UKR Journal of Multidisciplinary Studies (UKRJMS)
Homepage: https://ukrpublisher.com/ukrjms/
Email: submit.ukrpublisher@gmail.com
Volume 2, Issue 5, 2026 ISSN: 3049-432X (Online)

Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism

Mark Jaydrian C. Boniol[1], Samantha Xyra O. Aggalut[2], Danilo Jr T. Cariman[3], Kausar D. Sulayman[4], John Kerby C. Tapic[5], Gajil J. Santos[6]

[1,2,3,4,5,6] Western Mindanao State University, Zamboanga City, Philippines

***Corresponding Author**: Mark Jaydrian C. Boniol; Gajil J. Santos
DOI: *https://doi.org/10.5281/zenodo.20357040*

Article History
Original Research Article
Received: 16-03-2026
Accepted: 27-04-2026
Published: 23-05-2026

Citation: Mark Jaydrian C. Boniol, Samantha Xyra O. Aggalut, Danilo Jr T. Cariman, Kausar D. Sulayman, John Kerby C. Tapic, Gajil J. Santos. (2026). Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism. UKR Journal of Multidisciplinary Studies (UKRJMS), 2(5), 157-162.

Abstract

The Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism is an autonomous mobile system designed to perform consistent surface spraying along predefined indoor paths. The robot navigates using infrared sensors to detect line contrast, while color sensors trigger specific actions, including movement and activation of a servo-controlled dual-nozzle spraying mechanism. Passive Infrared (PIR) sensors ensure safe operation by temporarily inhibiting spraying when human motion is detected. Its structure features a motorized base housing the electronics, sensors, and pumps, combined with 3D-printed components for lightweight construction, ease of customization, and rapid prototyping. Coordinated by an Arduino microcontroller, the system integrates navigation, actuation, and safety functions using simple sensor-driven logic. The design emphasizes accessibility, low-cost implementation, and reliable performance, providing a practical platform for automation, prototyping, and educational applications in structured indoor environments.

Keywords: *Arduino, line-following, automated spraying.*

1.0 Introduction

Autonomous robotic systems have gained increasing attention in recent years because they can perform repetitive or predefined tasks with greater consistency and precision than manual human operation. In environments where tasks are structured and repetitive, robotic automation has been shown to reduce variability and improve the repeatability of outcomes (Koreis, 2024).

A line-following robot is a type of autonomous mobile robot that navigates along a predetermined path by following visual or physical guides, such as marked lines on the floor. These robots typically use onboard sensors, usually infrared or reflectance sensors, to detect the contrast between the line and the surrounding surface and adjust their motion accordingly (Telangana et al., 2025). This method allows the robot to traverse a track autonomously without relying on complex mapping systems, global positioning systems, or advanced vision algorithms.

Line-following robots are widely used in educational, research, and prototyping settings because of their accessibility and relative simplicity. Microcontroller platforms such as Arduino enable the creation of functional autonomous robots with minimal hardware and software requirements while still providing reliable navigation performance (Chandrashekar et al., 2025). In addition, the large developer community and extensive documentation for Arduino support rapid prototyping and iterative design.

Incorporating task-specific mechanisms, such as liquid dispensing or spraying actuators, further extends the functional capabilities of mobile robots. Previous studies have shown that combining mobility with actuation mechanisms allows robots to perform operational tasks autonomously, reducing reliance on human intervention and improving process consistency (Weber et al., 2023).

Despite the increasing use of robotics in various applications, many autonomous systems depend on expensive components, complex sensing frameworks, or proprietary platforms, which can limit accessibility for students, researchers, and institutions with limited resources. Open-source, microcontroller-based designs, especially those using the Arduino platform, offer a cost-effective alternative that supports functional automation while maintaining adequate control and flexibility (Tsebesebe et al., 2024).

