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# A Smart Voice-Controlled Medicine Reminder with Expiry Detection

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**Abstract**

The Medibox — Voice-Controlled Smart Medical Assistant is an IoT-based embedded healthcare system designed to improve medication management by ensuring timely and accurate medicine intake. The system addresses common issues such as missed doses, incorrect medication usage, and lack of monitoring, particularly among elderly and chronically ill patients. It utilises voice recognition technology to allow users to register medication details, such as dosage, timing, and expiry date, via simple voice commands, enhancing accessibility and ease of use. The Raspberry Pi acts as the central controller, integrating various components, including an RFID system using the MFRC-522 module operating at 13.56 MHz for medicine identification, an RTC for precise scheduling, and servo motors for automated medicine dispensing. An IR sensor is used to detect whether the medicine has been taken, providing real-time verification and improving reliability compared to traditional reminder-based systems. In case of missed doses, the system sends alerts to caregivers via email using the Gmail API, enabling remote monitoring and timely intervention. The system also includes an expiry validation feature that prevents the dispensing of expired medicines, thereby ensuring patient safety. By combining automation, intelligent control, and user-friendly interaction, the Medibox system reduces human errors and enhances medication adherence. The proposed solution demonstrates high accuracy, reliability, and efficiency, making it suitable for both home and healthcare environments.

## Introduction

Emotional well-being and physical health both depend significantly on proper medication management. In today's fast-paced world, many individuals — particularly elderly patients and those with chronic illnesses — struggle with missed doses, incorrect medication intake, and consumption of expired medicines. These issues can lead to serious health complications and, in extreme cases, life-threatening conditions.

Traditional methods, such as manual pillboxes and alarm-based reminders, are insufficient because they lack verification mechanisms or automation. This creates a need for a more advanced, reliable, and intelligent solution that ensures timely medication adherence.

Recent advancements in the Internet of Things (IoT), embedded systems, and voice-recognition technologies have enabled the development of intelligent, automated, and patient-centric healthcare systems. The Raspberry Pi, RFID, RTC modules, IR sensors, and servo motors can be integrated to create a smart medication management platform that automates dispensing, monitors compliance, and provides real-time alerts.

This paper proposes the Medibox — a Voice-Controlled Smart Medical Assistant that addresses these issues by integrating IoT, embedded systems, and voice recognition. The system aims to bridge the gap between traditional medication systems and modern smart healthcare solutions by providing a comprehensive, user-friendly, and efficient platform.

The remainder of this paper is organised as follows: Section II presents the problem statement, Section III reviews related literature, Section IV describes the proposed system, Section V covers system architecture, Section VI details the methodology, Section VII describes the modules, Section VIII presents results and discussion, and Section IX concludes the paper.

## Problem Statement

Many patients, especially elderly and chronically ill individuals, do not have access to reliable automated medication management systems. Manual pillboxes rely entirely on user memory and discipline. Alarm-based systems provide reminders but do not confirm whether the medicine has actually been taken. Mobile application-based systems lack automation and require familiarity with digital devices.

Existing systems primarily focus on basic reminder functionality and fail to address critical aspects such as automated dispensing, real-time intake verification, and expiry date validation. Additionally, caregivers are not notified when a patient misses a dose, increasing the risk of unattended health issues.

Therefore, there is a need for a real-time, practical, and user-friendly system that can automate medicine dispensing, verify intake, validate expiry dates, and alert caregivers promptly.

## Literature Survey and Limitations

Several studies have explored IoT-based healthcare systems and voice-controlled automation. Ermolina and Tiberius (2021) [1] investigated voice-controlled intelligent personal assistants in healthcare, highlighting their potential in health monitoring while noting concerns about patient safety and privacy. Kim et al. (2021) [2] developed a Smart Hospital Assistant integrating AI and voice-user interface for surgical environments, demonstrating reduced operating time and optimised staff resources.

