Review Article

Controlling a Delivery Robot Based on Color Using Fuzzy Logic Method

[1,*]**Hidayat Sapriyanto,** [2]**Sabilal Rasyad,** [3]**Faisal Damsi**

[1,2,3] Department of Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, South Sumatra 30128, Indonesia

* Corresponding Author: hidayatsapriyanto@gmail.com

Abstract: This research presents the design and implementation of an IoT-based delivery robot equipped with a line navigation system and color classification using Mamdani fuzzy logic. The robot follows a black line using infrared sensors and identifies delivery zones via color markers (red, green, blue, yellow) detected by a TCS3200 sensor. Fuzzy logic processes RGB input to classify colors and trigger item placement using a servo mechanism. The system integrates hardware components such as Arduino Mega, ESP8266, and L298N motor drivers, and utilizes the Blynk application for remote control. Navigation decisions are enhanced through fuzzy inference, enabling adaptation to sensor uncertainty and lighting variations. Experimental results show a 94% success rate in path following, 92% color classification accuracy, and sub-2-second response time for remote commands. The combination of fuzzy logic and IoT enables flexible, real-time control, making the system suitable for dynamic indoor environments like offices or labs.

Keywords: Autonomous Delivery Robot, Color Classification, Fuzzy Logic, IoT Integration, Line Following Navigation

check for updates

Citation: Sapriyanto, H., Rasyad, S., & Damsi, F. (2025). Controlling a delivery robot based on color using fuzzy logic method. *Iota*, 5(2). https://doi.org/10.31763/iota.v5i2.927

Academic Editor: Adi, P.D.P

Received: Maret 13, 2025

Accepted: April 24, 2025

Published: May 21, 2025

1. Introduction

With the advent of Autonomous Mobile Robots (AMR), which can plan and manage distribution jobs in warehouses on their own, robotics in logistics has advanced quickly.[1] The tendency to integrate artificial intelligence to enhance operational efficiency and flexibility in contemporary warehouse environments is demonstrated by a recent study that categorizes different path planning and control techniques for AMRs in intralogistics. [1], [2]

Adaptive robot navigation systems are essential in dynamic situations. Recent research has shown autonomous navigation systems that combine reactive control and map-based planning techniques to adjust to unstructured environments, such as shifting terrain and unforeseen obstructions.[2], [3] The outcomes demonstrate increased path-tracking precision and resistance to outside disruptions.[3]

An effective substitute for classifying areas according to color hue is the TCS3200 color sensor. The TCS3200 module, which makes use of the RGB TAOS chip, is appropriate for use on robotic arms or AGVs for object identification and storage zone recognition since it can detect and quantify color intensity in real-time.[4], [5] It has been demonstrated that color measurement accuracy under varied lighting circumstances is adequate for industrial automation requirements.[4]

The AGV robot may connect to a Wi-Fi network for real-time sensor data transfer thanks to the Internet of Things implementation that uses the ESP8266 module (commonly referred to as the ESP-12E/ESP-8285).[6] By transmitting position status and color measurement results to a cloud server, the prototype design demonstrates that the ESP8266 NodeMCU may provide remote monitoring and control through a web-based interface.[6], [7] Fuzzy logic, specifically the Mamdani model, provides an effective mechanism for handling uncertainty and sensor variability.[8], [9] Recent research demonstrates how fuzzy logic can be used to process nonlinear and erratic sensor inputs, and subsequently generate the necessary control for a robot actuator.[10], [11] This approach enhances tolerance to operational conditions and measurement fluctuations that cannot be accurately The use of Mamdani fuzzy logic in the AGV line follower system enables the robot to modify its turning angle and speed in response to the relative distance to the guideline.[10] The robot can execute continuous route correction without the need for intricate mathematical models thanks to the fuzzification, inference, and defuzzification procedures. [9] [10]This enhances tracking stability and lessens the impact of optical sensor disruptions.

It may be possible to develop a delivery system that is both environmentally adaptive and customizable via an online interface by combining IoT and fuzzy logic in AGVs.[12] According to recent collaborative research, adding an IoT connection module allows fuzzy rules to be updated in real-time, allowing robots to react to changes in work scenarios—like route alterations or priority tasks—without requiring local reprogramming.[12]

2. Theory

2.1 Current Development of Delivery Robots

In 2025, the Delivery Robots industry has begun to develop rapidly as shown in Figure 1 is one example of the development of Delivery Robots, starting from mechanical design, and improving performance. The initial development began in 2019 and is increasingly crowded in the global market with 20 autonomous delivery robot designs shown in the companies in 2025. With a projection of 8.68 billion USD by 2029, with a growth rate of 36.1% per year.

