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DESIGN AND DEVELOPMENT OF IOT BASED ROBOT FOR COMMERCIAL APPLICATIONS

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Abstract: The rapid advancement of technology, particularly in the fields of robotics and the Internet of Things (IoT), has significantly transformed various industries, including the hospitality sector. Automation in restaurants has become a focal point of innovation, leading to increased efficiency, reduced operational costs, and enhanced customer satisfaction. Traditional restaurant service relies heavily on human waitstaff, which introduces several challenges such as high labor costs, order inaccuracies, long wait times, and inconsistent service quality. With growing concerns regarding hygiene and social distancing, particularly in the post- pandemic era, automated food delivery systems have gained considerable attention as a viable alternative.

The development of an IoT-based waiter robot aims to streamline restaurant operations by automating the food delivery process. This paper presents the design and implementation of an autonomous food-serving robot that integrates IoT for remote monitoring and control. The system uses an Arduino Nano microcontroller, RF communication, ultrasonic sensors, voltage sensors, an LCD display, a motor driver, and wheels to enable smooth and efficient navigation within a restaurant environment. The robot follows a line- following mechanism for path navigation while employing ultrasonic sensors for obstacle detection and avoidance. The integration of IoT technology allows restaurant staff to remotely control and monitor the robot's movement, status, and battery levels through a web or mobile application.

Keywords*: IoT-Based Robot, Waiter Robot, Line-Following Robot, Obstacle Avoidance, RF Communication, Arduino Nano, Ultrasonic Sensor Navigation, Mobile App Control.*

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I. Introduction:

The rapid advancements in robotics and IoT have led to significant innovations in the hospitality industry. The automation of food delivery in restaurants enhances efficiency, reduces labor costs, and improves customer satisfaction. Over the years, the concept of service robots has evolved, integrating intelligent navigation, real-time communication, and IoT-driven management systems to optimize restaurant operations [1]. The restaurant industry faces numerous challenges, such as rising labor costs, human errors, inconsistent service quality, and the need for contactless services, especially in the post-pandemic era. A waiter robot integrated with IoT technology offers a viable solution to these challenges, enabling seamless communication between the robot and restaurant management systems [2]. The growing demand for automation in food service has driven research into autonomous robots equipped with AI, machine learning, and IoT frameworks for efficient task execution [3]. One of the primary motivations for developing an IoT-based waiter robot is its ability to operate autonomously, reducing dependency on human staff and improving service efficiency. Several studies have demonstrated the effectiveness of line-following robots in structured environments such as restaurants, where predefined paths can be established for autonomous movement [4]. The integration of ultrasonic sensors, infrared technology, and real-time data communication enhances the robot's ability to detect obstacles and navigate efficiently, ensuring smooth delivery of food to customers[5].

Furthermore, IoT-enabled robots can provide real-time updates on orders, allowing restaurant staff to monitor deliveries and manage workflows efficiently. This capability significantly reduces waiting times and improves customer experience. The ability to remotely control and track the robot via a mobile or web-based application further enhances operational efficiency [6]. Existing research highlights various approaches to designing restaurant service robots, including Bluetooth-based communication [7], RF module integration [8], and AI-driven decision-making systems [9]. While some studies focus on hardware development and navigation algorithms, others emphasize the importance of user interaction and interface design in improving customer satisfaction [10].

The implementation of IoT in waiter robots enables seamless integration with restaurant management systems, offering automated order processing and delivery tracking [11]. Research has also explored the potential of multi- functional service robots capable of assisting in various tasks such as table cleaning, customer interaction, and data collection for business insights [12]. However, challenges remain in terms of scalability, adaptability to different restaurant layouts, and energy efficiency. Future research aims to refine navigation algorithms, improve battery performance, and integrate AI for enhanced decision-making capabilities [13].

IoT-based waiter robots represent a transformative shift in restaurant automation, addressing critical industry challenges while offering an innovative dining experience. This paper explores the design, implementation, and performance evaluation of an IoT-driven waiter robot, emphasizing its role in improving restaurant operations and customer service [14].

II.RELATED WORKFLOW

The development of an IoT-based waiter robot involves several interconnected workflows to ensure smooth operations and effective functionality. The key components of the system, including the Arduino Nano, RF transmitter, RF receiver, ultrasonic sensor, motor driver, wheels, buzzer, and LCD I2C display, play essential roles in the workflow.