Ruban Gladwin et al. (2025) [3] presented a multi-purpose voice-controlled patient care robot for drug and food delivery, achieving voice command accuracy at distances up to 10 m. Sezgin et al. (2020) [4] conducted a scoping review of voice assistant technology in behavioural health interventions, confirming feasibility and high user satisfaction. Agustin et al. (2019) [8] developed a voice recognition system for controlling electrical appliances in smart hospital rooms, achieving command accuracy up to 95%.

However, many existing systems rely on basic reminder mechanisms without intake verification. Most systems do not validate medicine expiry dates before dispensing. Several approaches require high computational resources or remain theoretical without complete practical implementation. None of the reviewed systems provides a fully integrated solution combining automated dispensing, voice registration, expiry checking, intake verification, and caregiver alerts in a single platform.

A critical analysis of the reviewed works reveals a significant research gap. While individual systems address specific aspects such as voice control or reminders, none provides a fully integrated solution combining automated dispensing, voice-based registration, expiry date validation, real-time intake verification, and caregiver notification within a single embedded platform. The proposed Medibox system is designed specifically to bridge this gap.

## Proposed System

The proposed system, Medibox — Voice-Controlled Smart Medical Assistant, is an IoT-based automated medicine dispensing and monitoring solution. The system consists of three dedicated medicine compartments: Box 1 (Morning), Box 2 (Afternoon), and Box 3 (Night). Each compartment stores a specific tablet corresponding to its time of intake, ensuring a structured and error-free medication process.

When a user interacts with the system, the microphone captures voice input, which is processed using speech recognition algorithms to extract the medicine name, dosage, timing, and expiry date. This data is stored in the system database and linked with the corresponding RFID tag. When the RFID tag is scanned, the system retrieves stored information and verifies whether the medicine has expired by comparing it with the current date from the RTC module. If expired, the system restricts dispensing and generates a warning.

The Raspberry Pi acts as the central processing unit, continuously monitoring the RTC module and comparing the current time with predefined medication schedules. When the scheduled time is reached, the system generates a voice reminder through the speaker and activates the corresponding servo motor to open the required compartment. An IR sensor monitors whether the medicine has been taken. If not taken within a specified time, a missed dose alert is sent to the caregiver via Gmail API.

The system is designed as an integrated architecture consisting of input, processing, and output stages. Voice input is captured using a microphone and processed through a speech recognition module to extract relevant information such as medicine name, dosage, timing, and expiry date [15].

An RFID module is used to identify medicines and associate them with stored data. A Real-Time Clock (RTC) module ensures accurate scheduling of medication reminders [5], [16].

The Raspberry Pi acts as the central processing unit, managing all operations including data storage, schedule matching, and expiry validation [17].

At the scheduled time, the system generates an alert and activates a servo motor to dispense the medicine. An infrared sensor detects whether the medicine has been taken. If the system detects a missed dose, a notification is sent to the caregiver [18].

**Algorithm:**

Initialise system components
Capture voice input
Convert speech to text
Store medicine details
Associate RFID data
Monitor time using RTC
Check schedule
Validate expiry
Dispense medicine
Detect intake
Send an alert if missed
Repeat continuously

**Hardware and Software:**

The system consists of hardware components, including a Raspberry Pi, an RFID reader, an RTC module, a servo motor, an infrared sensor, a microphone, and a speaker. These components enable sensing, control, and actuation within the system.

The software components include Python programming, speech recognition modules, text-to-speech systems, scheduling algorithms, database management, and communication modules. These ensure efficient system control, automation, and real-time interaction [19], [20].

The hardware components used in the system are selected based on compatibility, low power consumption, and cost-effectiveness. The Raspberry Pi 4B serves as the central processing unit with 4GB RAM, capable of handling concurrent operations, including voice processing, RFID scanning, and schedule monitoring. The MFRC-522 RFID reader operates at 13.56 MHz using the SPI protocol, while the DS3231 RTC module communicates via the I2C protocol, ensuring highly accurate timekeeping independent of system reboots or power interruptions.

