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Application Of Fuzzy Logic in Mobile Robots With Arduino and IoT

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***Abstract*—Mobile robot technology has advanced rapidly and can be used in a variety of industries due to its capacity to accomplish certain duties quickly and productively. Deep sea exploration, outer space adventure, military, surveillance, disaster environment, scouting, petroleum operations, advanced robotics, and manufacturing all have a high demand for mobile robots. The purpose of this project is to build a mobile robot that can automatically move from one location to another. AIOR:21 and LFR:21 are two types of multifunction robots that have been developed. To function properly, this robot must be equipped with smart technology, and modifications are required on a regular basis. In the suggested robot system, fuzzy logic control is employed to assess and process the operator's voice commands more accurately and effectively. The proposed robot is equipped with an Arduino Uno microcontroller, L298N motor driver, SG90 DC motor, HC-05 Bluetooth module, ultrasonic sensor, and 4-channel infrared remote relays. Furthermore, line tracking robot technology is used as a guide for automated moving robots. Wireless communication and robot monitoring can be accomplished with IoT via cellphones. With this function, the operator can remotely watch the robot's behavior, and all sensor data can be stored in the internet cloud storage. Several experiments have been conducted to assess the capacity of the robots to identify lines and avoid colliding with objects. The limits of this project are also discussed in the concluding section for the researchers to consider for future improvement.**

Keywords—Fuzzy logic control, Mobile Robot, Line Following Robot, Obstacle Avoidance, Voice Recognition.

I. INTRODUCTION

When it comes to designing and building robots, robotics is a subfield of engineering. There are many ways in which robots may assist humans, and this is the goal of robotics research [1-4]. Robots come in a wide variety of shapes and sizes [5-7]. This might be in the shape of a robot application [8-10], like RPA (Robotic Process Automation), or it could be in the form of a robot that looks like a person.

One of the most rapidly expanding scientific fields is that of mobile robotics. A wide range of industries can benefit from mobile robots' abilities. You can use it to monitor everything from scouting and exploration to oil production and robots in the construction of individual facilities to transportation. This type of robot is called a "line follower" because it is designed to follow a specific path or path. Semi-autonomous to fully autonomous production is common for this type of robot. They are used as material movers in the manufacturing industry, but their capabilities could be applied in a variety of other areas of our day-to-day lives. If the other lines are occupied by obstacles, this robot must be able to traverse line crossovers and determine the best way to follow a crossover when the other lines are free. IR sensors, which are more precise than LDRs but less expensive than cameras, can be used to improve the accuracy of line tracking robots. Cameras can also be used to capture quick images of the line.

The primary goal of this research is to develop two multifunction robots (AIOR:21 and LFR:21) that can be adapted for various functions, such as being equipped with voice recognition and being able to carry goods to a location automatically and effectively while avoiding any obstacles that may be encountered. The robot also includes an IoT capability that allows it to be monitored via smartphone. Robots will be operated wirelessly as IoT technology is used, giving them greater flexibility. The communication will take place via a smartphone equipped with features such as voice recognition and buttons to control the robot's movement. Voice recognition can increase robot accuracy and responsiveness to certain tasks [11]. Fuzzy logic control is being used in this study to produce more accurate results when regular IR sensors and 4-channel infrared sensors are being used. It will control the robot's movement using the Line Following Robot (LFR) technique. A Line-Following Robot (LFR) is a mobile robot that uses a line as a route reference [12]. This indicates that if a robot is placed on the path of desire, it will function autonomously and without human supervision.

