IES International Journal of Multidisciplinary Engineering Research

Smart Medicine Dispensing Robot

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Abstract

The Smart Medicine Dispensing Robot is proposed as an automated healthcare support system intended to assist patients in managing prescribed medications accurately and on time. Medication non-adherence is a common issue among elderly individuals and patients with chronic illnesses due to memory lapses, physical limitations, and insufficient supervision, which can result in skipped doses or improper intake. To overcome these challenges, the developed system delivers medicines automatically according to a predefined schedule, provides timely alerts, and ensures precise dosage delivery to the user, thereby enhancing treatment compliance and patient safety. The system combines embedded control, sensing technologies, and IoT-based communication to form an efficient and interactive medical assistant. An ESP32 microcontroller serves as the core processing unit, coordinating servo motors for controlled dispensing, IR sensors for obstacle detection, and a voice recognition module for user interaction. Additional features such as a display unit, audio notifications, and an integrated water dispensing mechanism improve usability, particularly for users with reduced mobility. The modular architecture and economical design allow the system to be deployed in both domestic and clinical settings, with provisions for remote supervision and future expansion. Phase-1 development focuses on circuit design, simulation, and hardware integration to verify system functionality through virtual testing. The obtained results indicate that the proposed model is feasible, cost-effective, and capable of automating medication delivery reliably. Further development will include real-time implementation, IoT integration, and clinical evaluation to validate performance under practical conditions. Overall, the Smart Medicine Dispensing Robot aims to support independent patient care by integrating automation with essential healthcare assistance.

Keywords: Smart Medicine Dispenser, Medication Adherence, Healthcare Robotics, ESP32Microcontroller, Automated Drug Delivery, IoT-based Healthcare

DOI: https://doi.org/10.5281/zenodo.18846961

1. Introduction

Medication adherence plays a critical role in effective healthcare management, especially for elderly individuals and patients undergoing long-term treatment. Challenges such as memory loss, physical dependence, and limited access to continuous caregiver assistance often result in delayed, missed, or incorrect medication intake. These issues can lead to serious health complications and increased hospitalization rates. To minimize such risks, there is a growing need for automated systems that can assist patients in managing their daily medication routines accurately and independently. The Smart Medicine Dispensing Robot is developed as an assistive healthcare device that automates the dispensing of prescribed medicines while providing timely reminders and user interaction. By incorporating embedded control systems, sensing units, and IoT-based communication, the robot ensures accurate dose delivery at scheduled times. An ESP32 micro controller serves as the central processing unit, managing dispensing actions, monitoring environmental conditions, and enabling interaction through visual and voice-based interfaces. Additional features, including alert notifications and a water dispensing mechanism, further enhance user convenience and accessibility. This project primarily focuses on circuit design, simulation, and hardware implementation to validate the functional performance of the proposed system. The initial development phase demonstrates that the design is both technically feasible and economically practical. Future improvements will concentrate on real-time monitoring, expanded IoT functionality, and clinical validation to ensure dependable operation in real-world healthcare environments. Overall, the proposed system aims to enhance medication safety, reduce human dependency, and support independent living through intelligent healthcare automation.

1.1 Objectives

The main objective of this project is to design and develop an automated medicine dispensing system that delivers prescribed medications accurately and at scheduled times with minimal dependence on human assistance. The system aims to support elderly, disabled, and chronically ill patients by reducing missed doses and incorrect medication intake through reliable automation. Another objective is to integrate embedded hardware components such as the ESP32 microcontroller, sensors, servo motors, voice recognition modules, and IoT connectivity to enable precise control, real- time monitoring, and intuitive user interaction. The project also seeks to implement reminder alerts, direct medicine delivery, and supportive features such as audio notifications and water dispensing to improve ease of use. In addition, the project aims to create a cost-effective, modular, and expandable design suitable for both home-based and clinical applications. System performance is evaluated through circuit simulation, hardware testing, and planned real-world validation to ensure safety, accuracy, and dependable operation under practical healthcare conditions.