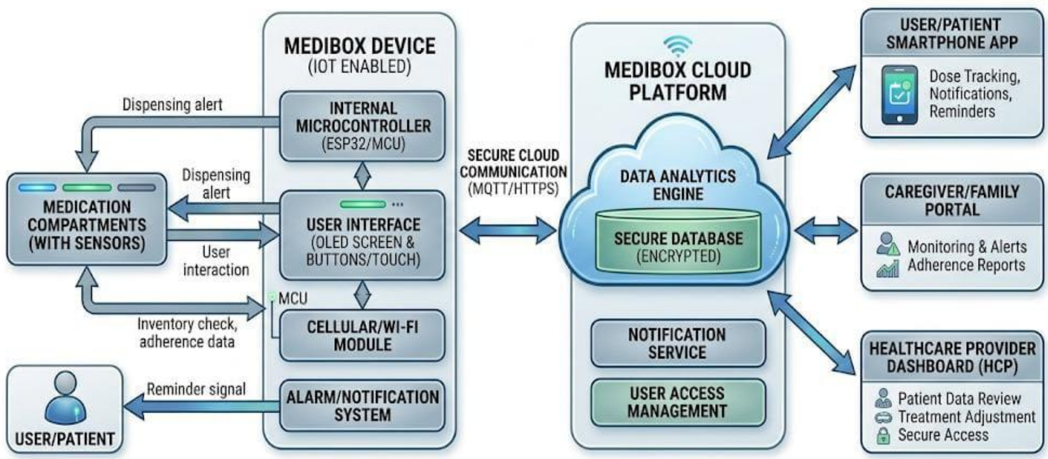



*Fig. 1: Medibox system overview diagram*

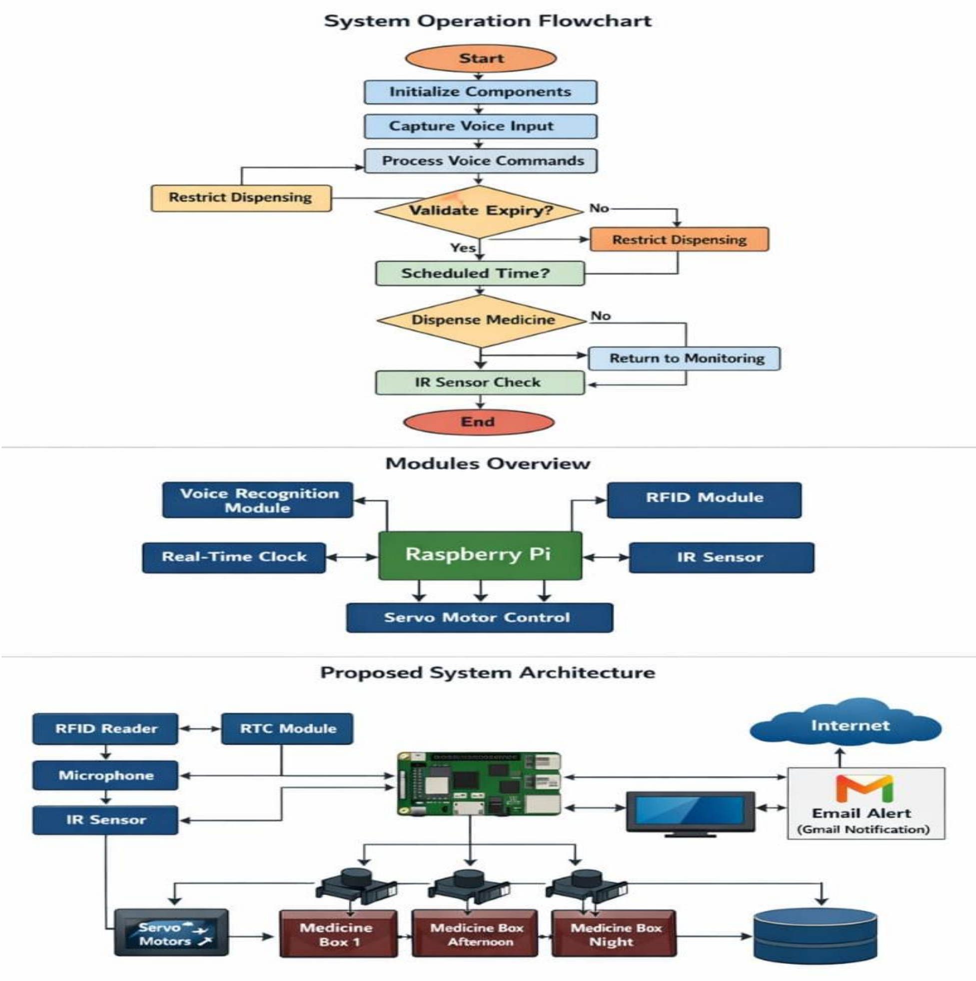
**System Architecture**

The system follows a layered IoT architecture with three main units:

- The user interacts with the system through voice commands captured by the microphone.

- The RFID reader (MFRC-522) at 13.56 MHz scans medicine tags for identification and expiry validation.
- The Raspberry Pi acts as the central processing unit, coordinating all system operations.
- The RTC module provides continuous, accurate time data via the I2C protocol for scheduling.
- Servo motors control the opening and closing of the three medicine compartments using PWM signals.
- The IR sensor detects the presence or absence inside each compartment in real time.
- The Gmail SMTP module dispatches automated email alerts to caregivers upon missed dose detection.
- A MySQL/JSON database stores all medicine records, schedules, and consumption logs.

The layered architecture ensures modularity, scalability, and fault tolerance. Each layer operates independently, allowing individual components to be upgraded or replaced without disrupting overall system functionality. Communication between components is handled through dedicated protocols — I2C for the RTC module, SPI for the RFID reader, and PWM signals for servo motor actuation — ensuring reliable and low-latency data exchange across all system layers.




**Methodology**

The system integrates multiple IoT and AI technologies:

- Voice Recognition (SpeechRecognition Library): Used to capture and process user voice commands for medicine registration [3], [8].