II. LITERATURE REVIEW

Commonly found in non-industrial settings are the service robots [13]. The use of robots in front-line service businesses is increasing. The study of service robots is gaining traction, and several definitions have been proposed. For example, "system-based autonomous and flexible interfaces that interact, communicate, and give service to an organization's consumers" are how Wirtz et al. [14] define them. A service robot can engage with humans in addition to its service-delivery capabilities [15-17]. Computer vision, speech recognition, sensors, and artificial intelligence have all improved at a rapid pace in tandem with the development of service robots. When it comes to the kind of jobs that need to be performed in dynamic environments, robots are getting smarter and more mobile thanks to developments in sensor and navigation technology, as well as machine learning and artificial intelligence. [18]. Multiple benefits, such as greater productivity and consistency in service quality while also reducing human costs, are possible with service robots. Robots allow organizations to collect and analyze data on the go, as well as adapt to changing customer needs, in real time. Self-driving cars and other autonomous vehicles are just a few instances of how technology is changing the way people interact with the world. When widespread adoption of smart robots occurs in five to ten years, they are projected to approach a plateau. Some of the costs associated with using service robots can be addressed by automation and labor substitution [19].

When wireless orders are transmitted to a mobile robot, the use of automatic speech recognition (ASR) has risen in popularity. There are several distractions in the car, like road noise, air conditioning, music, and passengers, that make it difficult for an ASR-based navigation system to understand spoken directions. Using a single-arm manipulator, P. Patel et al. demonstrated a mobile robot that can detect and respond to spoken directions with ease and precision. In their project, they used the MFCC (mel-frequency cepstral coefficient) speech recognition technique and applied it in MATLAB. The MFCC algorithm, which must process and respond to speech data in real-time, has undergone extensive training and testing. As a result of training and evaluating voice instructions from the five participants, the speech recognition system achieved 89 percent accuracy [11].

Mobile robot navigation has remained a challenge for the last two decades. In recent years, the use of mobile robots in material handling has increased considerably. They must operate in unfamiliar and difficult environments. It is inefficient for warehouse employees to manually handle orders while pushing carts around [20]. According to M. Faisal et al., a wireless control methodology can be used in a warehouse with static and dynamic obstacles to operate swarms of mobile robots. It was also used to operate a variety of mobile robots in the warehouse using fuzzy logic control [20]. A wheeled mobile robot (WMR) was studied in an unpredictable dynamic environment using fuzzy logic methodologies by M. Faisal and colleagues. It is a part of their project to use the robot in a warehouse. To reach as close to the warehouse as feasible, the experiment was run on one available mobile robot (ScoutII). A researcher was used as a moving obstacle. Extending the system to a group of mobile robots is straightforward, according to the findings of the studies. As a result of these discoveries, the fuzzy logic technique was used to build smooth paths in both structured and unstructured domains.

III. METHODOLOGY

Fig. 1 shows a line-following robot block diagram using an Arduino Uno as the microcontroller. The Arduino will be turned on by the power supply, and then the motor driver will be triggered. The procedure will be carried out, and the robot will move. Another sensor, an ultrasonic sensor, will identify whether there is anything in front of the robot.

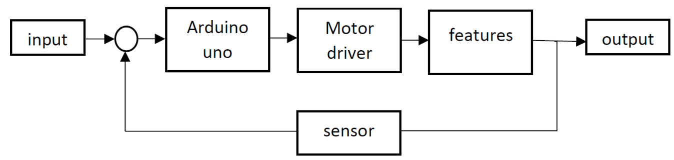


Fig 1. Robot block diagram.

The AIOR:21 is shown in isometric and side views in Fig. 2. Because it is simple to identify items taller than the robot's size, the ultrasonic sensor is placed higher than the other components. The Arduino Uno is positioned in the center to facilitate wire connections. Furthermore, the motor driver is located at the back of the unit, making it simple to connect to the DC motor.

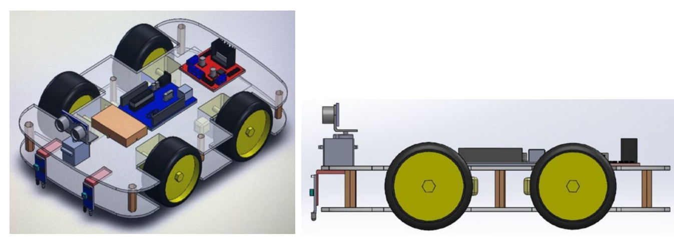


Fig. 2. AIOR:21 in isometric and side views.

