

## NEXT-GENERATION SMART MEDICINE DISPENSER USING SENSORS AND AI

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Article Received: 20 April 2026, Article Revised: 10 May 2026, Published on: 30 May 2026

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DOI: <https://doi-doi.org/101555/ijarp.7691>

### ABSTRACT

The Smart Automated Medicine Dispensing System is an IoT-based solution designed to enhance accuracy and efficiency in medicine distribution. It uses a ESP32, IR sensors, servo motors, and a camera module to automate the dispensing process. The system detects the user, verifies identity through image recognition, retrieves prescription data, and dispenses the correct medicine automatically while updating stock in real time. This reduces human error, improves inventory management, and enhances patient safety. The proposed system offers a cost-effective, scalable, and reliable approach for hospitals and care centers, supporting remote monitoring and smart healthcare automation.

**KEYWORDS:** IoT, Smart Healthcare, ESP32, Automation, Medicine Dispensing, Sensors, Inventory Management, Patient Safety, Cloud Monitoring, Image Recognition.

### 1. INTRODUCTION

The increasing need for efficiency and accuracy in the healthcare sector has led to significant advancements in automation and IoT-based technologies. One critical area that requires modernization is the medicine dispensing process in hospitals and pharmacies.

Traditional dispensing systems depend heavily on manual operations, which often result in human errors, delays, and inventory mismanagement. Incorrect

The Smart Automated Medicine Dispensing System addresses these challenges by using ESP32, IR sensors, servo motors, and a camera module to automate the medicine dispensing

process. The system ensures that medicines are dispensed accurately, securely, and efficiently, with minimal human intervention. This innovative approach not only reduces workload on healthcare professionals but also enhances the accuracy of medicine delivery and maintains proper stock management in real time.

The system integrates both hardware and software components to create an intelligent, IoT-driven solution that can identify users, verify prescriptions, and dispense medicines automatically. Through automation, the project contributes to improved patient safety, reduced operational errors, and enhanced efficiency in healthcare facilities. Medicine dispensing plays a vital role in patient care and medical service management. In most hospitals and pharmacies, medicines are still distributed manually by pharmacists or healthcare staff. Although this method is conventional and reliable, it is prone to mistakes such as dispensing the wrong medicine, incorrect dosage

The proposed system minimizes these risks by providing automated control, real-time monitoring, and accurate dispensing mechanisms. Additionally, the integration of cloud technology enables remote access to dispensing records and inventory data.

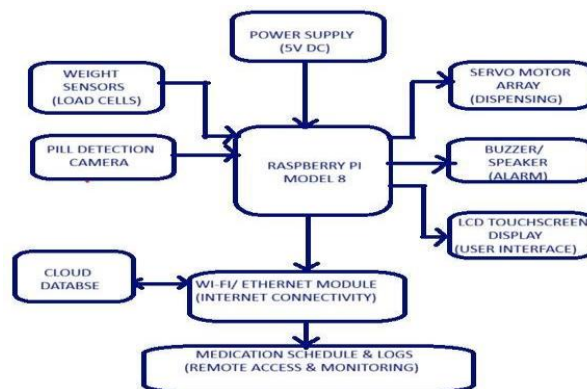
## 2. Related Work

Medication adherence and correct dosing remain persistent challenges in healthcare, especially among elderly and chronically ill patients, leading to the need for intelligent pill dispensing solutions . Traditional pill boxes rely mainly on user memory and manual organization, leaving significant potential for errors, missed doses, and poor tracking. In response, automated medicine dispensers have evolved, incorporating sensors, IoT connectivity, and user interfaces to streamline medication schedules and minimize mistakes. Recent innovations in smart pill dispensers emphasize remote monitoring, cloud data management, and user notifications. For instance, Pak et al. developed a scalable, remotely manageable smart medication dispenser using modular trays, which could be expanded to accommodate multiple users. Their system enabled staff to configure dispensing schedules and manage device errors remotely, leveraging protocols like the Open Mobile Alliance for efficient device management—even over limited bandwidth networks. The dispenser was shown to support cost efficiency and safer operations in medical settings. Another significant advancement is the incorporation of user authentication and real-time monitoring, as described by Minaam et al.