A. Microcontroller Integration

The Arduino Nano acts as the central processing unit, handling sensor data, controlling motor movements, and communicating with other components [3]. It processes input from the ultrasonic sensor and determines the best path for navigation while ensuring real-time updates via RF communication [6].

B. Obstacle Detection and Avoidance

The ultrasonic sensor continuously scans for obstacles in the robot's path. If an obstacle is detected, the Arduino Nano processes the data and instructs the motor driver to adjust the movement to avoid a collision. This workflow ensures seamless navigation within a restaurant setting [4].

C. Wireless Communication and Data Exchange

The RF transmitter and receiver modules facilitate wireless communication between the robot and the central restaurant management system. Orders are transmitted from the kitchen to the robot, and real-time status updates are sent back to the restaurant staff, ensuring an efficient workflow [6]. The seamless exchange of data allows for accurate order processing and reduces delays in food delivery.

D. Navigation and Movement Control

The motor driver regulates power distribution to the wheels based on commands from the Arduino Nano. The robot follows a predefined path using line-following algorithms, ensuring precise movement from the kitchen to the customer's table [5]. The motor driver ensures smooth acceleration and deceleration, optimizing power consumption.

E.User Interaction via LCD and Buzzer Alerts

When a customer enters their order into the LCD I2C display, the system processes the input and transmits the order details to the kitchen via the RF transmitter. Once the RF receiver in the kitchen receives the order, it triggers a buzzer alert to notify kitchen staff of the new request. This workflow ensures a streamlined process, allowing quick response times and improving service efficiency [7].

F. Energy Management and Battery Optimization

The Efficient power management is crucial for ensuring extended operational runtime. The Arduino Nano is programmed to regulate power usage by deactivating non- essential components when idle. The system incorporates a voltage sensor to monitor battery levels and issue alerts when recharging is required by using IoT Application. Future developments aim to integrate solar charging solutions to enhance sustainability [9].

G. Real-Time Performance Monitoring

To ensure optimal performance, real-time monitoring of the robot’s movements, battery life, and obstacle detection is crucial. Cloud-based analytics can track performance trends, helping restaurant managers optimize operations. Implementing predictive maintenance strategies can prevent unexpected failures, ensuring seamless operation during peak hours [10].

H. Work flow Optimization for Future Enhancements

Future optimizations include integrating AI-based decision-making for dynamic path adjustments, implementing cloud-based analytics for performance monitoring, and improving battery efficiency to extend operational runtime. Enhancing sensor accuracy and refining obstacle avoidance algorithms will further optimize workflow efficiency. Additionally, implementing a multi- robot coordination system can enable multiple waiter robots to operate simultaneously without interference, improving overall service delivery [9]. The incorporation of machine learning can allow the robot to predict busy hours and adjust its workflow accordingly.

I. Integration with Smart Restaurant Systems

The robot can be integrated into a smart restaurant system that connects with the restaurant’s order management and kitchen display system. This integration can automate the food preparation-to-delivery process, reducing human intervention and errors. Utilizing AI-based scheduling systems can enhance service efficiency and customer satisfaction [11].

III.METHODOLOGY

The methodology for this project is structured as follows, integrating both hardware and software elements to achieve a seamless IoT-based robotic waiter system.

A. System Design

- The design phase includes the development of the robot's hardware and software framework, integrating essential components such as microcontrollers, sensors, and motor drivers. The system is structured to support autonomous movement and intelligent decision-making.
- avoid The selection of an Arduino-based microcontroller ensures efficient processing of sensor data and control commands. The robot's mobility is driven by DC motors controlled through motor drivers, allowing smooth navigation [3], [5].

B. IoT Integration

- The IoT system is responsible for real-time communication between the kitchen and the robot. A cloud-based infrastructure enables staff to send notifications when an order is ready, and the robot retrieves and processes these notifications.
- The system leverages MQTT protocols for fast and

secure message exchange, reducing latency in communication. Data logs are maintained in a cloud database for tracking and analytics [7], [10], [16].

C. Navigation and Path Planning

- The robot follows a predefined path using a combination of line-following algorithms and real- time obstacle avoidance mechanisms. This hybrid approach ensures efficiency in dynamic restaurant environments.
- Sensors such as ultrasonic and infrared are integrated for real-time obstacle detection, ensuring safe maneuverability [4], [8], [15].