LFR:21 is shown in isometric and side views in Fig. 3. The difference in the usage of trolley type tires at the back compared to AIOR:21, which utilizes rubber tires on all four tires, is shown in this diagram. The diagram also shows the motor driver is in front of the robot so that the wire connection to the DC motor can be connected easily.

A flow chart for the obstacle avoidance feature is shown in Fig. 4a. When the left and right sensors generate high readings, it signifies there is resistance on the left and right, hence the AIOR:21 robot will go forward, as shown in Fig. 4a. If the left and right front sensors yield high values, the robot will travel rearward since there is resistance in front of it. If the right front sensor finds an obstruction and returns a high reading, the robot will turn left. If the left front sensor returns a high value, the robot will turn to the right.

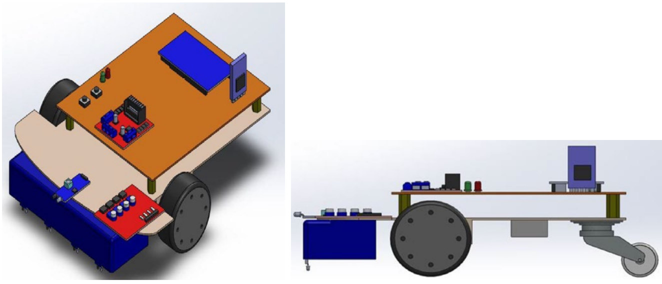
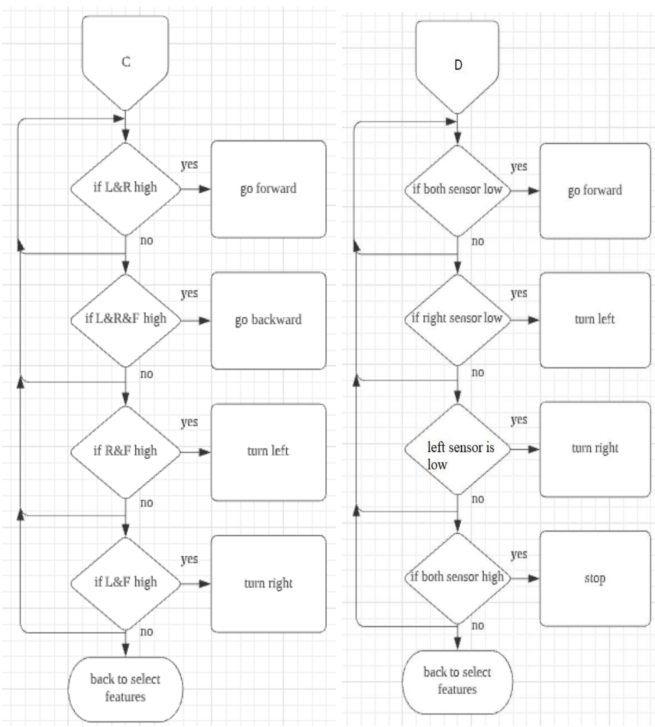


Fig. 3. LFR:21 in isometric and side views.

A flow chart for a line tracking system is shown in Fig. 4b. The AIOR:21 robot will drive forward if both IR sensors yield low readings. If the robot receives a low reading from the right IR sensor, it will turn left, and vice versa if the robot receives a low reading from the left IR sensor, it will turn right. The AIOR:21 robot will halt if both the left and right IR sensors generate high signals.



a. Obstacle avoidance b. Line tracking

Fig. 4. Flowcharts for obstacle avoidance and line tracking system for AIOR:21 robot.

Fig. 5 depicts the flow chart for the AIOR:21 robot's voice recognition system. Each instruction from the operator may be processed and received precisely by the robot in this system by employing a fuzzy logic control approach. Fig. 5 indicates that the robot will follow the operator's orders, for example, if the operator says, "go forward", the robot will move forward. If the operator says, "go down", the robot will take a step backwards. When the operator says, "turn left," the robot goes left, and when the operator says, "turn right", the robot goes right. If the operator issues the command "stop", the robot will come to a halt.