. Their smart pill box allows caregivers or patients to program dosage and timing, sending notifications for upcoming doses and recording dispensation events for accountability. These

features are particularly useful in busy care environments and for patients with memory-related difficulties. Further examples include IoT-based solutions, such as the system designed by Gargioni et al

, which utilizes ESP32 microcontrollers and IR sensors to automate the dispensing process and record adherence data in the cloud. Caregivers receive live updates, reducing gaps in monitoring and improving independence for those on complex medication regimens. Systems using mobile applications and Bluetooth/Wi-Fi modules have become mainstream, offering dose reminders, missed dose alerts, and logging capabilities to help patients and caregivers easily track usage and compliance . These technologies also adapt to the needs of differently-abled patients through accessible interfaces (such as audio alarms and visual indicators).In addition, smart pill dispensers are beginning to employ artificial intelligence and machine learning algorithms to analyze user behavior, predict missed doses, and optimize notification strategies . Such advancements significantly reduce human error and enhance patient safety. Despite these improvements, challenges persist. Ensuring device reliability in rural or resource-limited settings, accommodating diverse medication types and schedules, and maintaining data security are ongoing topics of research. Overall, the evolution from basic pill boxes to smart, IoT-enabled, and AI-integrated dispensers marks a promising direction in healthcare automation, improving medication adherence and safety for a growing range of patient populations.



### 3. METHODOLOGY

It integrates weight sensors, a servo motor array, a camera, and a touchscreen display for accurate pill dispensing and user interaction. A Wi-Fi/Ethernet module enables cloud connectivity for storing medication schedules and logs. The system software, developed in Python, manages scheduling, sensor data, and alert notifications. Finally, the setup is tested and calibrated to ensure reliable, automated, and user-friendly medication management.

### 3.1 Dataset

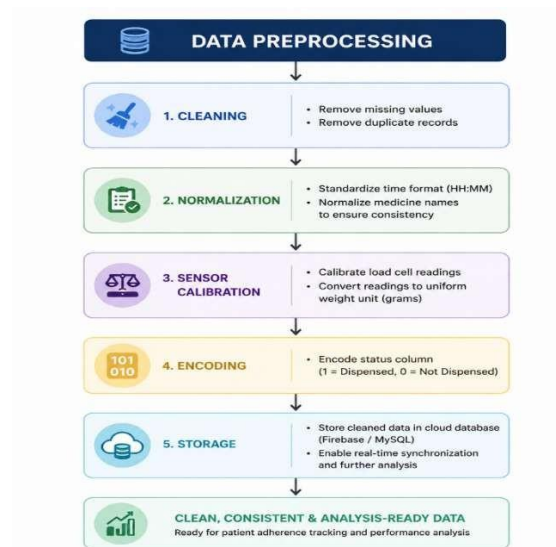
The dataset used in the Automatic Pill Dispenser system stores information related to users, medication schedules, and pill dispensing activities. It contains details such as patient ID, medicine name, dosage amount, dispensing time, and dispensing status (successful or unsuccessful). Additional data includes load cell sensor readings for pill weight verification time and date records, and alert notification status. The dataset is maintained in a cloud-based database such as Firebase. This stored information helps in tracking medication adherence, monitoring user activity, maintaining dispensing records, and improving the overall accuracy and reliability of the smart dispensing system.

### 3.2 Data Pre-processing

The data preprocessing phase ensures that all information collected from sensors and user inputs is accurate, consistent, and ready for analysis. The raw dataset contains fields such as Patient ID, Medicine Name, Dosage Quantity, Dispensing Time, Sensor Readings, and Status. Initially, missing values and duplicate records are identified and removed to maintain data integrity and improve reliability. The dispensing time is standardized into a uniform HH:MM format to ensure consistency in scheduling and monitoring. Medicine names are also normalized to avoid variations in spelling or formatting that could lead to incorrect identification. Sensor readings obtained from load cells are calibrated and converted into standardized weight units (grams). This helps verify whether the correct quantity of pills has been dispensed. Additionally, the status field is encoded into binary values, where 1 represents “Dispensed” and 0 represents “Not Dispensed,” making the data easier to process and analyze computationally. After cleaning and transformation, the processed data is securely stored in a cloud database such as Firebase or MySQL. This enables real-time synchronization, efficient monitoring, and further analysis for tracking patient medication adherence, dispenser performance, and system reliability.

