

Design And Construction Of Line Follower Robot Prototype Based On Arduino Mega

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Abstract

The development of automation in the restaurant industry has led to the innovation of a waiter robot based on Arduino Mega 2560. This robot is designed to simplify food delivery to customers by integrating technology with service efficiency. It is equipped with a TFT LCD screen as an interface that allows users to provide direct instructions, and ultrasonic sensors that detect obstacles to prevent collisions during operation. The navigation system applies a line follower model, enabling the robot to move automatically along predefined paths. The research focuses on the design and implementation of the prototype, highlighting its functionality in ensuring safe and accurate food delivery. The results indicate that the system performs effectively in real-time restaurant service conditions. This innovation demonstrates the potential of robotic applications in enhancing service quality, reducing human workload, and contributing to the advancement of automated service solutions.

Keywords : Arduino Mega, Waiter Robot, Line Follower

1. INTRODUCTION

Service is an activity or a sequence of activities that occurs through direct interaction between a person and another person or a machine, and it provides customer satisfaction. It can also be defined as an effort to fulfill the needs of others, while serving refers to the act of assisting, preparing, or managing what someone requires. Along with the development of society, the demands for services have undergone significant changes. Increasing life needs, higher mobility, and busier lifestyles encourage people to use their time more efficiently to remain productive. This condition drives the emergence of various service providers, including restaurants as facilities that fulfill basic needs in the form of food. In restaurants, service is commonly carried out by human waiters. However, their performance is often influenced by physical and psychological limitations such as fatigue, illness, and repetitive tasks. These limitations may lead to errors, including delays in delivering orders, incorrect table service, and a decline in customer interaction quality. If such issues continue, they can reduce customer satisfaction and damage the restaurant's reputation.

To

overcome these problems, innovations in service delivery are required to optimize human resources, minimize work errors, and maintain consistent service quality. One promising innovation is the application of robotics in

service automation. Initially, robots were developed for heavy, dangerous, repetitive, or dirty tasks, but technological advancements have expanded their roles into service sectors. Examples include nurse robots for patient care, rescue robots in disaster operations, housekeeping robots for daily household tasks, and window-cleaning robots for tall buildings. These cases highlight the opportunities for robots to support fast, accurate, and efficient restaurant services.

Several studies have examined the potential of service robots. Research developed a line follower-based waiter robot that could autonomously deliver food by following a programmed path. Meanwhile, another study emphasized that waiter robots can improve time efficiency, reduce human workload, and minimize delivery errors. Based on these findings, the integration of robotics into restaurant services presents a promising solution to enhance customer satisfaction, accelerate service processes, and reduce long-term operational costs. Therefore, this study aims to design and build a waiter robot based on the line follower method with the ability to deliver food to customer tables along predefined routes. The robot will be equipped with trays, sensors, and an integrated control system. This innovation is expected not only to improve efficiency in restaurant services but also to address human limitations and inspire further applications of robotics in the service sector.

2. METHOD

The research method consists of several stages including design, construction, and testing of the line follower waiter robot based on Arduino Mega 2560. The design stage begins with determining the specifications of the main components such as the microcontroller, sensors, actuators, power supply, and user interface. After that, the wiring design is arranged to determine the connectivity between units.

The implementation stage involves assembling the hardware which includes the Arduino Mega 2560, DC motors, L298N motor driver, LCD display, TCRT5000 line sensor, and HC-SR04 ultrasonic sensor. The power supply uses a 3.7V Li-ion/Li-Po battery with a voltage converter to ensure each component receives the required voltage.

The testing stage is carried out to evaluate the functionality of each component, including navigation using line sensors, obstacle detection using ultrasonic sensors, as well as message display on the LCD interface. Here is a picture of the network:

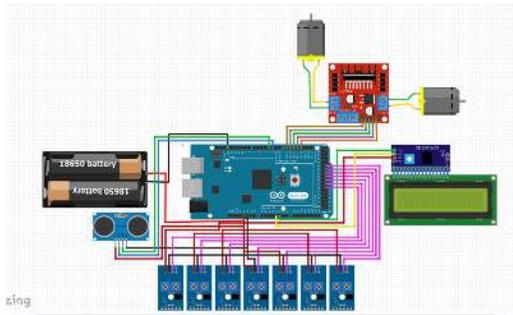


Figure 1 Circuit Schematic

The design was carried out by determining the specifications of the main components, namely:

1. Arduino Mega 2560 – as the control center that regulates all processes, from motor control and sensor readings to the LCD display.
2. 5V DC Motor – functions as the robot's wheel drive.
3. L298N Motor Driver – controls the direction and speed of the DC motor based on signals from the Arduino.
4. 12x6 LCD – used as an interface to display status or information.
5. TCRT5000 Sensor – detects lines on the path for the navigation system.
6. HC-SR04 Ultrasonic Sensor – detects the presence of objects so the robot can avoid collisions.
7. 3.7V Li-ion/Li-Po Battery – serves as the main power source that supplies electrical energy to the entire circuit.

