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Design and Implementation of an Arduino-Based Food Delivery Robot with Bluetooth Control

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ABSTRACT

The development of service robots has gained increasing attention as a solution to improve efficiency and consistency in food delivery services, particularly in environments with limited space and dynamic conditions. This study aims to design and implement an Arduino-based food delivery robot with Bluetooth control operated via a smartphone. The research employs a prototype-based development method, encompassing system requirement analysis, mechanical and electronic design, prototype construction, and functional testing. The robot is equipped with an Arduino Uno R3 microcontroller, DC gearbox motors, a Bluetooth HC-06 module for wireless communication, and an audio system to support basic human–robot interaction. System testing focuses on evaluating the robot's ability to respond to movement commands and audio activation instructions transmitted through a smartphone application. The results demonstrate that the developed prototype is capable of executing directional movement commands and activating the audio system consistently within the defined operational range. These findings indicate that low-cost embedded platforms can be effectively utilized to develop functional food delivery robot prototypes suitable for controlled environments such as parties or small-scale service settings. This study contributes to the validation of a simple and replicable service robot design that may serve as a foundation for further development toward more autonomous and intelligent robotic service systems.

Keywords: arduino; *bluetooth control; food delivery robot; service robot; smartphone control.*

INTRODUCTION

Recent advances in robotics and embedded systems have significantly accelerated the adoption of automation within the service sector, particularly in applications that require efficiency, consistency, and operational reliability. Service robots have emerged as an effective technological solution to support or substitute human labor in non-industrial environments, including food and beverage services, where repetitive and time-sensitive tasks are prevalent (Wirtz et al., 2018; Ivanov & Webster, 2019). The deployment of such robots has been shown to reduce operational errors, optimize labor utilization, and enhance service performance.

In conventional food-serving practices, especially during large-scale events such as parties or receptions, food delivery activities are predominantly carried out by human attendants. However, human performance is inherently affected by factors such as fatigue, health conditions, and workload intensity, which may reduce service efficiency and consistency. Prior studies have indicated that service robots are capable of mitigating these limitations by providing stable and repeatable performance, while still supporting acceptable levels of human–robot interaction when appropriately designed (Belanche et al., 2020; Kim et al., 2021).

Food delivery robots represent a specific category of mobile service robots designed to transport items within confined or semi-structured environments. These systems typically consist of integrated mechanical structures, electronic components, and control mechanisms to ensure reliable mobility and task execution (Siegwart et al., 2017). Several previous studies have explored microcontroller-based food delivery or service robots for restaurant applications. However, many existing implementations rely on fixed-path navigation or line-following mechanisms, which limit flexibility in dynamic environments (Eriyani et al., 2018; Ridarmin et al., 2019). As a result, their applicability to event-based settings such as parties, where spatial layouts frequently change, remains constrained.

The Arduino Uno R3 microcontroller is widely used as a control platform in prototype development due to its low cost, ease of programming, and extensive hardware–software ecosystem. Arduino-based systems have been demonstrated to be effective for early-stage robotic development, particularly in integrating actuators, communication modules, and control logic in a modular manner (Banzi & Shiloh, 2022; Monk, 2021). In addition, Bluetooth-based wireless communication enables direct and intuitive robot control via smartphones, allowing real-time operation without requiring complex network infrastructure. This approach is considered suitable for short-range service robot applications in controlled environments (Lu et al., 2022).

Based on these considerations, this study aims to design and implement an Arduino-based food delivery robot equipped with Bluetooth control through a smartphone interface. The research focuses on system design, prototype implementation, and functional performance evaluation to validate the feasibility of the proposed approach. The expected contribution of this study is the development of a simple, cost-effective, and replicable service robot prototype that can serve as a foundational model for further research and development toward more autonomous food delivery systems in limited and dynamic service environments.