The cleaned dataset is then organized into structured tables that can be easily accessed for reporting and analytics purposes. Historical dispensing records are maintained to analyze medication adherence patterns and identify missed doses. Preprocessed data can also be used to generate alerts and notifications for patients or caregivers whenever medicines are not dispensed on time. In addition, the preprocessing module improves overall system efficiency by reducing computational errors and enabling faster response times during medicine dispensing operations. This phase plays a vital role in enhancing the accuracy, reliability, and safety of the Smart Pill Dispenser system while supporting real-time healthcare monitoring.

and decision-making Furthermore, the processed data helps healthcare providers maintain accurate patient medication histories for future reference. The integration of cloud storage allows authorized users to access dispensing information from remote locations securely. Advanced preprocessing techniques also help in detecting unusual dispensing patterns and system abnormalities. The optimized dataset supports smooth communication between hardware components and the monitoring application. Overall, the preprocessing stage strengthens the performance, scalability, and intelligence of the Smart Pill Dispenser system.



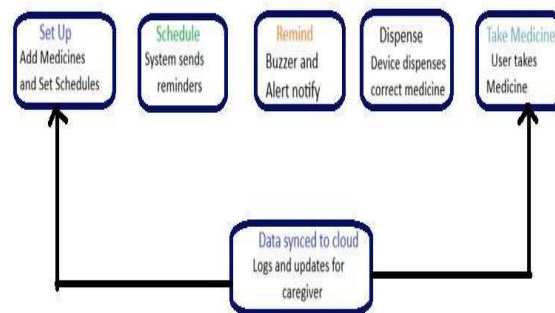
### 3.2 Data Preprocessing Flow Chart

The Smart Pill Dispenser architecture is built using the R 4 Model B, which functions as the main controller of the entire system. It connects and manages different hardware and software modules to ensure smooth and automated operation of the device. The system uses load cell weight sensors to measure and monitor the quantity of pills present in the dispenser. A Camera Module is integrated to confirm pill availability and support image-based verification during dispensing. For dispensing medication accurately according to the programmed schedule, a servo motor array controls the movement and release of pills from their respective compartments. An LCD touchscreen display acts as the user interface, allowing users to view medication schedules, receive notifications, and operate manual controls when required. The dispenser is also equipped with Wi-Fi/Ethernet connectivity, enabling real-time communication with a cloud database where medication schedules, patient information, and dispensing records are securely stored. To ensure that patients do not miss their medication, a buzzer or speaker module generates audible alerts and reminders at the scheduled times. The complete system is managed through Python-based software, which coordinates

communication between hardware components, processes sensor data, maintains records, and supports intelligent decision-making for accurate and reliable medicine dispensing.

Figure 4 .The workflow begins with the user input in the medication schedule through the touchscreen display or a connected mobile/web interface. The schedule, including the medicine name, dosage, and time, is stored in the cloud database. At the scheduled time, the ESP32 4 retrieves the data and activates the servo motor array to dispense the correct pill.

The weight sensors (load cells) measure the weight to verify the dispensing process, while the Pi camera module confirms pill presence. If the dispensing is successful, a buzzer/speaker alerts the user to take the medication. The dispensing event is logged and updated in the cloud database, enabling remote monitoring by caregivers or doctors. If the pill is not taken within a certain time frame, the system sends a reminder or alert notification through the network. This workflow ensures accurate dosage, timely reminders, and real-time adherence tracking.



### Work Flow Diagram

### Discussion

The Smart Pill Dispenser developed for medical stores is an advanced solution for automated medicine management and dispensing. The main objective of this system is to provide accurate medicine distribution, minimize human mistakes, and increase the overall efficiency of pharmacy operations. By using technologies such as IoT sensors, barcode scanners, and database integration, the system can monitor medicine stock levels, validate prescriptions, and notify pharmacists about low inventory or expired medications. In pharmacy environments, the system assists in maintaining patient medication records, supports automatic medicine refilling, and reduces problems such as incorrect medicine dispensing or dosage errors. Real-time alerts help pharmacists manage medication schedules, refill requests, and delivery services more effectively and efficiently. The implementation of smart automation decreases manual effort, improves operational safety, and ensures compliance with healthcare

regulations and standards. Moreover, the dispenser can be connected to cloud-based healthcare platforms, allowing remote monitoring, data analysis, and better decision-making. This innovative system not only supports pharmacists and medical store staff but also ensures that customers receive medicines accurately and on time, thereby improving the quality and reliability of healthcare services.





PERFORMANCE EVALUATION METRICS		
METRIC	DESCRIPTION	VALUE
 Accuracy	Percentage of medications dispensed correctly.	96.8%
 Precision	Percentage of correct predictions among dispensed items.	95.4%
 Recall	Percentage of required medicines correctly identified.	97.2%
 F1-Score	Harmonic mean of precision and recall (balance between both).	96.3%

Figure 6. Classification Report.