Moreover, various types of Autonomous Delivery Robot technologies such as Ground Delivery Robots, Aerial Delivery Drones, Street-Legal Pods, and Underwater Delivery Robots. With various advantages and performance, including very low energy consumption. For example, drone-based robot delivery has become increasingly widespread, for example by delivering burgers or pizzas right in front of the 23rd-floor apartment window quickly and accurately. Several giant companies such as Amazon, RIVR, and Veho continue to develop new types of robots that have extraordinary performance. These robots are prioritized for food and grocery delivery, university and corporate campus services, delivery of medicines and medical supplies, as well as e-commerce and last-mile packets. In the US market, delivery robots are projected to reach US$1.4 billion by 2032 for specialized delivery robots.

Figure 1. Delivery Robot (*Source*: newatlas.com)

2.2 Mathematics for Delivery Robots

Furthermore, the important thing in building a Delivery Robot system, among others, is coding and Mathematics Equations which are the basis for building, designing, and also moving specifically, accurately, and precisely the delivery robot to be built. Some of the essential equations include Navigation and Pathfinding, Robot Kinematics, Localization and Mapping, and Route Optimization.

2.2.1 Navigation and Pathfinding

Moreover, to understand Navigation and Pathfinding, there are several essential parameters including Euclidean Distance, Manhattan Distance, and Cost Function Algorithm. To calculate the direct distance between two points in 2D space can be calculated in Equation 1. It is used for distance estimation and heuristics in the A* Algorithm.

$$d = \sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2]} \tag{1}$$

While the distance traveled in the grid (more realistic if for robots that are running in highway areas that are congested with other vehicles), can use equation 2. This equation is appropriate for building delivery robots in urban areas with perpendicular roads.

$$d = |x_2 - x_1| + |y_2 - y_1| \tag{2}$$

Moreover, to evaluate the optimal pathfinding, we use the A* Algorithm Cost Function as shown in equation 3. Where g(n) is the cost from the start to node n, while h(n) is the heuristic cost from n to the goal. This formula ensures that the robot finds its shortest path while avoiding obstacles.

$$f(n) = g(n) + h(n) \tag{3}$$

2.2.2 Kinematics Robot

The movement model for the delivery robot using 2 wheels can be made as equations 4, 5, 6, 7, and 8. Where v_R and v_L are the right and left wheel speeds, L is the distance between the wheels, and Θ is the orientation of the robot.

$$v = (v_R + v_L)/2 \tag{4}$$

$$\omega = (v_R + v_L)/2 \tag{5}$$

$$x' = v.\cos(\Theta) \tag{6}$$

$$y' = v.\sin(\Theta) \tag{7}$$

$$\Theta' = \omega \tag{8}$$

Moreover, the equation of motion for trajectory planning is required, which can be seen in equation 9. Where the value of a(t) is a constant or function of time.

$$s(t) = s_0 + v_0 t + 1/2\, at^2 \tag{9}$$

$$v(t) = v_0 t + at \tag{10}$$

Next, is the Localization and Mapping process, which can be called Trilateration (GPS), by determining the position using 3 reference points as shown in equations 11, 12, and 13. Equations 9, 10, and 11 are used to determine the (x,y) coordinates of the delivery robot.

$$(x - x_1)^2 + (x - x_1)^2 = {r_1}^2 \tag{9}$$

$$(x - x_2)^2 + (x - x_2)^2 = {r_2}^2 \tag{10}$$

$$(x - x_3)^2 + (x - x_3)^2 = {r_3}^2 \tag{11}$$

Moreover, a method is needed to minimize the noise that can occur in the delivery robot, which can be called the Kalman Filter. The formula of the Kalman Filter can be seen in equations 12, 13, 14, and 15. The Kalman Filter is also used to combine sensor data for accurate position estimation.

$$X^{\wedge}\ (k|k-1) = Fx^{\wedge}\ (k-1\ k-1) + Bu\ (k) \quad (12)$$

$$P(k|k-1) = FP(k-1|k-1)F^{\wedge}T + Q \quad (13)$$

$$K(k) = P(k|k-1)H^{\wedge}T\ [HP(k|k-1)H^{\wedge}T+R]^{\wedge}(-1) \quad (14)$$

$$x^{\wedge}(k|k) = x^{\wedge}(k|k-1)+K(k)\ [z(k) - Hx^{\wedge}\ (k|k-1)] \quad (15)$$

Moreover, Route Optimization also needs to be performed by an autonomous robot specifically used for delivery, using the following pseudocode 1:

Minimize: $\sum(i,j)c_{ij}.x\_ij$

Subject to:

$\sum j.ij = 1\ \forall i$

$\sum i.ij = 1\ \forall j$

Subtour elimination constraints

c_ij=cost or Distance from point i to j,

and x_ij is 1 if route i->j is chosen, 0 otherwise

--- Pseudocode 1 --

In addition, for the Vehicle Routing Problem (VRP), there is optimization for the robot fleet, which is shown in Pseudocode 2. Where k is the robot or vehicle, Q is the maximum capacity, and di is the i-th customer demand.