2. Methodology

The development of the Smart Medicine Dispensing Robot follows a systematic approach that begins with identifying the limitations of conventional medication management practices and reviewing existing automated dispensing solutions. Based on this understanding, a functional system architecture is designed to combine automation, safety, and controlled mobility within a single robotic platform. The methodology emphasizes careful planning of both hardware and control logic prior to physical implementation. The design process includes defining system requirements, selecting appropriate electronic components, and developing detailed circuit schematics. Each subsystem such as the medicine dispensing unit, sensing module, mobility mechanism, and control unit is designed and tested individually to ensure proper operation. Circuit simulation is performed using Tinkercad to verify power distribution, sensor response, and motor control behavior under different operating conditions. This virtual testing stage helps identify design issues and optimize system parameters before hardware assembly. After successful simulation, the hardware components are integrated according to the finalized circuit design. Functional testing is carried out to evaluate dispensing accuracy, sensor reliability, and control response. The methodology is structured in phases, allowing future integration of IoT communication, mobile alerts, and real-time data acquisition. This step-by-step development strategy ensures system reliability, scalability, and cost efficiency while maintaining a strong focus on improving medication adherence through intelligent automation.

2.1 System design

The Smart Medicine Dispensing Robot is designed as an integrated system that combines mechanical structure, electronic control, and communication modules to enable accurate and dependable medication delivery. The mechanical framework consists of a lightweight base with a stable center of gravity, supporting a modular medicine storage arrangement such as cartridge trays or a rotating dispensing mechanism. A precision servo motor controls the release of medicine doses, while safety features like protective enclosures and interlocking mechanisms help prevent accidental access or incorrect dispensing. At the core of the electronic system is the ESP32 microcontroller, which coordinates all sensing, control, and actuation functions. Actuators including servo motors and DC motors are driven through suitable motor drivers to ensure smooth and controlled operation. Various sensors, such as IR or optical sensors and optional load-sensing elements, are employed to detect obstacles, confirm dispensing actions, and enhance operational safety. An RTC module provides accurate timekeeping for scheduled medicine delivery, while a display unit and voice interaction module allow clear communication with the user. Wireless communication capabilities of the ESP32, including Wi-Fi and Bluetooth, support remote monitoring and future cloud-based integration. The power subsystem consists of a rechargeable lithium-ion battery, managed by a TP4056 charging module and regulated power supplies that deliver appropriate voltage levels to logic and motor circuits. Electrical isolation and filtering components are incorporated to protect sensitive electronics from noise and power fluctuations. The modular and scalable design approach allows easy testing, maintenance, and future upgrades, making the system suitable for both home and clinical healthcare environments.

3. Block Diagram

The block diagram represents the overall functional structure of the Smart Medicine Dispensing Robot. The ESP32 micro-controller acts as the central unit, receiving inputs from sensors and the real-time clock while controlling output devices such as servo motors, DC motors, the LCD, and the voice module. A regulated power supply provides the required voltage to all modules. Communication interfaces like I²C, UART, and PWM enable proper data exchange, ensuring coordinated operation and easy system expansion.

