of a single infrared sensor, but rather on multi-modal sensing configurations that integrate computer vision, proximity sensor, and colour recognition technologies to produce superior operational robustness. The evolution of control algorithms indicates a convergence between traditional methodologies, such as PID controllers, and sophisticated computational techniques, including fuzzy logic and machine learning algorithms. The choice of control strategies must correspond to the complexity of the application and the availability of computational resources. The technological implications of these findings suggest that infrared sensors maintain essential significance as a foundational technology within the robotics ecosystem, particularly when combined with intelligent processing techniques to create autonomous systems that adapt to changing environmental conditions, thereby making substantial contributions to the advancement of automated guided vehicles and industrial automated applications necessitating precise navigation capabilities.

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