2. Block Diagram

The following is a block diagram of the line follower:

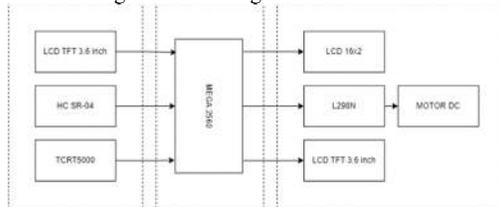


Figure 2 System Design Block Diagram

This research methodology explains the design, construction, and testing stages of an Arduino Mega 2560-based line follower waiter robot. The stages are described as follows:

1. Input

The TFT LCD serves as the primary interface between the user (waiter/customer) and the robot. This screen allows the user to provide instructions or select a delivery destination.

2. Process

The Arduino Mega 2560 acts as the primary controller of the entire robot system. It coordinates components ranging from sensors and motors to the TFT LCD.

3. Output

- 1) The 16x2 LCD displays a message such as "TAKE MENU & PLEASE ENJOY"
- 2) The TFT LCD displays the destination tale for food delivery.
- 3) The L298N module controls the power and direction of the DC motor.
- 4) The DC motor drives the robot to move along the line follower path.

Line Follower Waiter Robot Flowchart

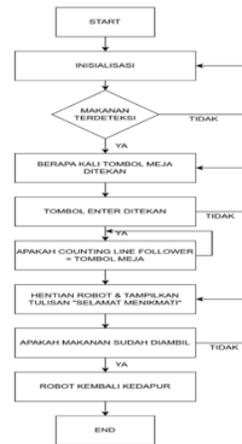


Figure 3 Line Follower System Flowchart

This research methodology explains the operating system of an Arduino Mega 2560-based waiter robot. The system's operation is shown in Figure 3 (Flowchart) and consists of the following steps:

1. Start: The system is turned on, and battery voltage is applied to the circuit. The current flowing to each component follows Ohm's law ($I=V/R$).
2. Robot Walk: The Arduino activates the DC motor through the L298N driver. The motor moves according to the received electrical power.
3. TCRT5000 Sensor Activated: The sensor reads the black line below the robot to maintain its direction of movement.
4. Line Following: The Arduino processes the TCRT5000 sensor data and adjusts the motor's direction to keep the robot on track.
5. Obstacle Detection: The robot uses the sensor to check for obstacles ahead. If there are any, the robot stops or finds a turning path.
6. Intersection Encounter: At the intersection, the robot turns according to the instructions displayed on the TFT LCD.
7. Destination Encounter: The motor stops, and current supply to the actuator is stopped.
8. 16x2 LCD Message: The 16x2 LCD displays the text "Take Menu" and "Please Enjoy"
9. Return to Kitchen: If the "HOME" button on the TFT LCD is touched, the Arduino commands the robot to return to its starting position.
10. Finish: The robot completes the delivery task.
11. (Here, a flowchart can be drawn: Start → Robot walks → Line sensor → Follow line → Check for obstacles → Turn/follow LCD → Reach destination → LCD displays a message → If HOME → Return → Finished).

4. Desain 3D

The robot waiter design can be seen in the image below. Robot Front View



Figure 4: Front Design of the Waiter Robot

Side View of the Robot



Figure 5 Side Design of Robot Waiter

Bottom View of the Robot

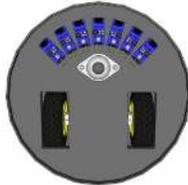


Figure 6 Bottom Design of Waiter Robot

3. RESULTS AND DISCUSSION

1. Research Data

To calculate the total current required by these components, we need to know the current draw of each component. Here are some commonly used current estimates based on the general specifications of each component:

- 1) 3.5-inch TFT LCD Average current: 250-350 mA when displaying a full-color image.
- 2) Ultrasonic sensor (e.g., HC-SR04) Average current: 15-20 mA when active.
- 3) 16x2 LCD (using backlight) Average current: 20-30 mA (without backlight) to 80-100 mA (with backlight).
- 4) 7 TCRT sensors (TCRT5000 optical distance sensor or similar) Average current per sensor: 10-20 mA. Total for 7 sensors: 70-140 mA.
- 5) L298N Motor Driver Own current: 30-40 mA (for logic and standby). Motor current depends on the load, motor type, and voltage. For small DC motors, it's typically between 300-500 mA per motor.
- 6) DC Motor with 5V Gearbox No-load: 100-300 mA. With load: 500-1000 mA depending on the mechanical load.