D. Wireless Communication

- The robot communicates with the central control system using RF modules, ensuring seamless data transmission. This wireless setup eliminates dependency on wired connections, making operations more flexible.
- The communication module ensures real-time status updates, allowing restaurant staff to monitor the robot's movement and operational status remotely [6], [11].

E. Block Diagram

1.Block Diagram of Robot: -

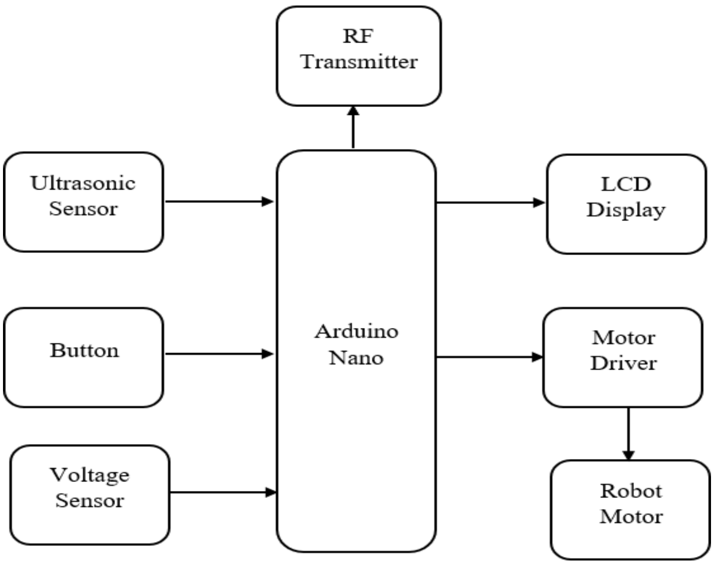

Fig.3.1 Block Diagram of Robot

The robot acts as the main system for customer interaction, order place, and food delivery. It autonomously moves between tables and the kitchen, ensuring a smooth order-taking and delivery process. The core components involved in the robot system are :-

1.1 Arduino Nano

The Arduino Nano is the brain of the robot, controlling all connected components. It is a small yet powerful microcontroller board based on the ATmega328P chip. It operates at 5V, has 14 digital I/O pins, and 8 analog input

pins, making it suitable for handling multiple sensors, buttons, and communication modules.

Fig.3.1.1 Arduino Nano

In this project, the Arduino receives input from the table button, ultrasonic sensor, keypad, and voltage sensor, processes the information, and controls the LCD display, motor driver, RF transmitter, and robot motors.

1.2 Ultrasonic Sensor

The ultrasonic sensor is used for obstacle detection and navigation. It works on the principle of sound wave reflection and can measure distances from 2 cm to 400 cm with an accuracy of ±3 mm.

Fig.3.1.2 Ultrasonic Sensor

The sensor continuously scans the environment and sends signals to the Arduino, ensuring the robot moves safely to the table without colliding with obstacles.

1.3 Button

A push button is placed on each table, allowing the customer to summon the robot. When pressed, it sends a signal to the Arduino, instructing the motor driver to move the robot to the respective table. The button operates at 3.3V to 5V and is designed for easy activation.

1.4 Voltage Sensor

The voltage sensor monitors the robot's battery level to prevent power failures. It has an input voltage range of 0V - 25V and provides an output voltage of 0V - 5V, making it compatible with the Arduino.

Fig.3.1.4 Voltage Sensor

The Arduino processes this data and displays warnings on the IoT application if the battery level is too low.

1.5 RF Transmitter

The RF transmitter module allows wireless communication between the robot and the kitchen. It operates at 433MHz frequency, has a range of up to 100 meters, and is powered by 3V - 12V.

Fig.3.1.5 RF Transmitter

Once the customer selects an item from the keypad, the Arduino encodes the order details and sends them wirelessly to the kitchen.

1.6 LCD Display (I2C)

A LCD screen is mounted on the robot to provide real- time information to customers. It operates at 5V and can display 16 characters per line on 2 lines. The screen updates the status, showing messages such as Dish1, Dish2,etc.

Fig.3.1.6 LCD Display (I2C)

1.7 Motor Driver (L298N)

The L298N motor driver is responsible for controlling the robot's movement. It operates at 5V - 35V and can supply up to 2A per channel.