In this study, the focus is on the design and development of an Arduino-Based autonomous line-following robot equipped with an automated alcohol spraying mechanism and safety sensors. The project emphasizes functional performance, navigation accuracy, actuator coordination, and overall system integration using sensor-based logic that is accessible and practical. Consistent with its engineering focus, the study evaluates navigation performance, actuation control, and cost-effectiveness rather than the chemical or biological efficacy of the dispensing system.

2.0 Methodology

The Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism is an autonomous mobile system designed to navigate along predefined indoor paths while performing automated surface spraying. The system employs line-following navigation, using a color sensor to detect floor strips, where each color cue triggers specific movements and spraying actions. PIR sensors detect human presence to ensure safety, preventing the sprayers from activating when motion is nearby. The Arduino microcontroller processes data from these sensors and controls the motors for movement, the servo-actuated spray mechanism, and the spray pumps connected to dual nozzles on each side.

2.1 Research Design

This study employed an experimental research design focused on the development and performance evaluation of an Arduino-Based Line-Following Robot with an Automated Alcohol Spraying Mechanism. The design involved constructing a functional prototype and subjecting it to controlled testing to assess navigation accuracy, spraying performance, and safety sensor responsiveness. An experimental approach was selected to enable direct observation and measurement of system behavior and subsystem integration. Performance indicators were evaluated through repeated trials under consistent environmental conditions. This design is appropriate for validating embedded systems and autonomous robotic applications.

2.2 Research Instrument

The research instrument used in this study was a researcher-developed robotic prototype and its embedded control system. The Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism, composed of an Arduino Mega 2560 microcontroller, infrared line sensors, TCS34725 color sensor, HC-SR501 passive infrared sensors, motors, servo actuators, and spraying mechanism, served as the primary instrument for data generation and performance evaluation. The embedded software, programmed in C++ using the Arduino Integrated Development Environment (IDE), functioned as the logical instrument that processed sensor inputs and controlled navigation, spraying, and safety operations. No test items, questionnaires, or interview instruments were utilized, as the study did not involve human participants. Instrument validity and reliability were established through repeated functional testing under controlled conditions.

2.3 Data Gathering Procedure

Data were collected through controlled experimental testing of the developed prototype in a simulated indoor environment. The testing setup utilized an illustration board as the floor surface, black electrical tape for line-following paths, and RGB color markers for triggering spraying actions. Multiple test trials were conducted to evaluate navigation accuracy, color detection reliability, spraying activation, safety sensor response, and effective spray range. Observations from each trial were systematically recorded, including operational outcomes and performance accuracy. All tests were conducted under controlled lighting and environmental conditions to ensure consistency of results.

2.4 Data Analysis Procedure

The collected data were analyzed using descriptive quantitative methods. System performance was evaluated by computing success rates and accuracy percentages based on repeated test trials. Results were summarized using tables to present navigation, spraying, and safety performance. Comparative analysis across trials was conducted to assess system reliability and integration effectiveness. Inferential statistical techniques were not applied, as the study focused on prototype performance validation.

2.5 Ethical Considerations

This study did not involve human participants; therefore, informed consent and confidentiality procedures were not applicable. Ethical considerations focused on ensuring operational safety and responsible system testing. Passive Infrared (PIR) sensors were integrated to automatically inhibit spraying when human motion was detected, reducing the risk of unintended exposure. All experiments were conducted in controlled environments following standard safety guidelines for handling isopropyl alcohol. The prototype was used strictly for academic and experimental purposes.

3.0 Results and Discussion

This section presents and discusses the results obtained from the experimental testing of the Arduino-Based Line-

Following Robot with Automated Alcohol Spraying Mechanism. The findings are organized to evaluate the system's navigation accuracy, color-based spraying activation, safety sensor performance, and effective spray range. Quantitative results from repeated test trials are presented using tables and figures, followed immediately by corresponding discussions that interpret observed behaviors and system limitations. The discussion relates the performance outcomes to the design objectives and highlights factors influencing system reliability and efficiency. This integrated presentation ensures that each result is directly examined in the context of the system's functional performance and operational design.