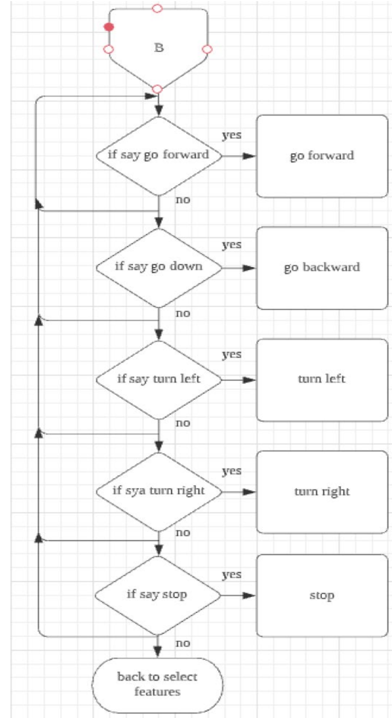


Fig. 5. Flowchart for voice recognition system for AIOR:21 robot.

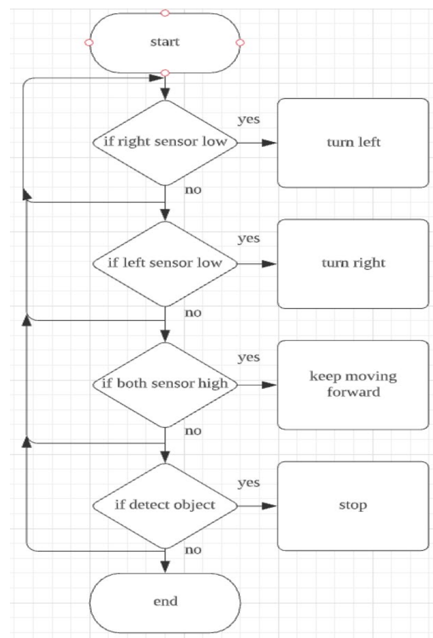


Fig. 6. Flowcharts for line tracking system for LFR:21 robot.

Obstacle and barrier avoidance is a critical component in the creation of a mobile robot capable of autonomous target detection. For a sensor to be useful on a large scale, it needs to be tiny, low-cost, easy to make, and functional. Additionally, it must be able to detect things with adequate bounds so that robots may react and travel accordingly. Only ultrasonic sensors are capable of meeting all of these requirements. An ultrasonic sensor, the HC-SR04, is employed in this study to measure distances between 2 cm and 400 cm at an angle of 15 degrees. Waves are sent into the air, and the reflected waves from objects are picked up by this sensor. In addition to the ground pin (GND), the VCC (5-volt) reference voltage, the DO digital output, and the analogue output, there are four other pins on the board (AO).

A flow chart for a line tracking system for an LFR:21 robot is shown in Fig. 6. If the right sensor returns a low value, the LFR:21 robot will turn left; if the left sensor returns a low reading, the robot will turn right. When both sensors give a high reading, the robot moves forward; if the sensor detects an object in front of the robot, the robot stops until the object is relocated, at which point the robot resumes its forward motion.

IV. RESULT AND DISCUSSION

As shown in Fig. 7, the average time taken by the two autonomous mobile robots to complete a task is depicted. This figure demonstrates that both mobile robots can reach the given location. The distance reached by the two robots determines the amount of time it takes to complete the mission. To arrive at a spot, the amount of time it takes for the two robots to travel is directly proportional to their distance travelled.

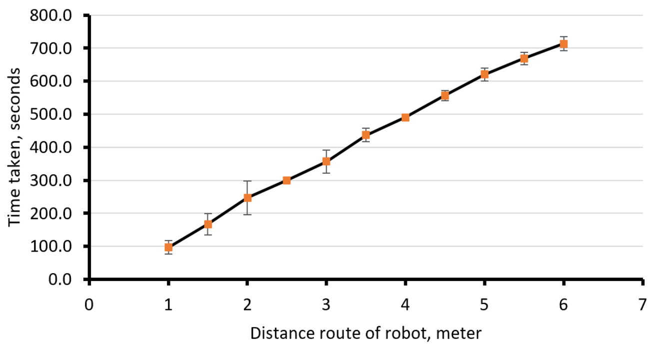


Fig. 7. The average time taken by two automated mobile robots to reach a destination.