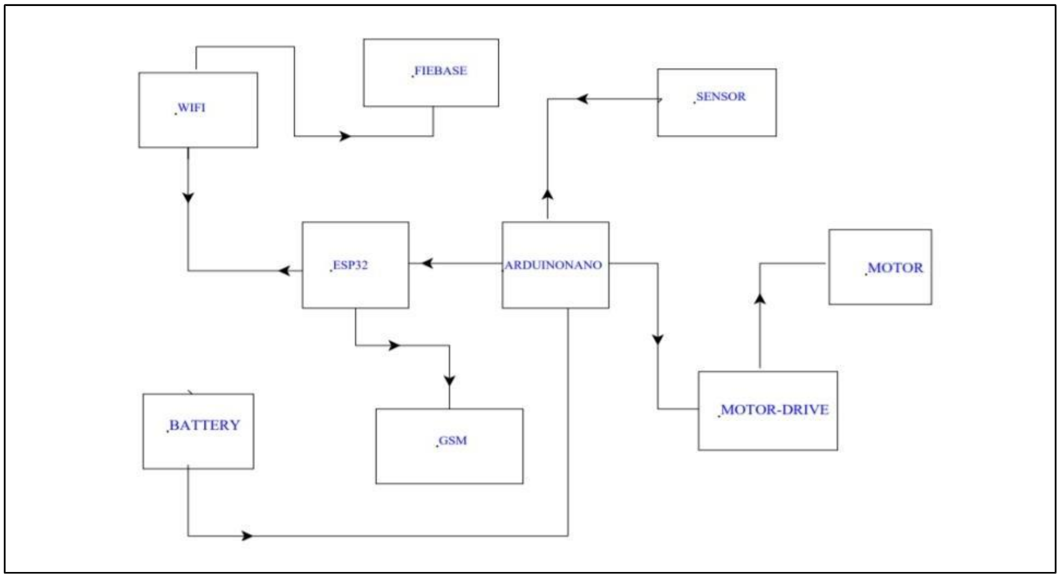

Figure 1: Block Diagram

4. Circuit Diagram

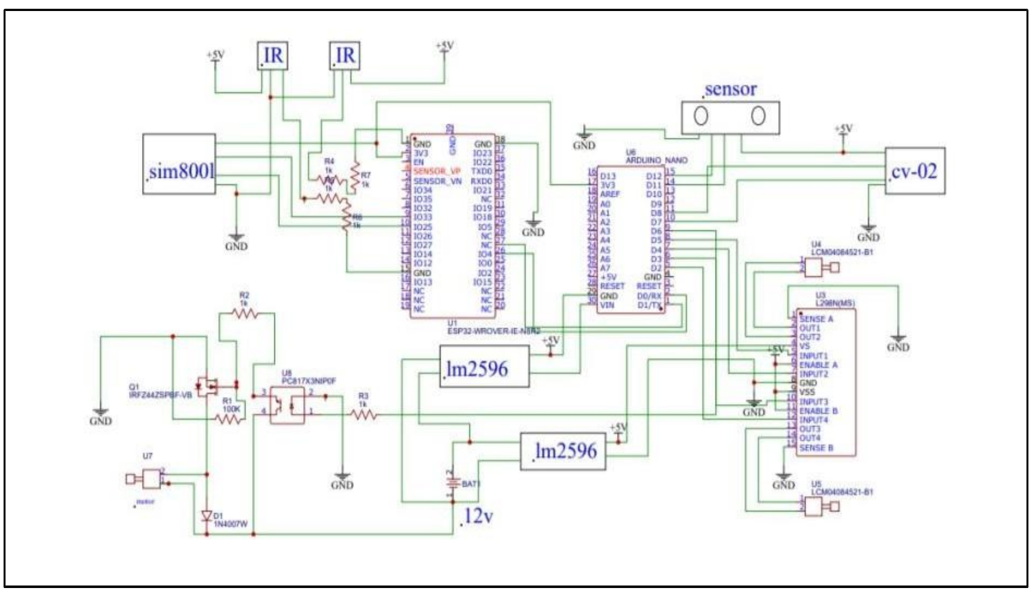

Figure 2: Circuit Diagram

The circuit represents an ESP32-based embedded control system where the ESP32 operates at 3.3 V and acts as the central controller for sensing, communication, and actuation. A 12 V battery supply is regulated using LM2596 buck converters to provide stable 5 V power for peripherals such as the L298N motor driver, MG995 servo, LCD, IR sensors, and voice/GSM modules. Motor control is handled through the L298N H-bridge, with PC817 optocoupler isolation, MOSFETs, and flyback diodes used to protect the low-power logic from high-current motor noise. Sensor inputs are interfaced directly to the controller, while proper grounding, filtering capacitors, and current-limiting resistors ensure reliable and noise-free operation. The overall design is organized into control, sensing, and actuation sections, making the system robust and easier to troubleshoot.

4.1 Power Supply and Control Flow

Power Supply:

Powered by a Li-ion battery with TP4056 for safe charging. Voltage regulators supply 3.3V to ESP32 and 5V to motors and sensors. Stable distribution ensures reliable operation.