Fig.3.1.7 Motor Driver

It receives signals from the Arduino and controls the DC motors, enabling smooth forward, backward, left, and right movements.

1.8Robot Motor (DC Motor)

The robot is driven by DC motors, which operate at 12V and provide speeds between 100 - 300 RPM. These motors ensure the robot moves quickly and efficiently to its destination. The Arduino controls the motors via the motor driver, ensuring precise navigation.

2.Block Diagram of Kitchen :-

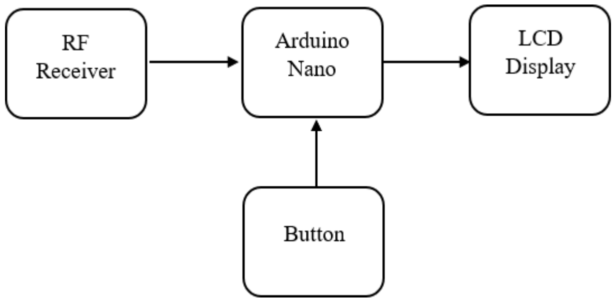

Fig.3.2 Block Diagram of Kitchen

2.1 Arduino Nano

Just like in the robot, an Arduino Nano is used in the kitchen to manage all inputs and outputs. It receives the order signal from the RF receiver, processes it, displays it on the LCD screen, and activates the buzzer to alert the kitchen staff. Once the food is prepared, it sends a message back to the robot.

2.2 RF Receiver (433MHz)

The RF receiver module is used to receive the order details from the robot. It operates at 433MHz frequency, with a range of up to 100 meters.

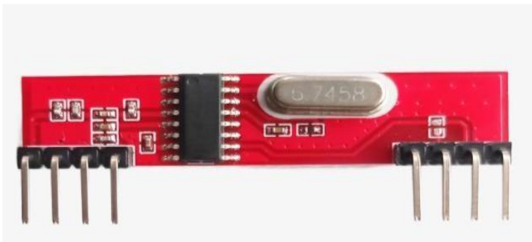

Fig.3.2.2 RF Receiver

Once the receiver gets the signal from the robot, it decodes the order information and sends it to the Arduino for further processing.

2.3 LCD Display (I2C)

A LCD screen is installed in the kitchen to show incoming orders. Operating at 5V, it displays "New Order Received: [Dish Name]" when an order is received.

Fig.3.2.3 LCD Display (I2C)

This ensures the kitchen staff is aware of all pending orders.

2.4 Reset Button

A reset button is included in the kitchen system to clear the LCD display once an order is prepared. This is a simple push button that operates at 3.3V - 5V.

Fig.3.2.4 Reset Button

When pressed, it signals the Arduino to remove the current order from the display and send a "Food Ready" message back to the robot.

2.5 Buzzer

A buzzer is used to alert kitchen staff when a new order is received. It operates at 3V - 12V and produces a loud beep (85dB - 95dB) to grab attention.

Fig.3.2.5 Buzzer

When an order is received via the RF module, the Arduino triggers the buzzer, ensuring the kitchen staff is immediately notified.

F. Flow Chart

1.Flow Chart for Robot :-

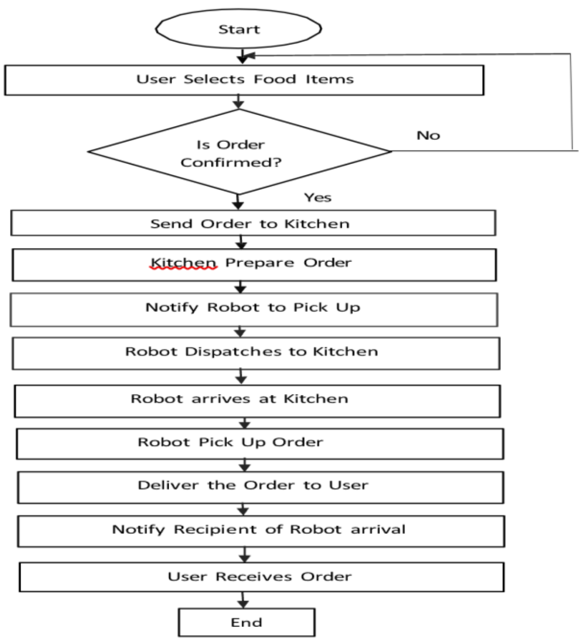

Fig.3.1 Flow Chart for Robot

The project is an automated food ordering and delivery system using a robot, designed to enhance efficiency and customer experience in a hotel or restaurant setting. The process begins when a customer arrives at the table and presses a button placed there. This action signals the robot, which then moves towards the table to take the order. The robot is equipped with a keypad displaying various food items, allowing the customer to select their desired dishes. Once the selection is complete, the order is confirmed, and it is then transmitted wirelessly to the kitchen using an RF (Radio Frequency) receiver.