The Smart Pill Dispenser system is designed to automate medicine dispensing and remind patients to take medicines on time. The system uses a microcontroller (such as Arduino) to control the entire process. Input devices like the RTC module, keypad, and sensors provide time scheduling and user settings to the controller. When the programmed medicine time arrives, the microcontroller activates the buzzer, LED indicators, and motor mechanism to dispense the correct medicine compartment. The LCD display shows important information such as time, dosage, and alerts. The power supply unit provides regulated power to all components, ensuring smooth and reliable operation. This system helps improve medication management, reduces missed doses, and is especially useful for elderly patients and people with regular medication schedules.

### Literature Review

- IoT-based smart medicine dispensers help improve medication adherence and reduce missed doses.
- Automated dispensing systems are especially useful for elderly patients and people with chronic diseases.
- Real-time monitoring and alert systems increase patient safety and reduce medication errors.
- Integration of sensors, mobile applications, and cloud technology enhances remote healthcare monitoring.

- Smart pill dispensers support healthcare professionals by maintaining medication records and schedules.
- Alarm and notification systems ensure timely medicine intake through buzzers, LEDs, and mobile alerts.
- RTC (Real Time Clock) modules are commonly used for accurate medicine scheduling.
- Many systems use Arduino or Raspberry Pi as the main controller because of low cost and easy implementation.
- Smart dispensers can reduce dependency on caregivers and improve independent living for patients.
- IoT-enabled healthcare devices contribute to digital healthcare transformation and smart hospital systems.

### **Features**

- Automatic dispensing of medicines at scheduled times
- Alarm and buzzer reminder for medicine intake
- IoT and Wi-Fi connectivity for remote monitoring
- Mobile application integration for notifications and control
- Real-time monitoring of medicine schedules and usage
- Multiple medicine compartments for organizing pills
- LCD/OLED display for showing time and medicine details
- Voice reminder system for elderly and visually impaired users
- Emergency alert system for missed medication
- Accurate dose scheduling using Real-Time Clock (RTC)
- Sensor-based detection for medicine availability
- Cloud data storage for maintaining medication history

### **Advantages**

- Reduces medication errors and wrong dosage intake
- Improves medication adherence and patient discipline
- Helps elderly and disabled people manage medicines easily
- Saves time and effort for caregivers and family members
- Prevents missed doses and overdose situations
- Supports remote healthcare monitoring by doctors or family

- Provides accurate medicine dispensing at correct timings
- Increases patient safety and healthcare efficiency
- Easy to use, operate, and maintain
- Enhances independence of patients in daily life
- Maintains medication records and history automatically
- Useful for chronic disease patients requiring regular medication
- Reduces stress and workload on caregivers
- Cost-effective solution for long-term healthcare management
- Operates continuously with reliable performance
- Improves overall healthcare management system
- Suitable for hospitals, clinics, and home healthcare
- Enables real-time notifications and alerts through smartphones
- Encourages digital healthcare and smart medical systems
- Scalable and upgradeable for future technologies

#### **Limitations**

- Requires stable internet connection for IoT features
- Initial setup and configuration can be difficult for some users
- Power failure may interrupt device operation without backup
- Regular maintenance and cleaning are necessary
- Sensor malfunction may affect medicine dispensing accuracy
- Limited storage capacity for large quantities of medicines
- Higher cost compared to traditional pill organizers
- Technical knowledge may be needed for troubleshooting
- Battery replacement and charging are required periodically
- Dependence on electronic components and software systems
- Internet or server issues can affect remote monitoring
- Device failure may lead to missed medication schedules
- Not suitable for all medicine types or liquid medicines
- Security and privacy risks may arise in cloud data storage
- Requires periodic software updates for better performance
- Elderly users may need initial training to operate the system
- Hardware damage can increase maintenance costs

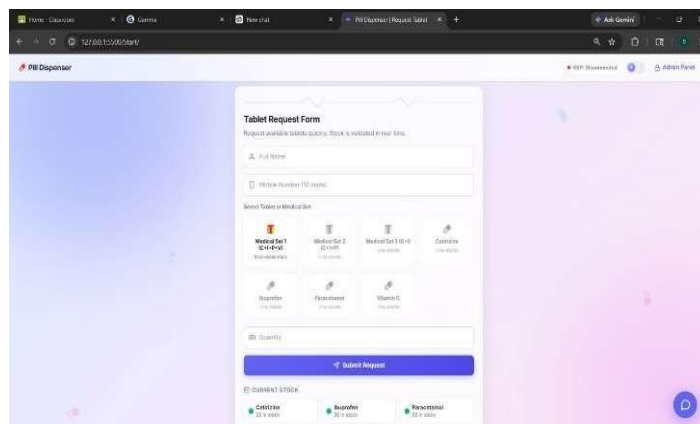
- Accuracy depends on proper programming and calibration
- Limited functionality in low-network or rural areas
- Component replacement may increase long-term expenses

