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An Arduino-Based Autonomous Serving Robot with GPS Navigation for Cost-Effective Service Automation

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Abstract

Robots built for service are no longer confined to research labs or luxury hotels; they are starting to appear in everyday spaces where speed and consistency make a real difference. In a restaurant, for example, a robot that can deliver meals and clear trays reduces staff workload, while in hospitals, it can free nurses from routine errands. Schools, too, can benefit by using such machines for both practical and teaching purposes. In this study, we developed and tested a compact, low-cost serving robot intended for these environments. The design relied on an Arduino controller as the central unit and used a PVC pipe frame to keep the structure both light and strong. Servo motors, DC motors, and a GPS module were used to handle movement and navigation. Building the system required mechanical assembly, circuit integration, and several cycles of programming and adjustment—trial and error, as any engineer would admit, was part of the process. When tested, the robot performed reliably: it completed more than 93 percent of its delivery tasks, carried up to 1.2 kilograms without tipping, and ran for more than two hours on a single charge. These results show that a straightforward, modular approach can deliver a working solution at a fraction of the cost of commercial robots. More importantly, they demonstrate that service automation can be made accessible even to small institutions with limited budgets.

Keywords: Autonomous serving robot, Arduino-based control, GPS navigation system, low-cost modular design, service robotics

INTRODUCTION

Over the past decade, robotics has shifted from being a specialist tool in factories to something that people are beginning to encounter in their daily lives. One of the fastest-growing areas is service robotics, where machines are designed to handle repetitive, time-consuming, or physically tiring jobs. In hospitals, for example, a robot can deliver supplies down long corridors; in restaurants, it can carry dishes to tables; and at home, it might help with simple household chores. The appeal lies not only in their efficiency but also in the consistency these systems can offer.

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Well-known commercial robots such as BellaBot, Temi, and Relay have already demonstrated the effectiveness of automation in the service industry. These machines deliver food, guide customers, and provide interactive support. However, their adoption remains restricted. The price tags are high, the designs are technologically demanding, and most require infrastructure and maintenance that small organizations cannot afford. As one review put it, "robots for service exist, but they are often designed for those who need them the least." Smaller restaurants, schools, and community clinics rarely have the means to access these solutions, even though they might benefit from them the most.

The work described in this paper addresses this gap. We set out to design a robot that is simple, affordable, and flexible enough for use by institutions with limited resources. The prototype we built stands approximately two feet tall and is made from PVC pipes, which provide strength without adding weight. Its control system is based on an Arduino Uno, an inexpensive and widely supported platform. DC and servo motors provide movement and tray operation, whereas a GPS module allows the robot to follow predefined routes. An LCD and LEDs provide basic feedback to the user.

The accessibility of the system is as important as its technical design. Because it is modular, the robot can be modified, repaired, and upgraded with relative ease. This makes it a useful tool for service tasks and a practical teaching and research platform. A small business, classroom, or local hospital ward can experiment with it, adapt it, and put it to work without the overhead of commercial solutions [1].

LITERATURE REVIEW

The field of service robotics has advanced through a combination of university research projects and industrial prototypes, each contributing to a different piece of the puzzle. Some studies have focused on motion control and obstacle avoidance, whereas others have explored user interaction or long-range navigation. Although progress has been steady, its broad adoption remains limited. High cost, lack of modularity, and difficulty of deployment remain persistent barriers, especially for institutions outside large, well-funded organizations.

An early example was the Arduino-based delivery robot built by Krishnamurthy et al. (2019). Their design used ultrasonic sensors to detect obstacles and avoid collisions, which proved effective in guiding the robot along the predetermined paths. However, it only worked in confined indoor spaces because no GPS was included. Without GPS, the design cannot be easily scaled to larger facilities or outdoor environments, limiting its practical reach.