THEORETICAL BACKGROUND

Service Robots

Service robots are defined as robotic systems designed to perform useful tasks for humans or equipment in non-industrial environments, particularly within service-oriented sectors such as hospitality, healthcare, and food services (Wirtz et al., 2018). Unlike industrial robots that operate in highly structured settings, service robots are required to function in semi-structured or dynamic environments and often interact directly with human users. Consequently, reliability, safety, and usability are critical design considerations in service robot development.

Previous studies have highlighted that the implementation of service robots can improve operational efficiency, reduce human workload, and enhance service consistency, especially for repetitive and routine tasks (Ivanov & Webster, 2019). In the food service domain, service robots are increasingly adopted to support food delivery, order handling, and customer interaction, contributing to improved service performance when appropriately integrated into the service process (Belanche et al., 2020).

Food Delivery Robots

Food delivery robots represent a subclass of mobile service robots designed to transport food items within confined or controlled environments. These robots typically integrate mechanical structures, electronic subsystems, and control mechanisms to ensure stable movement and task execution (Siegwart et al., 2017). In indoor applications, food delivery robots are commonly employed in restaurants, hotels, and event venues where predefined operational boundaries exist.

Several prior studies have reported successful development of food delivery or restaurant service robots using microcontroller-based platforms. However, many implementations rely on fixed navigation paths or line-following techniques, which limit adaptability in environments with frequently changing layouts (Eriyani et al., 2018; Ridarmin et al., 2019). As a result, manually controlled or semi-autonomous systems remain relevant alternatives, particularly for event-based settings such as parties, where flexibility and direct operator control are required.

Arduino Uno R3 as a Robotic Control Platform

Arduino Uno R3 is a widely used microcontroller development board based on the ATmega328P architecture and is commonly employed in embedded system and robotics research. Its popularity stems from its low cost, simplicity, open-source ecosystem, and extensive community support (Banzi & Shiloh, 2022). Arduino Uno R3 supports programming in C/C++ through the Arduino Integrated Development Environment (IDE), enabling rapid development and testing of control algorithms.

In robotic applications, Arduino-based platforms are frequently utilized during the prototyping stage to validate system concepts and functional integration. Previous studies have demonstrated that Arduino microcontrollers are capable of controlling actuators, processing sensor inputs, and managing communication modules effectively, making them suitable for the development of low-cost robotic prototypes (Monk, 2021).

Bluetooth-Based Control Systems

Bluetooth is a short-range wireless communication technology widely adopted in embedded systems and robotics due to its ease of implementation and low power consumption. Modules such as the HC-06 enable serial communication between microcontrollers and external devices, including smartphones, in real time. Bluetooth-based control systems are particularly suitable for applications that require direct user interaction within limited operational distances (Lu et al., 2022).

In service robot applications, Bluetooth communication allows intuitive and responsive control through smartphone interfaces without requiring complex network infrastructure. Previous research indicates that Bluetooth-based control provides sufficient reliability and responsiveness for indoor robotic applications, especially during the prototyping and validation stages (Kim et al., 2021).

Smartphone-Controlled Robotic Systems

Smartphone-controlled robotic systems utilize mobile devices as human–machine interfaces for sending control commands to robotic platforms. This approach leverages the widespread availability of smartphones and their built-in capabilities, such as touch interfaces and wireless connectivity. In such systems, smartphones function as command transmitters, while the robot executes received instructions through its embedded control unit (Siciliano & Khatib, 2016).

The use of smartphones for robot control has been shown to improve usability and reduce system complexity, particularly in service robot applications that require manual supervision. This control strategy is suitable for environments where autonomous navigation is not yet required, allowing operators to maintain direct control over robot movement and interaction functions.

RESEARCH METHODS

Research Design

This study adopts a prototype-based research design aimed at developing, implementing, and functionally validating a food delivery robot system. The prototype approach is appropriate for engineering-oriented studies that emphasize system construction and direct performance verification prior to large-scale deployment. The methodology focuses on translating system requirements into a functional prototype and evaluating its operational performance under controlled conditions.