3.1 Functional Performance and System Integration Test Results

Function	Expected Outcome	Test 1	Test 2	Test 3	Test 4	Result/Accuracy
Line Following	Robot moves forward when centered, adjusts left/right when needed, and stops at endpoints	Pass	Pass	Pass	Pass	100%
Color Detection (Spray Trigger)	Robot pauses navigation and activates correct spraying routine based on detected color	Pass	Pass	Pass	Pass	100%
Left-Side Safety Motion Detection	Spraying is enabled only when no human motion is detected on the left side	Pass	Pass	Pass	Pass	100%
Right-Side Safety Motion Detection	Spraying is enabled only when no human motion is detected on the right side	Pass	Pass	Pass	Pass	100%
Dual-Side Safety Motion Detection	Spraying on both sides is enabled only when no motion is detected	Pass	Pass	Pass	Pass	100%
Automated Alcohol Spraying Mechanism	Sprayer releases alcohol smoothly on correct side(s)	Fail	Pass	Pass	Pass	75%
System Integration	Robot transitions correctly between navigation, spraying, and safety states	Pass	Pass	Pass	Pass	100%

Figure 1. *Functional Performance and System Integration Testing of the Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism*

Figure 1 presents the functional performance results of the proposed robotic system. The robot achieved a 100% success rate in line-following navigation, color-based command recognition, and motion-based safety detection. The automated spraying mechanism recorded a 75% success rate due to a single instance of actuator timing delay during testing. Despite this limitation, the system demonstrated reliable coordination among navigation, spraying, and safety modules. The results indicate that the core system functions operate effectively, with minor improvements required to enhance spraying consistency.

3.2 Spray Module Testing (Effective Spray Range)

Test Distance (cm)	Expected Outcome	Result / Accuracy
15	Alcohol reaches intended area	Pass
25	Alcohol reaches intended area	Pass
35	Alcohol reaches intended area	Pass
45	Alcohol reaches intended area	Fail

Figure 2. *Effective Spray Range Testing of the Automated Alcohol Spraying Mechanism*

Figure 2 summarizes the performance of the automated alcohol spraying mechanism at varying distances. The spray successfully reached the intended target area at distances of 15 cm, 25 cm, and 35 cm. However, at 45 cm, the spray failed to reach the target, indicating a limitation in the maximum effective spray range. These results suggest that the spraying mechanism performs reliably within short to moderate distances, while further mechanical or pressure optimization may be required for extended range operation.

3.3 Safety and Navigation Sensor Performance Evaluation

Sensor	Expected Outcome	Result / Accuracy
Color Sensor (TCS34725)	Detects color-coded paths and triggers corresponding system actions	Pass
IR Sensor (3-Way)	Ensures accurate line-following navigation	Pass
PIR Sensor (HC-SR501)	Detects human motion to prevent spraying during presence	Pass

Figure 3. *Effective Spray Range Testing of the Automated Alcohol Spraying Mechanism*

Figure 3 presents the performance evaluation of the sensors integrated into the robotic system. The TCS34725 color sensor accurately identified color-coded paths, enabling appropriate command execution. The three-way infrared sensor provided reliable line detection, ensuring stable navigation along predefined routes. The HC-SR501 passive infrared sensor consistently detected human motion, successfully suspending the spraying operation to ensure user safety. Overall, the sensor modules demonstrated dependable performance, supporting safe and accurate autonomous operation

4.0 Conclusion

The testing results demonstrate that the Arduino-Based Line-Following Robot with Automated Alcohol Spraying Mechanism is capable of performing its core functions with a high degree of accuracy and operational reliability. The robot achieved 100% success in line following, color-based spray activation, and motion detection, indicating that the navigation and safety mechanisms are fully functional and capable of supporting autonomous operation. Sensor integration was validated through successful performance across all trials, confirming the effective coordination of the TCS34725 color sensor, 3-way IR sensor, and HC-SR501 PIR motion sensor in enabling precise detection and responsive control actions.