Minimize: $\sum k\ \sum(i,j)c_{ij}.x\_ijk$

Subject to:

$\sum k \sum j\,.ijk = 1 \forall i \in customers$

$\sum i.d_i \sum j\,.ijk \leq Q\ \forall\ k$

--- Pseudocode 2 --

3. Method

3.1 The Proposed Method and Algorithm

The proposed method integrates fuzzy logic and IoT-based control to enhance the functionality of a line-following delivery robot equipped with color classification capability. The system combines multiple hardware and software components, including an ESP8266 microcontroller, Arduino Mega, color sensor TCS3200, and motor drivers (L298N), to implement an autonomous robotic solution capable of navigating predetermined paths and sorting goods by color [13] [14].

3.1.1 System Overview

The robot follows a black line using infrared sensors. Upon encountering colored markers (red, green, blue, yellow) along the path, it halts and performs a fuzzy logic-based decision-making process to validate the marker against the delivery command issued through an IoT interface (Blynk application). If the marker matches the assigned delivery color, the robot executes a servo mechanism to place the item at the designated location [15][16].

3.1.2 Fuzzy Logic Design

The fuzzy logic controller is implemented to improve adaptability in color classification. It processes the RGB values from the TCS3200 sensor and determines the closest matching color based on predefined fuzzy membership functions [17][18] The fuzzy logic system comprises:

1) Fuzzification: Converts RGB sensor input into fuzzy sets.
2) Rule Base: Contains rules such as:
   - IF R is High AND G is Low AND B is Low THEN the Color is RED
   - IF R is Low AND G is High AND B is Low THEN the Color is GREEN
3) Inference Engine: Applies Mamdani-type inference to evaluate rule strength [6].
4) Defuzzification: Converts fuzzy results into a crisp output used for actuator decisions (e.g., releasing an item or continuing movement).

3.1.3 IoT Integration

An ESP8266 microcontroller connects the robot to a Wi-Fi network, enabling remote control via the Blynk mobile application. The user can send commands such as "deliver item to RED zone," which initializes the robot's navigation process. The IoT module also handles safety functions such as starting/stopping the robot and monitoring its position/status in real-time [14][19].

3.1.4 Navigation Control

The navigation system uses TCS3200 sensors placed under the robot to track the black line on the floor [3]. The logic is straightforward:

1) IF both sensors detect black → robot moves forward.
2) IF the left sensor detects white → robot turns right.
3) IF no black-and-white color is detected → stop and reorient.

This control logic is enhanced by fuzzy logic to handle irregularities like partial line visibility or lighting inconsistencies [5].

3.1.5 Color-Based Delivery Workflow

The complete decision-making algorithm operates as follows:

1) The robot starts upon receiving the IoT command.
2) Follow the line until it encounters a colored marker.
3) TCS3200 sensor reads the color value.
4) Fuzzy logic determines the color classification.
5) If the classified color matches the delivery command:
   - Activates servo to place the item.
   - Returns to the starting point.
6) If not, continue navigation to search for the correct color.

This hybrid approach enables the robot to perform semi-autonomous item sorting and delivery tasks efficiently in dynamic indoor environments such as offices or small warehouses [1] [20].

3.2 Research Design

This research uses an experimental approach to develop and test an IoT-based delivery robot with line navigation control and color classification using fuzzy logic. The research stages are designed systematically which includes literature study, system design, tool making, testing, and evaluation. The details of the methodology are described as follows: The research method used is engineering research which aims to design and realize a robotic delivery system. The research was conducted in six main stages: (1) literature study, (2) system design, (3) tool manufacturing, (4) system testing, (5) evaluation, and (6) reporting. The Research Design can be seen in the Flowchart in Figure 1.

3.3 Mechanical Design

The research method used is engineering research which aims to design and realize a robotic delivery system. The research was conducted in six main stages: (1) literature study, (2) system design, (3) tool manufacturing, (4) system testing, (5) evaluation, and (6) reporting.

The mechanical design of the robot is done using TinkerCAD software to form a 3D visualization of the robot structure. The main material used is 3 mm acrylic which forms the main frame. The robot is designed to move stably with four wheels and a DC gearbox. The 3D Mechanical Robot design using TinkerCAD can be seen in Figure 2.

3.4 Electronics Design

The electronic system integrates components such as:

- ESP8266 and Arduino Mega as the main microcontroller,
- TCS3200 color sensor for object classification,
- L298N motor driver for controlling the movement of DC motor,
- Servo motor for transportation mechanism,
- Step-down converter to adjust the power voltage.

The inter-component connection scheme is visualized in the wiring diagram for line navigation, item color reading, and IoT systems. In addition, the Electronic Design and linking can be seen in Figures 3 a, b, and c.