Table 1. Result testing for AIOR:21 and LFR:21

FEATURES	AIOR:21	LFR:21
Line Following	Three experiments were conducted, with two distinct outcomes: the IR sensor delayed after detecting the black line, causing the robot to move away from the line. Second, when the robot's speed is reduced so that it can follow the line even after the delay, AIOR:21 becomes stuck at the corner since there isn't enough power to drive the motor owing to the reduced speed.	Three experiments were also conducted for LFR:21 and yielded diverse results, all of which were successful in following the line till the finish.
Obstacle Avoidance	The first and second experiments were carried out with a 4X3. 4v battery. The two studies were unsuccessful because the robot moved too quickly and hit every box. The robot used a 2X4v battery for the third and fourth experiments, and the results were successful. Even after adjusting the pace to the fastest, the robot still manages to avoid all the boxes.	An obstacle sensor, the IR sensor, is detecting sunlight even when there is no obstruction in front of the robot. Information about the robot's distance from the barrier is sent through smartphone app to the robot's operator. The robot will continue to move after the barrier is eliminated.
Voice Recognition	Three tests have been carried out, and all have been deemed successful. The experiment was carried out in the open. As a result, there are still some errors when the command is misheard by fuzzy logic control system.	The robot doesn't has this features.
Manual Control	All experiments were successful, but there were notable differences between the 4x3.7v battery and the 2x3.7v battery. When the robot uses four 3,7v batteries rather than two, manual control is more comfortable. However, there is a greater benefit to using two 3.7v batteries in this robot.	The robot doesn't has this features.
Speed Control	The speed can be controlled by the user and set by the controller.	The speed can be controlled by the user and set by the controller.
Loading Career	Depending on the situation and demand, the prototype can switch between line following and transport career. As a result, AIOR:21 can be used in a variety of ways and applications that are appropriate for the robot.	This prototype can only follow a straight line and can be used to transfer from point A to point B.

Table 1 summarizes some of the tests that have been carried out on AIOR:21 and LFR:21. These studies were repeated multiple times to guarantee that the results were accurate and precise.

V. CONCLUSION AND RECOMMENDATION

Overall, the project's goal of developing automated mobile robots AIOR:21 and LFR:21 using Arduino and IoT has been achieved. The fuzzy logic control for voice recognition has been effectively applied in the system for the AIOR:21 robot, and the operator can operate the robot by just giving voice command on the smartphone. Finally, the two proposed robots can be remotely controlled and monitored by IoT operators utilizing smartphone devices.

These stated limits correspond to experience gained when doing prototype experiments as well as compatibility difficulties. The first drawback is that when a researcher conducts field studies, the IR sensor cannot be directly exposed to sunlight, and it takes a long time to send data to the Arduino. Furthermore, Arduino microcontrollers have a history of trouble connecting to the internet. Although developers have shields and libraries, the procedure is not simple. An Arduino may not be ideal for a project that requires someone to develop sophisticated software or a whole arrangement of software or protocols.

Fuzzy logic control and dead reckoning are among the future suggestions for wheeled mobility robots (WMR). Because it was moving, Wheel Mobile Robots WMR used dead reckoning to determine their current location and direction. A WMR's rapid dynamic motion can't be reliably tracked using this method. The precision, on the other hand, is adequate for a WMR's low dynamics motion. As a result, the low dynamic motion of the WMR is used to approximate the real configuration of the mobile robot in the experimental part of the dead-reckoning method. The mobile robot is guided by two fuzzy logic controllers from its original configuration to its destination. TFLC and OAFLC are used to guide the mobile robot to its destination along a collision-free path, ensuring its safety. The algorithm for this work begins with TFLC. The OAFLC control algorithm is activated if the robot's sensors detect any obstacles in its route. TFLC and OAFLC produce the left and right wheel velocities as their outputs. Use TFLC to make sure the WMR reaches its destination in a timely manner.

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