Control Flow:

ESP32 reads sensors and executes programmed tasks. At scheduled time, it activates servo to dispense medicine and updates LCD/speaker.

IR sensors guide navigation and obstacle avoidance.

Feedback loops improve accuracy and reduce power consumption

4.2 Interfacing of Sensors and Modules

The IR sensors are connected to the ESP32 through digital pins for obstacle detection. The pulse oximeter and thermometer communicate with the controller using I2C or single-wire interfaces. The voice recognition module uses UART communication to send commands to the ESP32.The LCD display operates through the I2C interface for showing system status and messages. Servo motors and DC motors are controlled using PWM outputs from the ESP32 for precise movement. The PC817 optocoupler provides electrical isolation to protect the micro controller from motor noise. Short, shielded wires and proper grounding techniques are used to maintain reliable signal transmission.

4.3 Data Communication and Signal Flow

The ESP32 functions as the central unit that collects sensor data and sends control signals to various modules. When the IR sensor detects an obstacle, the controller stops or redirects the robot. The RTC module provides accurate timing to trigger the medicine dispensing process at the scheduled moment. The microcontroller sends output signals to the motors, servo motor, LCD display, and audio units for coordinated operation. The system is designed to support future IoT connectivity for remote monitoring and control. A stable and well-structured signal flow ensures accurate, smooth, and reliable functioning of the entire robot.

5. Working of the Project

The Smart Medicine Dispensing Robot operates through coordinated interaction between sensors, control logic, and mechanical components. The ESP32 microcontroller functions as the main controller, continuously monitoring inputs from the real-time clock and sensors. When the preset medication time is reached, the controller activates the servo motor to dispense the required medicine dose. Simultaneously, visual information is displayed on the LCD, and audio alerts are generated to notify the user. During movement, IR sensors detect obstacles in the robot's path and send signals to the ESP32. Based on this input, the controller regulates the DC motors through the motor driver to stop or change direction, ensuring safe navigation. All components receive stable power from a regulated lithium-ion battery system managed by a charging module. The system operates in a closed-loop manner, where sensor feedback is continuously processed to control actions accurately. By activating only the necessary modules at specific times, the robot conserves power while maintaining reliable operation. Overall, the project provides an automated and dependable solution for timely medicine dispensing and assisted mobility in healthcare applications.