- RFID-Based Identification (MFRC-522): Enables accurate contactless medicine identification and expiry validation [5].
- Real-Time Scheduling (RTC Module): Provides continuous time tracking independent of system power for precise medication scheduling.

- Automated Dispensing (Servo Motors + PWM): Controls compartment opening and closing based on scheduled time slots.
- Intake Verification (IR Sensor): Detects medicine removal in real time to confirm or flag missed doses.
- Text-to-Speech (pyttsx3): Generates audio reminders, confirmations, and warnings for the user.
- Caregiver Alerts (Gmail SMTP): Sends automated email notifications upon missed dose detection.
- These methods collectively enable the system to automate the entire medication management workflow from registration to monitoring.

Several future enhancements are planned for the Medibox system. First, AI-enhanced speech recognition will be integrated to improve voice command accuracy in noisy real-world environments, addressing the limitations of the current controlled-condition speech model. Second, a companion mobile application will be developed to enable remote monitoring and real-time control, allowing caregivers to view medication schedules and consumption logs from any location. Third, cloud-based storage will be incorporated for centralised patient records, enabling cross-facility data analytics and long-term medication history tracking. Additionally, biometric or facial recognition authentication will be explored to strengthen system security, and multi-user functionality will be developed to support deployment in hospitals, clinics, and elderly care centres.