The spraying mechanism achieved a 75% success rate, with intermittent timing issues observed during activation. While the module demonstrated effective spraying area coverage at distances up to 35 cm, the failure at 45 cm confirms a limitation in its maximum effective range. These findings indicate that the robot performs reliably within short to moderate spraying distances but would benefit from refinement of the dispensing system to improve consistency and extend operational coverage.

Overall, the results validate the feasibility of an autonomous, sensor-based alcohol spraying system using readily available components. The prototype demonstrates strong performance in navigation, detection, and safety functions, with optimization of the spraying mechanism identified as the primary area for further improvement. The outcomes provide a solid foundation for future iterations aimed at increasing spraying reliability, enhancing system integration, and expanding the effective area coverage for broader application environments.

References

1. Abidin, Z., Arifudin, R., Hardyanto, W., Akhlis, I., Umer, R., & Kurniawan, N. (2021). Low-cost educational robotics for promoting STEM education. Journal of Physics Conference Series, 1918(4), 042018. https://doi.org/10.1088/1742-6596/1918/4/042018
2. Aher, S. (2024). Smart Pesticides spraying robot. International Journal for Research in Applied Science and Engineering Technology, 12(9), 139–144. https://doi.org/10.22214/ijraset.2024.64152
3. Balasingham, D., Samarathunga, S., Arachchige, G. G., Bandara, A., Wellalage, S., Pandithage, D., Hansika, M. D. J. T., & de Silva, R. (2024). SPARROW: Smart precision agriculture robot for ridding of weeds. arXiv. https://arxiv.org/abs/2405.20896
4. Barradas, R., Lencastre, J. A., Soares, S. P., & Valente, A. (2024). Arduino-Based Mobile Robotics for Fostering Computational Thinking Development: An Empirical Study with Elementary School Students Using Problem-Based Learning Across Europe. Robotics, 13(11), 159. https://doi.org/10.3390/robotics13110159
5. Brigido, W. J. H., & De Oliveira, J. M. P. (2025). The line follower robot: a meta-analytic approach. PeerJ Computer Science, 11, e2744. https://doi.org/10.7717/peerj-cs.2744
6. Chandrashekar, K., Kumar, M. S., Rajashekarchari, N., & Vyshavi, P. (2025). Line Following Robot Using Arduino. International Journal of Engineering Research and Science & Technology, 21(3(1)), 764–770. https://doi.org/10.62643/
7. Ghafar, A. S. A., Hajjaj, S. S. H., Gsangaya, K. R., Sultan, M. T. H., Mail, M. F., & Hua, L. S. (2021). Design and development of a robot for spraying fertilizers and pesticides for agriculture. Materials Today Proceedings, 81, 242–248. https://doi.org/10.1016/j.matpr.2021.03.174
8. Holland, J., Kingston, L., McCarthy, C., Armstrong, E., O'Dwyer, P., Merz, F., & McConnell, M. (2021). Service robots in the healthcare sector. Robotics, 10(1), 47. https://doi.org/10.3390/robotics10010047
9. Jat, D., Dubey, K., Potdar, R. R., Chakraborty, S. K., Kumar, S. P., Chandel, N. S., Rajwade, Y. A., & A, S. (2023). Development of an automated mobile robotic sprayer to prevent workers' exposure of agro-chemicals inside polyhouse. Journal of Field Robotics, 40(6), 1388–1407. https://doi.org/10.1002/rob.22181
10. Júnior, M. R. B., Santos, R. G. D., De Azevedo Sales, L., Da Silva Martins, J. V., De Almeida Santos, J. G., & De Oliveira, L. P. (2025). Designing and Implementing a Ground-Based Robotic System to support spraying drone operations: a step toward collaborative Robotics. Actuators, 14(8), 365. https://doi.org/10.3390/act14080365
11. Koopaee, M. J., Haouas, W., & Kaddouh, B. (2025). A mobile robotic system design and approach for autonomous targeted disinfection. Robotics, 14(12), 178. https://doi.org/10.3390/robotics14120178
12. Koreis, J. (2024). Human–robot vs. human–manual teams: Understanding the dynamics of experience and performance variability in picker-to-parts order picking. Computers & Industrial Engineering, 200, 110750. https://doi.org/10.1016/j.cie.2024.110750