In the kitchen, an RF receiver captures the order details and displays them on an LCD screen. Simultaneously, a buzzer sounds to alert the kitchen staff that a new order has been received. The kitchen staff then reviews the order and begins preparing the food. Once the food is ready, they send a notification to the robot through an IoT-based communication system, which could be Wi-Fi or Bluetooth. Upon receiving the notification, the robot autonomously moves to the kitchen to pick up the order.

When the robot reaches the kitchen, the staff places the prepared food onto the robot's tray or storage compartment. A confirmation is sent to the robot, which then navigates back to the customer's table. The robot ensures smooth navigation using pre-programmed paths, sensors, to avoid obstacles and deliver the food efficiently. To confirm receipt, the customer can press a "Complete Order" button on the robot, signaling that the process is finished. Once confirmed, the robot returns to its standby position, ready for the next order. This entire system minimizes human intervention, reducing the need for waiters, lowering labor costs, and enhancing overall hygiene.

The technology used in this system includes an interactive keypad or touchscreen for ordering, an RF communication module for order transmission, an IoT module for real-time updates, and a navigation system equipped with sensors for smooth movement. The kitchen is fitted with an LCD display and a buzzer to alert staff about new orders, ensuring efficiency in order processing.

This automated system offers several advantages, including increased accuracy in order placement and delivery, reduced wait times, and an improved customer experience. Additionally, it minimizes human errors and enhances hygiene by reducing direct human contact with food. Future enhancements could include integrating a mobile app for order placement, voice recognition for hands-free ordering, AI-based navigation for better movement, and payment integration for seamless transactions.

2. Flow Chart for Obstacle Avoidance

The robot continuously scans for obstacles while moving. If no obstacle is detected, it follows its path smoothly. If an obstacle appears, the robot checks for clearance. If there is enough space, it continues moving. If the path is blocked, the robot waits for the obstacle to be cleared.

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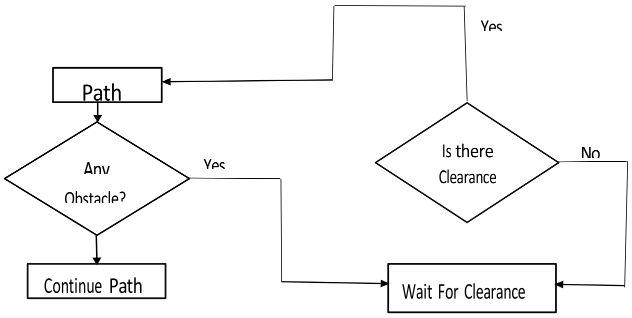

Fig.3.2 Flow Chart for Obstacle Avoidance

If the obstacle remains for too long and the robot cannot move, it automatically sends a message to the hotel manager, requesting assistance. Once the path is cleared, the robot resumes its journey to complete the delivery. This system ensures smooth navigation and prevents delays in food service.