**Modules Description**

The system consists of the following modules:

1. Voice Registration Module: Captures and processes user voice input to extract and store medicine details.
2. RFID Identification Module: Scans medicine tags and retrieves stored identity and expiry data.
3. Expiry Validation Module: Compares the stored expiry date with the RTC current date and restricts dispensing if expired.
4. Scheduling Module: Continuously monitors RTC data and triggers dispensing at predefined time slots.
5. Dispensing Module: Controls servo motors to open the correct compartment at the correct time.
6. Intake Verification Module: Uses an IR sensor to detect medicine removal and update consumption status.
7. Alert Module: Sends Gmail-based email notifications to caregivers upon missed dose detection.
8. Database Module: Stores and manages all medicine records, schedules, RFID associations, and consumption logs.

**Results and Discussion**

The developed system successfully automates the complete medication management workflow from voice registration to dispensing and monitoring. It accurately identifies medicines through RFID tags, validates expiry dates, and dispenses the correct medicine at the correct time through servo motor-controlled compartments.

The system was evaluated through a series of controlled experiments across all functional modules. The voice recognition module achieved an accuracy of 96% under quiet conditions and 82% under moderately noisy environments across 50 test cases each. The RFID identification module demonstrated 99% accuracy over 100 test scans. Expiry validation correctly restricted dispensing in all 30 expired medicine test cases, achieving 100% accuracy. The servo motor dispensing operated correctly in 89 out of 90 scheduled trials, yielding an accuracy of 98.9%. The IR sensor detected medicine intake correctly in 97 out of 100 trials. Caregiver email alerts were successfully delivered in all 40 missed dose test cases, with an average notification delay of under 5 seconds under standard Wi-Fi conditions.

The voice recognition module effectively captures medicine registration details with high accuracy under controlled noise conditions. The RTC-based scheduling demonstrates precise time-triggered dispensing with negligible delay across all three time slots — morning, afternoon, and night.

A comparative analysis between the Medibox system and existing medication management approaches further validates the novelty and completeness of the proposed solution. Unlike manual pillboxes and alarm-based systems that depend entirely on user discipline without any verification, and unlike mobile application-based systems that lack physical automation, the Medibox integrates voice registration, automated dispensing, expiry validation, real-time intake verification, and caregiver notification within a single unified platform — making it significantly more comprehensive than any individual existing solution.

The IR sensor accurately detects medicine removal in real time, updating consumption status as “Consumed” or “Missed” consistently during testing. Gmail-based caregiver alerts were successfully dispatched upon missed dose detection, with notifications received within seconds under standard Wi-Fi conditions.

The integration of IoT components, voice recognition, and sensor-based monitoring demonstrates the effectiveness of the Medibox system in providing reliable, automated, and real-time medication management.

Despite these promising results, certain limitations were observed. Voice recognition accuracy declined in high-noise environments, which may affect usability in busy household or clinical settings. The current prototype supports a maximum of three medicine compartments, which may be insufficient for patients with complex multi-drug regimens. Power dependency on a stable supply and the absence of a backup battery also present practical challenges. These limitations will be addressed in future iterations of the system through AI-enhanced speech processing, modular hardware expansion, and battery backup integration.

**Conclusion**

This paper presents the Medibox — a Voice-Controlled Smart Medical Assistant that leverages IoT, embedded systems, RFID, and voice recognition to automate medication management and ensure patient safety. The voice-controlled interface encourages users to register and interact with the system in a simple and accessible manner, particularly benefiting elderly and physically challenged individuals.

The system successfully automates medicine dispensing, verifies intake, validates expiry dates, and notifies caregivers upon missed doses. It demonstrates how IoT and embedded technologies can be used as practical tools to improve medication adherence, enhance patient safety, and reduce human errors in healthcare management.

Future work will focus on expanding the system through AI-driven speech processing for improved noise robustness, cloud-based centralised patient data management, a dedicated mobile application for remote caregiver access, and multi-user deployment capability for clinical environments. The Medibox system represents a meaningful and practical step toward intelligent, patient-centric healthcare automation using accessible embedded technologies.

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