13. Londhe, K. P., Sawant, S., Khazi, Z., & Mirgane, O. (2025). Agricultural pesticide spraying robot car. International Journal of Creative Research Thoughts (IJCRT), 13(6). https://www.ijcrt.org/papers/IJCRT2506811.pdf

14. Martins, C. V., Xavier, C., & Cobrado, L. (2021). Disinfection methods against SARS-CoV-2: a systematic review. Journal of Hospital Infection, 119, 84–117. https://doi.org/10.1016/j.jhin.2021.07.014

15. Mohan, N. A. (2025). Line-Following robot for automatic delivery in classrooms or libraries. Universal Research Reports, 12(3), 93–103. https://doi.org/10.36676/urr.v12.i3.1588

16. Rayhan, A. (2023). Artificial intelligence in robotics: From automation to autonomous systems. ResearchGate. https://doi.org/10.13140/RG.2.2.15540.42889

17. Rodríguez-Martínez, E. A., Flores-Fuentes, W., Achakir, F., Sergiyenko, O., & Murrieta-Rico, F. N. (2025). Vision-Based Navigation and Perception for Autonomous Robots: sensors, SLAM, control Strategies, and Cross-Domain Applications—A review. Eng—Advances in Engineering, 6(7), 153. https://doi.org/10.3390/eng6070153

18. Ruan, K., Wu, Z., & Xu, Q. (2021). Smart Cleaner: a new autonomous indoor disinfection robot for combating the COVID-19 pandemic. Robotics, 10(3), 87. https://doi.org/10.3390/robotics10030087

19. Sk. Gousiya Begum, Obulesu, A., Aggula, S. K., Bangaru, V., Vinay, L., & Vadde, H. (2025). Autonomous Obstacle Avoiding and Pesticide Spraying Robot for Smart Farming. International Journal of Innovative Science and Research Technology (IJISRT), 10(4), 1054–1057. https://doi.org/10.38124/ijisrt/25apr1207

20. Telangana, S., Srija, K., Reddy, G. J., Gowthami, G., & Sanjana, Y. (2025). Design and implementation of an autonomous line-following robot using Arduino microcontroller. International Journal of Scientific Research in Engineering and Management, 9(11), 1–9. https://doi.org/10.55041/ijsrem54030

21. Tsebesebe, N. T., Mpofu, K., Sivarasu, S., & Mthunzi-Kufa, P. (2025). Arduino-based devices in healthcare and environmental monitoring. Discover Internet of Things, 5(1).

22. https://doi.org/10.1007/s43926-025-00139-z

23. Udoka, E. V. H., Edozie, E., Davis, M., Dickens, T., Janat, W., Wisdom, O., Umaru, K., Nafuna, R., & Yudaya, N. (2023). Mobile Disinfectant Spraying Robot and its Implementation Components for Virus Outbreak: Case Study of COVID-19. International Journal of Artificial Intelligence, 10(2), 69–78. https://doi.org/10.36079/lamintang.ijai-01002.551

24. Weber, A. M., Gambao, E., & Brunete, A. (2023). A survey on Autonomous Offline Path Generation for Robot-Assisted Spraying Applications. Actuators, 12(11), 403. https://doi.org/10.3390/act12110403

25. Wijesundara, W. M. T. D., Wanigathunga, T. D., Waas, M. N. C., Hithanadura, R. T., & Munasinghe, S. R. (2023). Accurate Crop Spraying with RTK and Machine Learning on an Autonomous Field Robot. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2310.16812

26. Yuichi Hasuda, Keigo Ozaki, Masahiro Iida. (2022). The Pesticide Spraying Robot Moving in A Greenhouse with A Line-Trace. International Journal of Engineering Research & Technology (IJERT), 11(01), 1–6. https://doi.org/10.17577/IJERTV11IS010054