The research workflow consists of four main stages: (1) system requirement analysis, (2) system design, (3) prototype construction and integration, and (4) functional testing and evaluation.

System Requirements Analysis

System requirements were identified to ensure that the developed prototype fulfills the intended function as a food delivery robot with smartphone-based control. The requirements analysis covers both hardware and software components necessary for system operation.

Table 1. Hardware Requirements for the Food Delivery Robot Prototype

No.	Component Name	Quantity
1	Arduino Uno R3	1
2	Jumper Wires	20
3	DC Gearbox Motor	2
4	Bluetooth HC-06 Module	1
5	L298N Motor Driver	2
6	18650 Battery	5
7	18650 Battery Holder	2
8	PAM8403 Audio Amplifier	1
9	DFPlayer Mini	1
10	DC Step-Down Converter	1
11	5V Relay Module	1
12	On/Off Switch	2
13	Speaker Driver	1

The hardware requirements include a microcontroller unit, DC gearbox motors as actuators, a motor driver module, a Bluetooth communication module, a power supply system, and an audio output unit. These components collectively support robot mobility, wireless control, and basic human–robot interaction.

Table 2. Software Requirements for Programming and Control of the Robot Prototype

No.	Software Name	Function
1	Arduino IDE	Used for programming and uploading the control code to the Arduino Uno microcontroller.
2	Bluetooth RC Controller	Used to control the robot’s movement through a smartphone-based application.

The software requirements consist of the Arduino Integrated Development Environment (IDE) for programming the microcontroller and a smartphone-based Bluetooth control application used to transmit control commands to the robot. The selected software tools enable real-time command transmission and rapid system testing.

System Design

The system design stage involves mechanical design, electronic circuit design, and control logic design. The mechanical structure of the robot is designed to support food and beverage loads while maintaining balance and stable movement on flat surfaces. The arrangement of components follows the mechanical design illustrated in the prototype design figures provided in the manuscript.

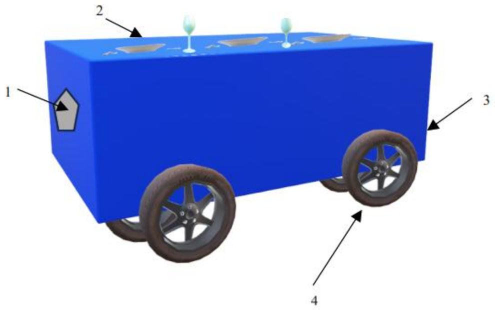

Figure 1. Mechanical Design of the Food Delivery Robot Prototype

The electronic system integrates the Arduino Uno R3 microcontroller as the main control unit, DC motors for locomotion, a motor driver for actuator control, a Bluetooth HC-06 module for wireless communication, and an audio module for sound output. The electronic circuit configuration follows the schematic diagrams presented in the manuscript and serves as a reference for system assembly.

Table 3. Description of Components in the Mechanical Design of the Robot Prototype

Label Number	Description
1	IBIK Logo
2	Plates and Glasses
3	Arduino and Electronic Components Storage Box
4	DC Gearbox Motor and Wheels

Control logic is implemented through a program written in C/C++ using the Arduino IDE. The control algorithm is designed to interpret incoming Bluetooth commands and translate them into corresponding motor actions and audio outputs.

Prototype Construction and Integration

Prototype construction is carried out by assembling the mechanical structure and installing all electronic components according to the predefined design. The integration process includes wiring the electronic components, configuring the power supply, and embedding the programmed microcontroller into the system.