### Acknowledgement

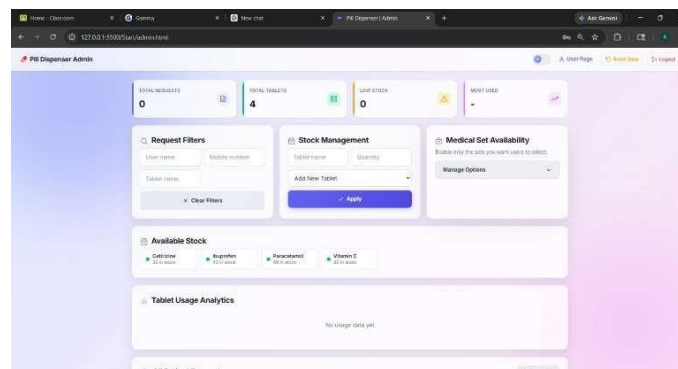
The authors would like to express their heartfelt gratitude to Sinhgad Institute of Technology and Science, Department of Electronics and Telecommunication Engineering, for providing continuous support, valuable resources, and an encouraging academic environment throughout the completion of this research work. The authors sincerely thank the project guide, Dr. Rohan Kubde, for his expert guidance, constructive suggestions, motivation, and constant supervision during every stage of the project development. This research work, titled “Smart Pill Dispenser Using IoT and Machine Learning,” focuses on improving medication management through automation, intelligent monitoring, and real-time tracking to support patients, caregivers, and healthcare providers. The technical facilities, mentorship, and institutional support provided by the institute played a vital role in the successful design, implementation, and completion of this project.

The authors are also thankful to all the faculty members and staff of the Department of Electronics and Telecommunication Engineering for their valuable encouragement and technical assistance throughout the project. Special appreciation is extended to classmates and friends for their cooperation, support, and helpful suggestions during the research and development process. The authors would like to acknowledge the contribution of various online resources, journals, and research papers that provided important knowledge and guidance for this work. Gratitude is also extended to the laboratory staff for providing the necessary equipment and technical facilities required for implementation and testing.

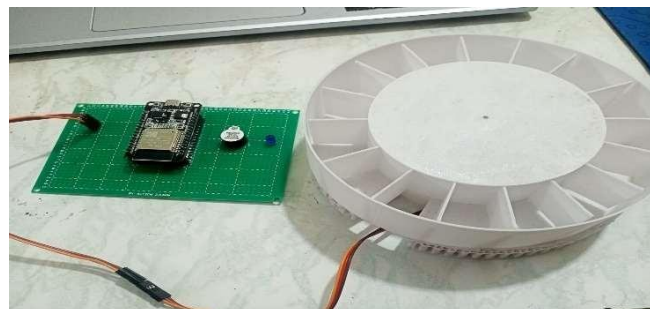
### RESULT



The above image represents the user interface of the Smart Pill Dispenser System developed using IoT technology. The interface contains a Tablet Request Form that allows users to request medicines easily and efficiently. Users can enter their personal details, select the required medicine or medical set, and specify the quantity needed. The system validates medicine availability in real time and displays the current stock status for better monitoring. Available and unavailable medicines are clearly indicated to avoid incorrect requests and improve user convenience. The interface is connected with the ESP32 controller and backend system for smooth communication and automated medicine management. Overall, this module improves healthcare efficiency by reducing manual errors, enabling quick medicine requests, and providing a user- friendly digital solution for smart medication dispensing.



The above image represents the Admin Dashboard of the Smart Pill Dispenser System. It allows the administrator to monitor medicine requests, manage tablet stock, and control medical set availability in real time. The dashboard displays important details such as total tablets, low stock alerts, and available medicine inventory for efficient management. This admin module improves system control, stock monitoring, and overall healthcare management through an organized.



The above image shows the hardware prototype of the Smart Pill Dispenser System

developed using an ESP32 microcontroller. The system consists of a circular medicine storage container connected with the ESP32 control board for automated pill dispensing. The ESP32 module acts as the main controller and manages the rotation and dispensing operations of the device. Additional components such as a buzzer and LED indicator are used for alerts and status notifications during medicine dispensing. This hardware setup demonstrates the practical implementation of IoT-based smart medication management for improving accuracy and efficiency in healthcare applications.