Step 1: Calculate the total battery energy.

Battery energy is calculated as capacity in watt-hours (Wh): $Wh = V \times Ah$ $Wh = 12 V \times 6 Ah = 72 Wh$

Step 2: Calculate the load power. The load power is calculated as: $W = V \times A$ $W = 5 V \times 1.54 A = 7.7 W$

Step 3: Calculate the efficiency with a converter. Power consumption = $(7.7 W)/0.85 = 9.06 W$

Step 4: Calculate the usage time. Time = $(72 Wh)/(9.06 W) = 7.95$ hours

Without a converter: Time = $(72 Wh)/(7.7 W) = 9.35$ hours

Battery series-parallel formula Batteries used are 3.7 V 2000 mAh (3 in series and 3 in parallel). Series configuration The total voltage increases, while the capacity remains the same.

Formula:

$V_{total} = n_{series} \times V_{cell}$ Total capacity (series) = capacity of each cell

For 3 batteries in series:

$V_{total} = 3 \times 3.7 V = 11.1 V$

Total capacity (series) = 2000 mAh = 2 Ah

2. Parallel Configuration

Total capacity increases, while voltage remains the same

Formula:

Total capacity (parallel) = $n_{parallel} \times$ capacity of each cell $V_{total} (parallel) = V_{each\ cell}$

For 3 batteries in parallel:

Total capacity (parallel) = $3 \times 2000\ mAh = 6000\ mAh = 6\ Ah$

$V_{total} (parallel) = 3.7 V$

3. Series-Parallel Combination (3S3P)

Voltage is calculated from the series configuration.

Capacity is calculated from the parallel configuration.

Final formula:

$V_{total} = n_{series} \times V_{cell}$

Total capacity = $n_{parallel} \times$ capacity of each cell

For a 3S3P configuration:

$V_{total} = 3 \times 3.7 V = 11.1 V$

Total capacity = $3 \times 2000\ mAh = 6000\ mAh = 6\ Ah$

2. Test Data

Table 1. TCRT5000 Sensor Calibration Data

actual distance(cm)	readable distance (cm)
2	2.1
5	5.0
10	9.9
15	14.7

Tabel 2 Data Kalibrasi HCSR-04

Sensor	Black (V)	White(V)
Sensor 1	5.06	0.39
Sensor 2	5.02	0.42
Sensor 3	5.10	0.38
Sensor 4	5.08	0.40
Sensor 5	5.04	0.41
Sensor 6	5.03	0.39
Sensor 7	5.07	0.37

Data Analysis

Calculating Device Operation Time Operating Time (Battery Capacity (mAh))/(Load Current (mA))

Conversion

Battery capacity = 6000mAh = 6Ah

Load current = 2.6A

Operating Time 6Ah/2.6A = 2.31 hours

4. Power Measurement

Power Formula

$P = V \times I$

$V = 12V$ (load voltage)

$I = 2.6\text{A}$ (load current)

$P = 12\text{V} \times 2.6\text{A} = 31.2\text{ W}$

So, the power of the load is 31.2 watts (W).

CONCLUSION AND SUGGESTIONS

The development of the line follower-based waiter robot demonstrates that automation can significantly improve restaurant service efficiency. The robot is capable of delivering food and beverages independently to customer tables, which accelerates service, reduces staff workload, and minimizes customer waiting time. The integration of ultrasonic sensors ensures that the robot can detect obstacles and avoid collisions, enhancing operational safety in crowded restaurant environments. The LCD TFT interface provides an intuitive means for users to monitor the robot's status, specify delivery destinations, and interact with the system effectively. Despite these advantages, several limitations remain. The robot's obstacle detection is limited to ultrasonic sensing, which may not identify all types of obstacles in complex environments. Battery capacity also restricts the operational time before recharging is required. Furthermore, the current user interface, while functional, could be enhanced to support more interactive features for both staff and customers.

For further research, several improvements can be considered. First, additional sensing technologies such as infrared sensors or LIDAR can be implemented to improve obstacle detection accuracy and operational safety. Second, higher-capacity batteries should be explored to extend the robot's operating time, allowing it to function throughout long restaurant service periods without frequent recharging. Third, the user interface can be further developed to include interactive menus, table selection options, or digital maps of restaurant layouts to enhance convenience and interactivity.

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