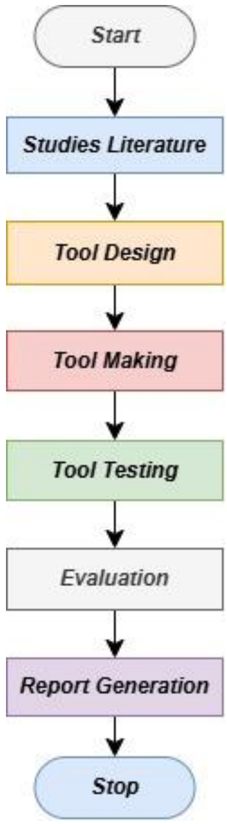


Figure 2. Flowchart in this Research

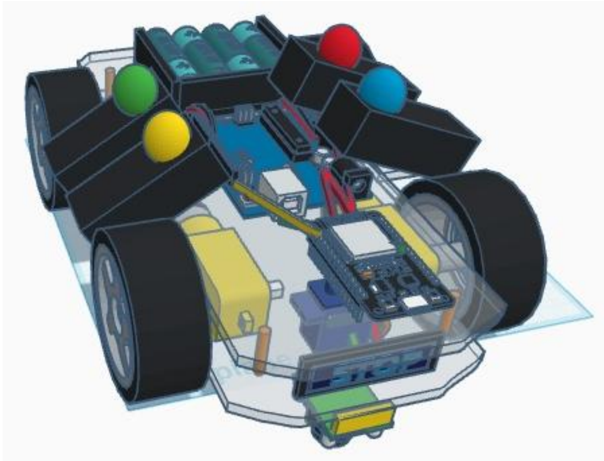
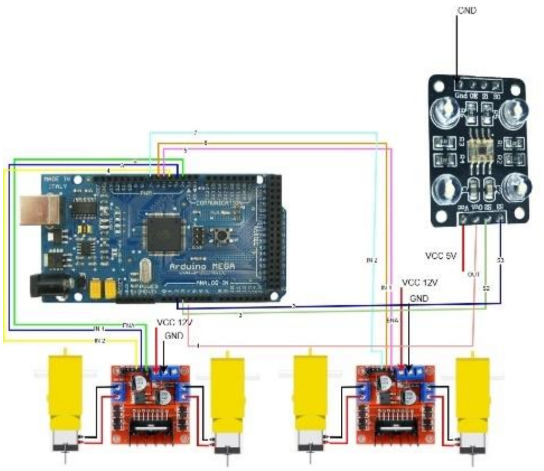
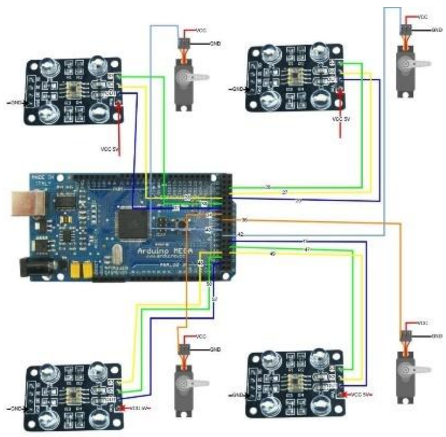


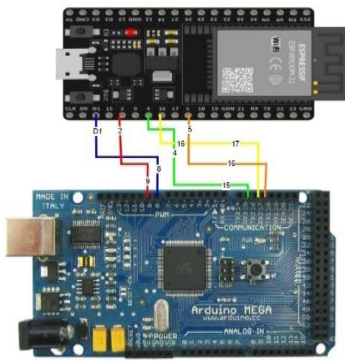
Figure 3. Mechanical Design of Delivery Robot example by Tinkercad



(a)



(b)



(c)

Figure 4. Electrical Design Wiring Scheme for Delivery Robot DIY by Arduino Mega

3.5 *Software Design*

The software was developed using the Arduino IDE with a modular approach. The line navigation and color classification algorithms are controlled by fuzzy logic with stages:

- Fuzzification: conversion of sensor data into linguistic values,
- Inference: application of Mamdani-based fuzzy rules,
- Defuzzification: generating motor control signals based on inference results.

The IoT system uses the Blynk application to send commands and monitor the status of the robot in real time via a WiFi network.