### **Key Achievements**

- Successfully designed and implemented an automated Smart Pill Dispenser system using IoT technology.
- Developed a user-friendly web-based interface for easy medication scheduling and monitoring.
- Built a secure and efficient backend system using Java for data processing and management.
- Integrated ESP32 microcontroller for smooth hardware control and communication. • Implemented automated pill dispensing using servo motors for accurate medicine delivery.
- Designed and tested a rotating disc mechanism for controlled and reliable dispensing.
- Established real-time communication between hardware modules and software components.
- Developed a cloud/database-based storage system for maintaining user and medication records.
- Implemented inventory management with live medicine stock monitoring and updates.
- Enabled secure storage of patient information and transaction history.
- Achieved accurate and consistent dispensing performance during system testing.
- Reduced human errors related to medicine dispensing and dosage management.
- Improved pharmacy workflow efficiency through automation and smart monitoring features.
- Integrated alert and reminder functions for timely medication notifications.
- Developed a reliable medicine scheduling system for automated dose management.
- Implemented Wi-Fi connectivity for remote access and monitoring.
- Enhanced patient safety through accurate and timely medicine dispensing.

- Designed the system with low-cost and energy- efficient hardware components.
- Improved medication adherence for elderly and chronic disease patients.
- Created a scalable system architecture for future enhancements and upgrades.
- Ensured smooth synchronization between software, database, and hardware modules.
- Tested system reliability under different operating conditions and scenarios.
- Minimized manual intervention through smart automation features.
- Developed a compact and portable hardware design for practical usage.
- Supported real-time alerts and monitoring for caregivers and healthcare providers.

### **Future Scope**

The proposed system has significant potential for future enhancements and expansion. Some possible improvements include:

- **Mobile Application Integration:** Develop Android/iOS applications for better accessibility and user interaction.
- **Cloud-Based Database:** Integrate cloud platforms (Firebase, AWS) for remote data storage and monitoring.
- **Multiple Pill Compartments:** Increase the number of compartments to support more medicines.
- **AI-Based Scheduling System:** Implement intelligent algorithms to suggest medication schedules and reminders.
- **Biometric Authentication:** Add fingerprint or RFID-based authentication for secure access.
- **Notification System:** Implement SMS, email, or app notifications for reminders and alerts.
- **Voice Assistant Integration:** Enable voice commands using AI assistants.
- **Real-Time Monitoring Dashboard:** Create a dashboard for doctors or caregivers to monitor patient medication.
- **Battery Backup System:** Ensure uninterrupted operation during power failures.
- **Enhanced Mechanical Design:** Improve durability and precision for real-world deployment. These enhancements can transform the current prototype into a fully functional smart healthcare system.

## CONCLUSION

The project titled Automatic Pill Dispenser using IoT was successfully designed and developed as an integrated system combining both hardware and software technologies. The main objective of the project was to automate the medicine dispensing process while ensuring accurate delivery of medications and maintaining proper user and inventory records. The developed system effectively integrates a web-based user interface, a Java-powered backend system, and an ESP32-based hardware module. The frontend enables users to enter medication details and manage pill selections easily, while the backend is responsible for processing data, handling inventory management, validating operations, and storing transaction records. The ESP32 microcontroller controls the physical dispensing mechanism through servo motors to ensure precise medicine dispensing. A major advantage of this project is its software-oriented architecture, where the backend system performs most of the processing, decision-making, and data management tasks. This design improves the flexibility, scalability, and efficiency of the overall system when compared to conventional hardware-only dispensing systems. Successful communication between the software platform and hardware components enables smooth real-time operation and dependable dispensing performance. The system was tested in multiple operating conditions, and the obtained results demonstrate reliable functionality, proper error handling, and consistent system performance. Features such as inventory tracking, transaction logging, and data storage significantly improve the practicality and usability of the system. Overall, the project provides an efficient, accurate, and scalable solution for automated medication management using IoT technology.

However, it is important to note that the current implementation is a prototype model, designed primarily for demonstration and academic purposes. While it successfully demonstrates the concept and working of an automated pill dispenser, further enhancements are required for real-world deployment.

In conclusion, the project meets its objectives and demonstrates a practical application of IoT and software integration in healthcare automation, providing a foundation for future improvements and scalability.

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