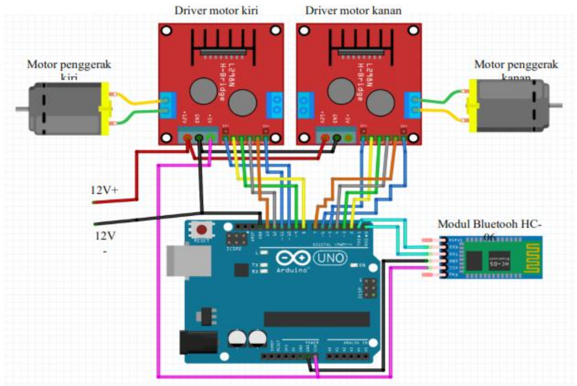

Figure 2. Electronic Circuit Schematic of the Arduino-Based Robot System

Programming is performed incrementally, starting with basic motor control tests, followed by Bluetooth communication validation, and finally integrating the audio system. This stepwise integration approach ensures that each subsystem functions correctly before full system operation.

Functional Testing Procedure

Functional testing is conducted to evaluate the operational performance of the prototype robot. Testing focuses on verifying the system's ability to respond accurately to control commands transmitted via a smartphone application.

The testing procedure includes issuing directional commands (forward, backward, left, and right) and observing the corresponding robot movements. In addition, audio system functionality is tested by activating sound output commands with predefined interaction scenarios. All test results are recorded in the functional testing tables presented in the manuscript.

Data Analysis Technique

Data analysis in this study is performed using a descriptive qualitative approach. The analysis evaluates whether the observed system responses correspond to the predefined functional requirements. The testing outcomes are used to determine the reliability and consistency of the prototype in executing movement and audio commands, thereby validating the feasibility of the proposed system design.

RESULTS AND DISCUSSION

Research Result

This section presents the implementation and testing results of the Arduino-based food delivery robot with Bluetooth control via a smartphone. The results are organized in accordance with the research objectives and methodology, focusing on system implementation, electronic integration, and functional performance outcomes.

Prototype Implementation Results

The implementation results demonstrate that the developed food delivery robot prototype successfully integrates the mechanical structure and electronic components as specified in the system design. The assembled prototype represents the physical realization of the mechanical design and electronic configuration described in the Methodology section.

Figure 3. Assembled Food Delivery Robot Prototype after System Integration

The prototype is capable of supporting food and beverage items placed on the upper platform while maintaining structural stability during movement on flat surfaces. These results indicate that the mechanical design and component placement adequately fulfill the basic functional requirements of a food delivery robot intended for controlled environments.

Electronic System Implementation Results

The electronic system implementation shows that all electronic components are properly interconnected and operate as an integrated control system. The Arduino Uno R3 functions as the central control unit, receiving command signals from the Bluetooth module and executing corresponding control actions.

Figure 4. Implementation of the Electronic System after Assembly

The motor driver modules successfully regulate the rotation and direction of the DC gearbox motors, enabling controlled robot movement. In addition, the integrated audio system operates as intended, allowing sound output to be activated through commands transmitted from the smartphone. These outcomes confirm that the electronic configuration supports both mobility control and basic human–robot interaction functions.

Functional Testing Results

Functional testing was conducted to evaluate the robot's response to control commands transmitted via the smartphone-based Bluetooth application. The overall functional testing results are summarized in Table 4, which presents the relationship between control commands, motor responses, and audio system activation.

Table 4. Functional Testing Results of Robot Control and Audio System

No.	Control Button	Motor Movement	Speaker Output
1	Forward	Moves forward	–
2	Backward	Moves backward	–
3	Right	Turns right	–
4	Left	Turns left	–
5	Speaker icon (1× click)	–	Continuous sound output
6	Speaker icon (2× clicks)	–	Single sound output

The test results indicate that the robot responds appropriately to directional movement commands, including forward, backward, left, and right motions. Each command issued through the control application produces a corresponding and consistent physical response from the robot. Furthermore, the audio system functions according to the predefined interaction scenarios, activating continuous or single sound output based on the control input provided.

The functional testing results demonstrate that the Bluetooth-based control system performs reliably within the specified operational range. The robot consistently receives and executes control commands during the testing process, indicating stable system performance under the tested conditions.