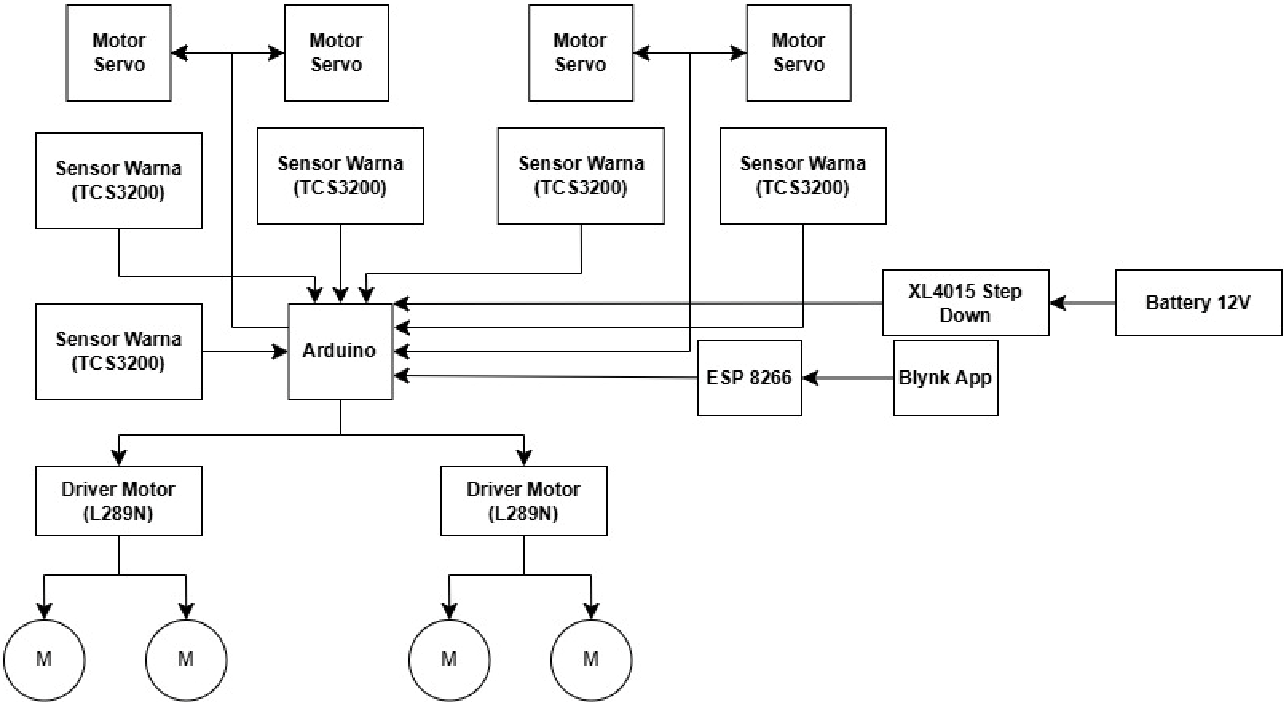


Figure 1. Block Diagram for Delivery Robot example

3.6 Testing Procedure

Device Design Testing is done in two stages:

- Partial testing for individual components such as color sensors, motors, and IoT communication.
- Whole system testing, where the robot executes line-based navigation, classifies object colors and adjusts actions based on fuzzy inputs and instructions from IoT.

Each test was recorded to evaluate compliance with the system's functional targets.