6. Simulation Diagram

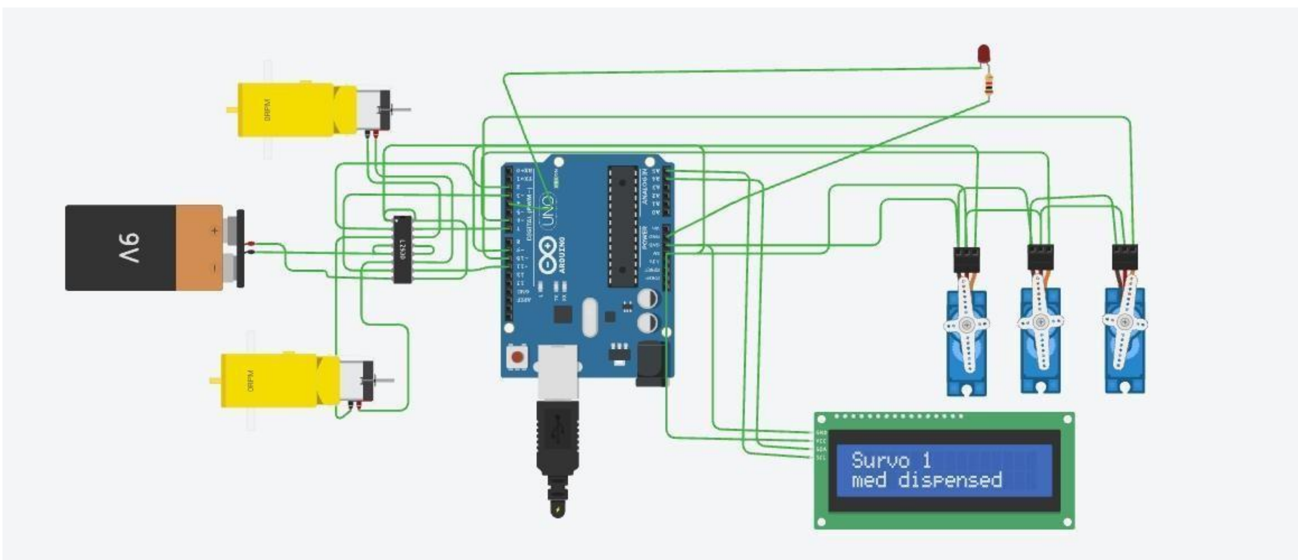

Figure 3: Simulation Diagram

7. Hardware

The Smart Medicine Dispensing Robot is constructed using a set of carefully selected electronic and mechanical components to achieve accurate dispensing, controlled movement, and reliable monitoring. The physical structure is built with lightweight materials to ensure stability and ease of motion during operation. DC gear motors, controlled through an L298N motor driver, provide smooth directional movement of the robot. An MG995 servo motor is used for the dispensing mechanism, enabling precise rotation to release the correct quantity of medicine at scheduled times.

The ESP32 microcontroller serves as the central control unit, processing sensor data, managing timing functions, and controlling all actuators. IR sensors are employed for obstacle detection, allowing the robot to navigate safely. A liquid crystal display (LCD) provides real-time system status and notifications, while a voice recognition module enables basic user interaction through audio commands. To protect low-power control circuits, a PC817 optocoupler is used to isolate the microcontroller from high-current motor sections.

Power is supplied by a rechargeable lithium-ion battery supported by a TP4056 charging module and voltage regulators that provide stable 3.3 V and 5 V outputs to different components. Communication between the ESP32 and peripheral modules is achieved using interfaces such as I²C, UART, digital GPIOs, and PWM signals. Proper grounding, short wiring paths, and noise-filtering components are incorporated to enhance system reliability. The integrated hardware configuration allows the robot to perform accurate medicine dispensing, safe navigation, and effective user notification, making it suitable for automated healthcare assistance.

8. Conclusion

The Smart Medicine Dispensing Robot provides a reliable and efficient solution for automating medication management, particularly benefiting elderly and chronically ill patients who often struggle with adherence to prescribed schedules. By combining embedded electronics, multiple sensors, and an ESP32-based control system, the robot ensures accurate dosing, timely alerts, and enhanced patient safety, directly reducing the risk of missed or incorrect medications. Its modular design, complemented by features such as obstacle detection, voice-assisted interaction, and integrated water dispensing, improves usability, accessibility, and patient independence. The Phase 1 development including circuit design, simulation, and hardware integration demonstrates the system's technical feasibility and cost- effectiveness. Its autonomous operation, error reduction, and capability for remote monitoring highlight tangible improvements in healthcare efficiency and reliability. Future enhancements, such as IoT integration, advanced sensing, adaptive algorithms, and real-world testing, will allow the system to scale for broader home and clinical applications. Overall, this project establishes a strong foundation for measurable improvements in patient compliance, safety, and quality of care, positioning the robot as a significant step forward in intelligent, patient-centered healthcare solutions.

9. Future Scope

The Smart Medicine Dispensing Robot can be further improved by integrating complete IoT and cloud connectivity, allowing caregivers and doctors to track medication schedules, receive alerts, and monitor patient health remotely. The dispensing mechanism can be enhanced to handle different forms of medicines and include barcode or image-based verification to reduce loading errors. Future versions may also incorporate additional health sensors such as blood pressure, ECG, or glucose monitors, making the robot a more comprehensive health-monitoring system. Advanced navigation features like LiDAR or AI based vision can help the robot move autonomously and deliver medicines directly to patients. Power upgrades, such as wireless charging or long-life batteries, will improve reliability.With these improvements, the robot can be adapted for use not only in homes but also in hospitals, pharmacies, and elderly-care centers, helping reduce human errors and improving medication management efficiency.

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