IV.RESULT AND DISCUSSION

A.Overview of Project :-

In the overview we explain the concept of Layout of the Restaurant

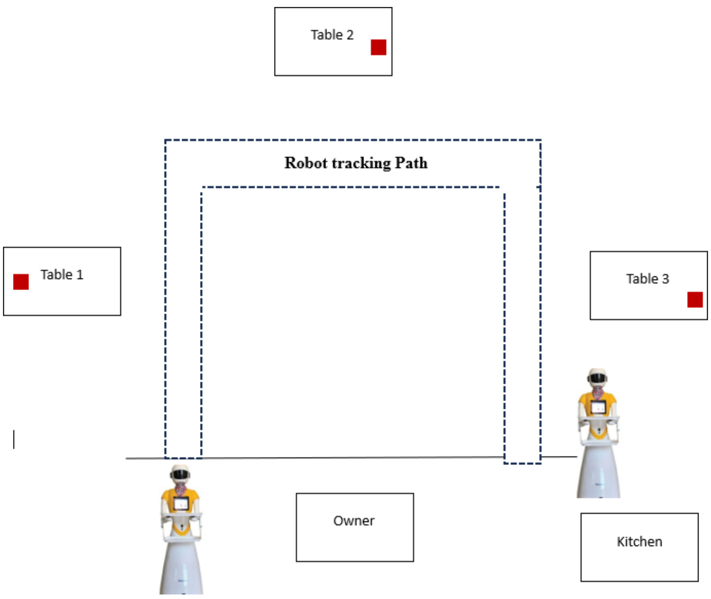

Fig.4.1 Overview of Project

1.Tables (Table 1, Table 2, Table 3)

These represent the customer dining areas where guests sit. Each table has a call button to request service from the robot. When a customer presses the button, the robot moves to that table.

2.Owner Section

This is where the restaurant owner or manager is located. The system sends messages to the owner when an issue (like an obstacle) occurs.

3.Kitchen Section

This is where orders are prepared. When the food is ready, the kitchen sends a notification to the robot via IoT. The robot picks up the food and delivers it to the correct table.

4.Robot Tracking Path (Dashed Line)

This is the predefined path that the robot follows using IR sensors. The robot moves between tables, kitchen, and reception, ensuring efficient service. The robot stops at specific points (tables and kitchen) based on requests.

B. Step-by-Step explanation of the System

Step 1: Customer Calls the Robot

- Each table is equipped with a push button.
- When a customer presses the button, a signal is sent to the robot.
- The robot moves from its resting position (near the kitchen) to the requested table by following the tracking path.
- The IR sensors detect the black line and guide the robot toward the correct table.

Step 2: Customer Places an Order

- The robot has an LCD display and a keypad for order selection.
- The customer chooses a dish from the menu by pressing the corresponding button.
- The order is transmitted wirelessly (RF communication or IoT) to the kitchen.
- The kitchen staff receives the order on an LCD screen and starts preparing the food.

Step 3: Kitchen Receives the Order

- The kitchen has an RF receiver to receive the order.
- The order is displayed on an LCD to notify the kitchen staff.
- A buzzer sounds to alert the kitchen that a new order has been placed.
- Once the food is prepared, the kitchen staff presses a button to notify the robot.

Step 4: Robot Picks Up the Food

- When the kitchen confirms the order is ready, the robot moves back to the kitchen.
- The robot stops at the kitchen pickup area and waits for the food.
- The kitchen staff places the food on the robot's tray.
- The kitchen sends an IoT signal to the robot, confirming that the order is loaded.

Step 5: Robot Delivers Food to the Correct Table

- The robot moves from the kitchen to the table where the order was placed.
- It stops at the correct table, allowing the customer to pick up their order.

- The robot sends a message to the reception, confirming that the order has been delivered.

Step 6: Obstacle Detection & Notification

- If the robot detects an obstacle (e.g., chair, person) in its path, it stops immediately.
- The robot sends a message to the hotel manager via IoT.
- The hotel manager or staff clears the obstacle, and the robot resumes movement.

Step 7: Robot Returns to Resting Position

- After successful delivery, the robot moves back to its default position near the kitchen.
- The system waits for the next order request from customers.

V.CONCLUSION

The line-following restaurant robot is a smart automation system designed to enhance food ordering and delivery in restaurants. By utilizing IR sensors, the robot follows a predefined tracking path to navigate between tables, the kitchen, and the reception area. Customers can call the robot using a push button at their table, and once the robot arrives, they can select their food items via a keypad and LCD display. The order is then wirelessly transmitted to the kitchen using RF communication or IoT.

In the kitchen, the order is displayed on an LCD, and a buzzer alerts staff about new requests. Once the food is ready, the kitchen staff sends an IoT signal to the robot, prompting it to return to the kitchen for pickup. The robot then delivers the meal to the correct table and sends a notification to reception confirming the delivery. If an obstacle is detected, the robot stops and alerts the hotel manager for assistance.

This project reduces human effort, improves service speed, enhances customer satisfaction, and minimizes errors in food delivery. With IoT integration, obstacle detection, and automated navigation, it is an efficient and scalable solution for modern smart restaurants.

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