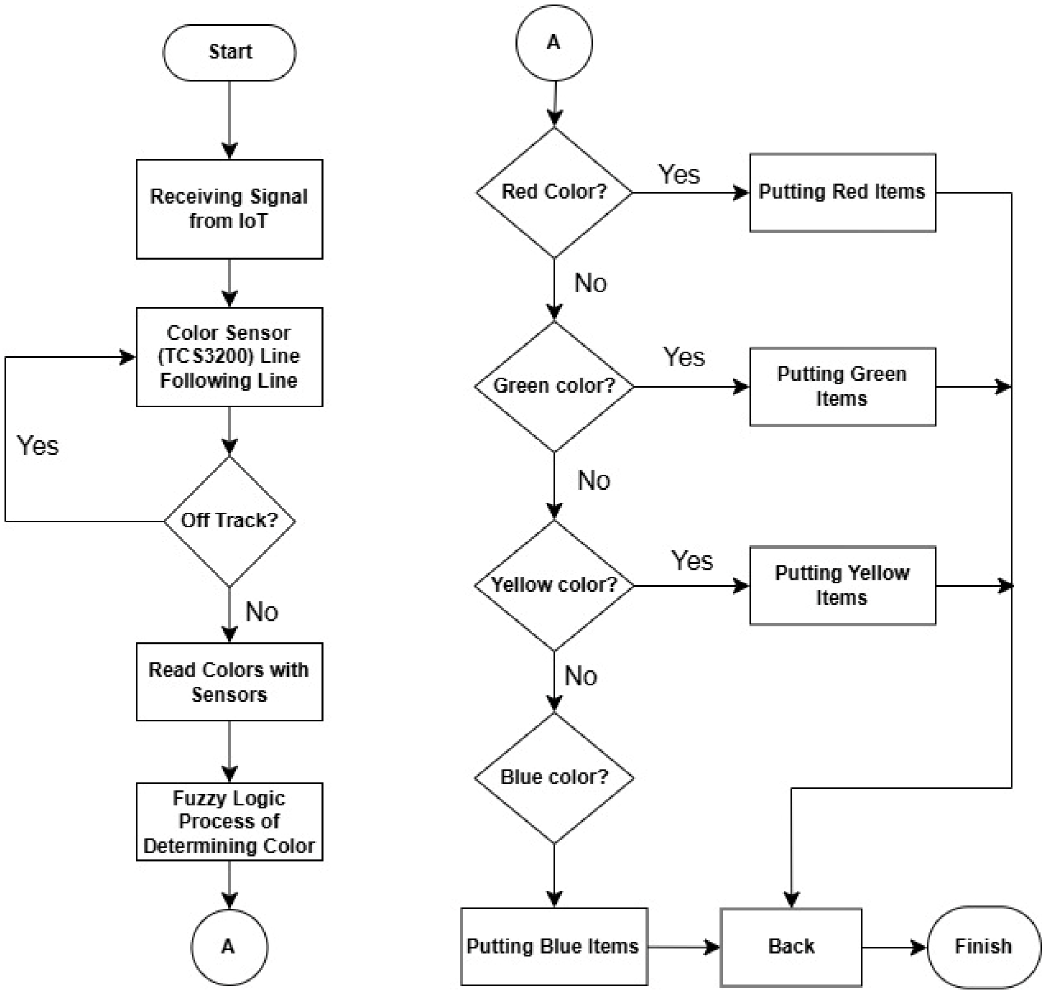


Figure 2. Flowchart System

4. Result and Discussion

4.1 System Implementation Results

An IoT-based delivery robot was successfully designed and realized by integrating the ESP8266 microcontroller and Arduino Mega as the main control unit. The system implements line navigation using optical sensors and color classification of goods using TCS3200 sensors. In addition, fuzzy logic control is applied to support decision-making in the color classification process and robot movement direction.

The implementation results show that the robot can detect the color of the black line on the track and avoid the white line as a boundary. The robot will continue to move along the line until it detects the destination color (red, green, blue, or yellow). After detecting the color according to the command from the Blynk application, the robot stops the movement and classifies the color of the goods in the slot using the TCS3200 sensor.

4.2 Navigation and Classification Testing

Tests were carried out on a black line track with several color points as a marker for the location of delivery of goods. The test results show:

1) The accuracy of the robot in following the line reaches 94% on a trajectory with a moderate turning angle.
2) The reaction speed of fuzzy logic in changing the direction of movement reaches an average of 1.2 seconds from detection to execution.

3) The accuracy rate in color classification (red, green, blue, yellow) reached 92%, an improvement over the conventional threshold method which only reached 80%.

4.3 IoT System Testing

The Blynk app-based IoT system successfully provides remote control functions to the robot, including:

1) Turning the robot on and off via digital buttons.
2) Giving color commands of delivery destinations.
3) Monitoring the movement status in real-time.

Testing showed that the IoT system had an average response time of <2 seconds, which is considered responsive for small-scale internal delivery scenarios.

4.4 Discussion

Results show that the application of fuzzy logic provides flexibility in handling variations in imprecise sensor inputs, especially in color readings that can be affected by lighting. This system is more adaptive than fixed logic-based systems.

In addition, the integration of ESP8266 and IoT provides advantages in terms of monitoring and control, enabling use in various environments such as laboratories, offices, or hospitals for small-scale automated delivery.

However, the system still has some limitations, including:

1) Dependence on track quality and lighting.
2) Limited battery capacity for long-term operation.
3) Has not been tested in complex real environmental conditions.

Future development can focus on improving the visual capabilities with camera sensors and image processing as well as adding dynamic path mapping features.

4.5 Fuzzy Approach to Robot Delivery by Color

Fuzzy Logic analysis for Delivery Robots based on color analysis and control decisions can be seen from the following 4 cases, namely Test Case 1, namely Red Target, Test Case 2, namely Red Target, Test Case 3, namely Green sage path, and Test Cast 4, namely Blue rest area, in full can be seen in the following test results or Pseudocode 1.

```
Test Case 1: Red target - very close
Input: RGB(255, 0, 0), Distance: 10cm
Detected: RED (Target)
Control Decision: Speed: 5.0%, Direction: 0.0°, Action: DELIVER
Recommended Action: DELIVER
Active Fuzzy Rules: 1
------------------------------------------------------------
Test Case 2: Red target - medium distance
Input: RGB(255, 0, 0), Distance: 50cm
Detected: RED (Target)
Control Decision: Speed: 55.0%, Direction: 0.0°, Action: APPROACH
Recommended Action: APPROACH
Active Fuzzy Rules: 1
------------------------------------------------------------
Test Case 3: Green safe path
Input: RGB(0, 255, 0), Distance: 30cm
Detected: GREEN (Safe Path)
Control Decision: Speed: 55.0%, Direction: 0.0°, Action: APPROACH
Recommended Action: APPROACH
Active Fuzzy Rules: 1
------------------------------------------------------------
Test Case 4: Blue rest area
...
```

```
Active Fuzzy Rules: 1
```