A 2018 study adopted a different approach by emphasizing GPS-enabled navigation. The proposed platform could follow preset geographic routes, demonstrating how robotic systems can be deployed for long-distance delivery applications. Although the system demonstrated the promise of location-based navigation, it was expensive and technically complex. Smaller institutions or anyone working on a limited budget would find it nearly impossible to replicate.

Healthcare has emerged as a natural testbed for the development of service robots. A 2021 study developed a hospital delivery system that utilized infrared sensors for navigation and servomotors for mobility. The system operated effectively within the ward environment and helped reduce the staff workload; however, it demonstrated limited flexibility [2–4].

Modifying the system meant significant redesign, and the absence of real-time communication limited its usefulness in dynamic hospital settings, where interaction with patients and staff could have added real value.

Educational applications have leaned more toward simplicity. A 2020 study developed a line-following Arduino-based robot aimed at teaching fundamental robotics concepts. Its affordability and simple design made it an effective educational tool in classroom settings. However, its dependence on basic line-tracking algorithms limited its suitability for real-world service applications. The system lacked adaptability to unexpected conditions and offered minimal interaction capabilities.

Human–robot interaction has been another theme in recent research. A 2022 study introduced a voice-controlled delivery robot, demonstrating how natural language commands can enhance accessibility and make operations more intuitive for users. By lowering the barrier to interaction, the system improves user convenience. However, its complete reliance on external commands limits its autonomy and independent decision-making capabilities [3].

As one researcher observed, “a delivery robot that waits for instructions is more an assistant than an independent worker.”

A 2020 study emphasized affordability through the development of a low-cost robotic system that incorporated an LCD-based feedback interface and a manual override feature, thereby enhancing user control while maintaining cost efficiency. Their design represents a step toward accessibility, but it still relies heavily on manual operation. Future enhancements, such as GPS and Internet of Things (IoT) integration, have been proposed; however, in its current form, the system is better seen as a transitional stage rather than a fully autonomous solution.

Taken together, these studies show a recurring pattern: most designs solve one part of the challenge while leaving other aspects underdeveloped or neglected. Robots that focus on navigation often neglect user interactions. Systems built around interactions sometimes sacrifice autonomy. Affordable designs tend to lack advanced sensing and adaptability. This imbalance highlights a clear gap in the literature: the absence of service robots that are affordable, modular, autonomous, and genuinely interactive [4].

METHODOLOGY

The development of the autonomous serving robot was carried out step-by-step, with each stage designed to build upon the previous one. The process began by identifying what was needed in such a system and ended with a working prototype tested in realistic scenarios. This structured approach made it possible to maintain both technical accuracy and the practical feasibility of the model.

Requirement Analysis

The first task was to decide what the robot should do and what resources were available to make it happen. The aim was straightforward: a machine that could follow a set route, carry light loads such as trays or documents, and provide simple interaction with users. To keep the design affordable, components were chosen carefully [5]. Arduino Uno was selected as the central controller because of its low cost and flexibility. DC motors provided movement, servo motors controlled the tray mechanism, and a GPS module was added for navigation. A basic LCD screen and LED indicators were included for user feedback. The frame was built using PVC pipes, chosen because they are inexpensive, light, and easy to work with. As one design manual reminds us, “the best material is often the one you can replace or repair without difficulty.”

Mechanical Design and Fabrication

The mechanical design aimed to produce a compact but sturdy framework that could house and support all the required components. Constructed from PVC, the structure stood approximately two feet tall and incorporated specific slots for the Arduino board, motor drivers, battery, and display unit. This arrangement ensured both balance and accessibility of the data. The framework was deliberately kept modular, allowing parts to be replaced or upgraded without complete reconstruction. In doing so, the design enhanced not only durability but also the potential for experimentation and future adaptations.

Electronic Circuit Design

The electronic system ties everything together. The DC motors were connected to the Arduino through L298N motor drivers, providing precise control of speed and direction. Servo motors were added to move the tray smoothly, and the GPS module supported navigation. The LCD and LED indicators provide real-time updates to the user. Careful wiring was important; circuits were arranged to minimize interference, distribute power efficiently, and ensure that the robot could run reliably for long stretches without failure.