Discussions

The results of this study demonstrate that the developed Arduino-based food delivery robot with Bluetooth control is capable of performing its intended service functions reliably within a controlled environment. The prototype consistently responded to directional movement commands and audio activation instructions transmitted via a smartphone interface, indicating that the system architecture and control logic were implemented effectively. These findings confirm that the functional objectives of the research were achieved without requiring complex navigation or sensing mechanisms.

From a theoretical perspective, the observed system performance aligns with the fundamental principles of service robot design, particularly for mobile service robots operating in semi-structured environments. Service robots are expected to prioritize reliability, usability, and task repeatability rather than full autonomy at early development stages (Wirtz et al., 2018). The use of a microcontroller-based control system enables stable coordination between mechanical actuation and electronic control, supporting the notion that low-cost embedded platforms can adequately fulfill basic service robot requirements (Ivanov & Webster, 2019).

When compared with previous studies on food delivery and restaurant service robots, the results of this research are consistent with findings reported by Eriyani et al. (2018) and Ridarmin et al. (2019), who demonstrated that microcontroller-driven robots can effectively support food delivery tasks in indoor environments. However, unlike many earlier implementations that rely on fixed-path navigation or line-following techniques, the robot developed in this study employs direct smartphone-based Bluetooth control. This approach offers greater operational flexibility in environments where spatial layouts are not fixed, such as parties or temporary event settings. Similar control strategies have been recognized as suitable alternatives for early-stage service robot applications where adaptability is prioritized over autonomy (Lu et al., 2022).

In terms of practical implications, the findings suggest that the proposed prototype can serve as a functional support system for food distribution in small-scale service scenarios. The integration of an audio output mechanism provides a simple yet effective form of human–robot interaction, enhancing user awareness during food delivery tasks. Additionally, the use of widely available components such as Arduino Uno R3 and Bluetooth modules contributes to the system's affordability and replicability, making it accessible for educational purposes, small businesses, or further experimental development.

From a broader theoretical standpoint, this study contributes to the growing body of literature on low-cost service robot development by demonstrating that meaningful service functionality can be achieved through simplified control architectures. The results reinforce prior research suggesting that manual or semi-manual control strategies remain relevant, particularly in contexts where full autonomy may be impractical or unnecessary (Belanche et al., 2020; Kim et al., 2021). As such, the prototype presented in this study may be viewed as an intermediate step toward more advanced service robot systems.

Despite these contributions, several limitations should be acknowledged. The robot's operational range is constrained by Bluetooth communication, limiting its use to short-distance applications. Furthermore, the system does not incorporate autonomous navigation, obstacle detection, or adaptive decision-making capabilities. These limitations indicate that the developed prototype is best characterized as a proof-of-concept rather than a fully autonomous service robot. Future research is therefore recommended to integrate longer-range communication technologies, environmental sensors, and autonomous navigation algorithms to enhance system scalability and intelligence.

CONCLUSION

This study has successfully designed and implemented an Arduino-based food delivery robot controlled via Bluetooth using a smartphone interface. The developed prototype demonstrates reliable execution of basic service functions, including directional movement control and audio activation, in accordance with the defined system requirements. These results confirm the feasibility of employing a low-cost embedded platform to develop a functional service robot prototype for controlled environments.

The main contribution of this research lies in validating a simple and replicable design approach for food delivery robots that does not rely on complex navigation or autonomous decision-making. By utilizing widely available hardware components and a straightforward control architecture, the proposed system offers a practical foundation for early-stage service robot development and experimental applications in small-scale service settings, such as parties or temporary events.

From a practical perspective, the findings indicate that the proposed prototype can support food distribution tasks by assisting human operators and improving service efficiency. However, the system remains limited by short-range Bluetooth communication and the absence of autonomous navigation and environmental sensing capabilities. Future work is therefore recommended to incorporate longer-range communication technologies, obstacle detection sensors, and autonomous navigation algorithms to enhance the system’s adaptability and operational scope.

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