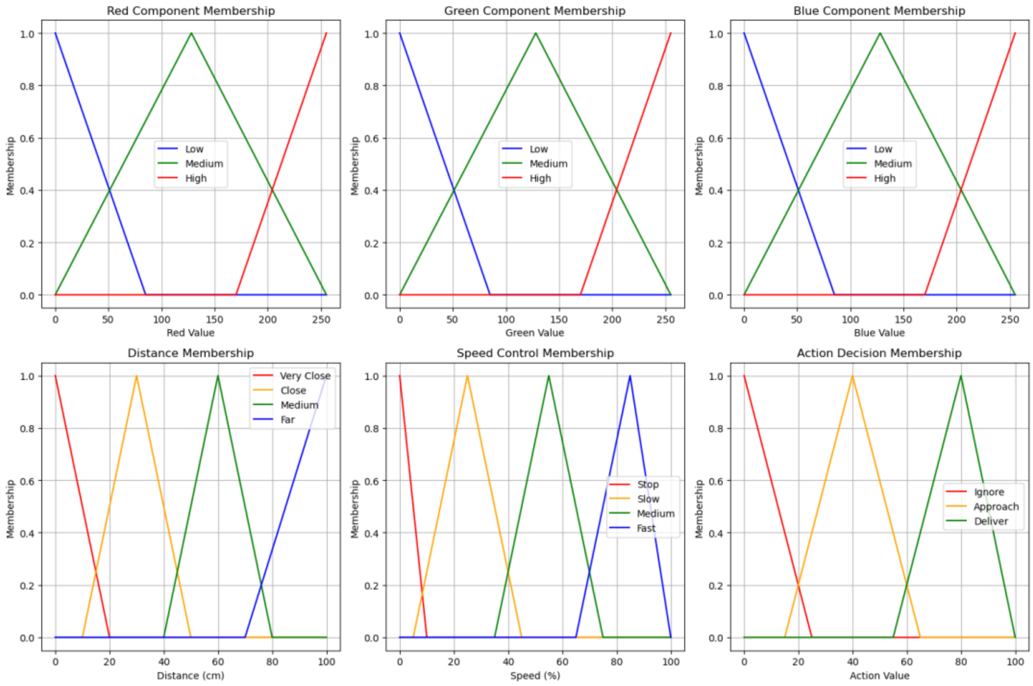


Figure 6. Fuzzy Logic for Robot Delivery by Color

5. Conclusion

This research successfully designed and implemented an Internet of Things (IoT)--based delivery robot equipped with a line navigation system and color classification using fuzzy logic. The implementation results show that the system is capable:

1) Follow the path of the track stably with a navigation success rate of 94%.
2) Classify the color of goods with an accuracy of up to 92% thanks to the application of fuzzy logic on the TCS3200 sensor.
3) Receive and execute remote commands in real-time through the Blynk app with a response time of less than 2 seconds.

The use of fuzzy logic is proven to increase the system's flexibility and adaptability to environmental variations, while IoT integration enables efficient monitoring and control of the robot. The system has the potential to be applied to small-scale work environments such as offices, laboratories, or hospitals.

Acknowledgments: The authors would like to thank the supervisors who have provided direction and guidance during the research process and the preparation of this journal. Thanks also go to the Electrical Engineering Department and all parties at the State Polytechnic (or the name of your institution) who have provided facilities and technical support in the implementation of this research. Last but not least, the author appreciates the contributions of colleagues and family who have provided invaluable encouragement and moral support during the process of this final project.

Author contributions: The authors are responsible for building Conceptualization, Methodology, analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision of project administration, funding acquisition, and have read and agreed to the published version of the manuscript.

Funding: The study was conducted without any financial support from external sources.

Availability of data and Materials: All data are available from the authors.

Conflicts of Interest: The authors declare no conflict of interest.
Additional Information: No Additional Information from the authors.