Programming and Logic Development

The control software was developed using an Arduino IDE. Algorithms were developed to handle navigation, obstacle avoidance, and task execution. Motor control was achieved through pulse-width modulation (PWM), which allowed for the fine regulation of speed and direction. To expand its functionality, Bluetooth and Wi-Fi modules were integrated, making it possible to monitor or control the robot externally. Safety was also a priority; a manual override system, implemented via a potentiometer, enabled users to intervene in case of a malfunction or unexpected behavior [6].

System Integration and Assembly

Once the main parts were built and tested individually, they were combined into a single system. The hardware was mounted on a PVC frame, and the connections were checked for stability. Integration meant not only joining the parts together but also ensuring that they worked smoothly as one unit. Careful calibration ensured that the motor output, GPS input, and user feedback were properly synchronized.

Testing and Calibration

The prototype was first tested piece by piece and then in full operation. Unit testing confirmed that each component functioned as expected, while integration tests simulated real-world use cases, such as a hospital corridor, restaurant aisle, and home hallway. Measurements were obtained for navigation accuracy, payload stability, and battery performance. Adjustments were made when the motors drifted or when the GPS signals lagged. This iterative process helped refine the system until the performance was consistent.

Optimization and Final Implementation

In the final stage, small but important improvements were implemented. The structure was reinforced to carry slightly heavier loads, and the power distribution was adjusted to extend the battery life. After optimization, the robot was able to complete more than 93 percent of the delivery tasks successfully in controlled trials. These results confirm the strength of the systematic step-by-step approach adopted throughout the development process.

RESULTS AND DISCUSSION

The finished prototype was able to meet its main goal of carrying out delivery tasks independently in controlled environments. At just under two feet tall, the PVC frame provided a balance of lightness and strength, so the robot remained steady while moving. The Arduino controller effectively coordinated the DC and servo motors, allowing the machine to follow its path and transport items without losing stability.

The performance trials yielded consistent results. Across 30 test runs, the robot completed more than 93 percent of its deliveries successfully. It could carry loads of up to 1.2 kg and managed a 10-meter route in approximately 1.2 min. The battery life was also respectable, running for more than 2.3 h on a single charge—enough for small restaurants, healthcare wards, or classrooms where tasks are repetitive but not continuous.

However, some weaknesses were observed. The navigation system occasionally drifted in areas where GPS signals were weak, and the servo motors showed slight jitters after prolonged use. Adding capacitors reduced the latter problem but did not eliminate it. The performance on uneven flooring was also less reliable, indicating the need for better sensing. As one study observed, “true autonomy depends not only on motion but also on awareness of the environment.”

Overall, the results confirm that a straightforward Arduino-based design can deliver dependable automation at a low cost. The prototype demonstrated that affordable service robots are practical and can offer real benefits in restaurants, hospitals, and homes, bridging the gap between expensive commercial systems and the needs of everyday users [7–10].

CONCLUSION AND FUTURE WORK

This project set out to test whether an autonomous serving robot could be built using modest resources, and the answer was yes. Using Arduino as the control platform and PVC for the frame, the prototype could complete delivery tasks with a high success rate. Its lightweight structure, affordability, and modular design make it well-suited for small-scale settings—restaurants, healthcare wards, or classrooms—where budgets are tight, but the need for automation is real. By combining GPS navigation with real-time feedback, the system addresses gaps in accessibility that are often left open by commercial robots.

Looking forward, there is room for growth. The addition of artificial intelligence could make the robot more adaptive in complex spaces, while IoT integration would allow remote monitoring and fleet coordination. LiDAR, computer vision, and more efficient power systems would also expand their usefulness. As one engineer remarked, "A prototype becomes truly valuable when it can leave the lab and thrive in the messiness of daily life." These directions suggest a clear path from controlled demonstrations to service-ready solutions.

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