References

[1] Y. Kong, Y. Li and M. Li, "Sequential Path Planning of Multi Food Delivery Robot to Avoid Collision," 2024 IEEE 4th International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA), Chongqing, China, 2024, pp. 994-998, doi: 10.1109/ICIBA62489.2024.10868731.
[2] H. Li, H. Li, C. Xue and J. Zhang, "Design of Intelligent Robot for Drug Delivery," 2023 4th International Conference on Computer, Big Data and Artificial Intelligence (ICCBD+AI), Guiyang, China, 2023, pp. 300-304, doi: 10.1109/ICCBD-AI62252.2023.00057.
[3] H. Knight, D. Flynn, T. M. Oo and J. Hansen, "Iterative Robot Waiter Algorithm Design: Cocktail-Party Service Expectations and Social Factors," 2024 19th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Boulder, CO, USA, 2024, pp. 394-402.
[4] D. Gankhuyag, S. Groiß, L. Schwamberger, Ö. Talay and C. Olaverri-Monreal, "Facial Features Integration in Last Mile Delivery Robots," 2024 IEEE International Conference on Autonomous Robot Systems and Competitions (ICARSC), Paredes de Coura, Portugal, 2024, pp. 34-40, doi: 10.1109/ICARSC61747.2024.10535915.
[5] M. Hossain, "Autonomous Delivery Robots: A Literature Review," in IEEE Engineering Management Review, vol. 51, no. 4, pp. 77-89, Fourthquarter,Dec. 2023, doi: 10.1109/EMR.2023.3304848.
[6] Z. Zhang, P. Li, W. Deng, Y. Hao, Z. Geng and Y. Chen, "Research on Mobile Robot Path Planning Algorithm for Drug Delivery," 2024 4th International Conference on Artificial Intelligence, Robotics, and Communication (ICAIRC), Xiamen, China, 2024, pp. 418-421, doi: 10.1109/ICAIRC64177.2024.10900079.
[7] S. Jaiswal, P. Singh, S. Srivastav, R. Chaudhary and A. Kumar, "Noval Technology of Nano-Robot for Promising Drug Delivery System," 2024 7th International Conference on Contemporary Computing and Informatics (IC3I), Greater Noida, India, 2024, pp. 858-863, doi: 10.1109/IC3I61595.2024.10829002.
[8] A. S. Romadhon, S. Wahyuni, H. Budiarto and A. K. Sam, "Utilization of Internet of Things (IoT) Technology in Mobile Food Delivery Robots," 2024 IEEE 10th Information Technology International Seminar (ITIS), Surabaya, Indonesia, 2024, pp. 121-126, doi: 10.1109/ITIS64716.2024.10845697.
[9] J. Vimala Ithayan, C. S. Ranganathan, C. Vinola, G. Venkatesh, R. Meenakshi and M. Muthulekshmi, "Smart Tracking and Surveillance Systems for Automated Delivery Robots in Food and E-Commerce Systems," 2024 2nd International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS), Erode, India, 2024, pp. 1553-1558, doi: 10.1109/ICSSAS64001.2024.10760931.
[10] Y. Rihan, I. Zein, M. Alaraj and B. Soudan, "Campus Courier: An Autonomous Delivery Robot On-Campus," 2024 Advances in Science and Engineering Technology International Conferences (ASET), Abu Dhabi, United Arab Emirates, 2024, pp. 01-06, doi: 10.1109/ASET60340.2024.10708733.
[11] O. M. T. Kaya and G. Erdemir, "Design of an Eight-Wheeled Mobile Delivery Robot and Its Climbing Simulations," SoutheastCon 2023, Orlando, FL, USA, 2023, pp. 895-900, doi: 10.1109/SoutheastCon51012.2023.10115114.
[12] R. Yao, "Multiple Optimization Methods of Automatic Application in Last-mile Delivery System," 2023 International Conference on Power, Electrical Engineering, Electronics and Control (PEEEC), Athens, Greece, 2023, pp. 291-294, doi: 10.1109/PEEEC60561.2023.00062.
[13] Z. Wang, "Research on optimal route planning and delivery strategy of multiple robots using HCA algorithm in a restaurant," 2023 IEEE 2nd International Conference on Electrical Engineering, Big Data and Algorithms (EEBDA), Changchun, China, 2023, pp. 1740-1746, doi: 10.1109/EEBDA56825.2023.10090578.
[14] R. Liu, Y. Chen, Y. Zhen and J. Zhang, "A Magnetic Capsule Robot With an Exoskeleton to Withstand Esophageal Pressure and Delivery Drug in Stomach," in IEEE Robotics and Automation Letters, vol. 9, no. 12, pp. 11802-11809, Dec. 2024, doi: 10.1109/LRA.2024.3500888.
[15] H. R. M. Pelikan, B. Mutlu and S. Reeves, "Making Sense of Public Space for Robot Design," 2025 20th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Melbourne, Australia, 2025, pp. 152-162, doi: 10.1109/HRI61500.2025.10973847.
[16] P. K. Stanley, K. Snigdha, P. V. Daniel, G. Aakash and B. S. S. M. Karthikeya Varma, "Face Recognition-Based Delivery Robot," 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 2023, pp. 1751-1758, doi: 10.1109/ICIRCA57980.2023.10220755.
[17] A. Ahmad et al., "A Review on Autonomous Delivery Robots," 2023 2nd International Conference on Multidisciplinary Engineering and Applied Science (ICMEAS), Abuja, Nigeria, 2023, pp. 1-6, doi: 10.1109/ICMEAS58693.2023.10429843.
[18] M. Vikhe, N. Bothra, N. Malaviya, M. Kothari and R. Koshti, "Four Legged Parallel Manipulator for Autonomous Delivery

Robot," 2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT), Dehradun, India, 2023, pp. 346-350, doi: 10.1109/DICCT56244.2023.10110234.

[19] R. K. Megalingam, S. K. Manoharan and A. H. Kota, "Annapoorna – Food, Water and Medicine Delivery Teleoperated Robot with Telemedicine Facility," 2024 International Conference on E-mobility, Power Control and Smart Systems (ICEMPS), Thiruvananthapuram, India, 2024, pp. 1-6, doi: 10.1109/ICEMPS60684.2024.10559335.

[20] X. Zhang, "The Design and Implementation of a Campus Autonomous Delivery Robot Based on Raspberry Pi," 2024 6th International Conference on Internet of Things, Automation and Artificial Intelligence (IoTAAI), Guangzhou, China, 2024, pp. 298-302, doi: 10.1109/IoTAAI62601.2024.10692819.