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# IoT-Based Pillbox with Caregiver Connectivity

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**Abstract**: *Medication adherence remains a critical challenge in chronic disease management. In India, over half of patients (55.14%) with diabetes struggle to follow their antidiabetic therapy correctly, and nearly 60% admit to missing doses or taking them at incorrect times. These lapses not only undermine treatment efficacy but also increase the risk of complications, hospitalizations, and healthcare costs. To address this gap, this research paper incorporates an intelligent, automated medication dispenser designed to improve adherence through real-time reminders and remote monitoring. The system integrates a microcontroller-driven pill dispenser, onboard sensors to verify dose retrieval, a buzzer and LCD for local alerts, and a wireless module to relay adherence data to caregivers and healthcare providers via a mobile application. When it's time for medication, the pillbox issues an audible and visual alert and releases the correct dose. If the patient fails to retrieve the medication within a preset interval, the device records a "missed dose" event and sends an immediate notification to designated caregivers. This dual approach—local prompting and remote oversight—ensures that patients receive timely support, while caregivers gain peace of mind and actionable insights..*

**Keywords**: Smart pillbox, Smart pill dispenser, Medication Adherence, IoT-Based Medication Reminder, Remote Caregiving.

## I. INTRODUCTION

Medication adherence, as defined by the World Health Organization (WHO), is "the degree to which an individual's behaviour corresponds to agreement with any advice or suggestions from a health care professional who delivers health care." Yet despite this clear benchmark, maintaining consistent medication routines remains a global challenge. Recent data indicate that only 40–50% of patients on long-term therapies in the Czech Republic adhere fully to their regimens, with similarly low rates in India (around 50%) [1]. In the United States, more than 80% of elderly patients deviate from their prescribed schedules, and over half discontinue antihypertensive treatments within twelve months [1]. The WHO attributes these lapses to a multifaceted web of influences—including socioeconomic constraints, gaps in healthcare delivery, complexities of therapy, condition-specific challenges, and individual patient factors—underscoring that true adherence demands active engagement rather than passive compliance.

The repercussions of poor adherence extend far beyond missed doses: in 2017 alone, non-adherence in the U.S. was linked to an estimated 125,000 deaths and 10% of all hospital admissions, imposing avoidable costs of approximately $105 billion annually [1][2]. Reviews of adherence research have catalogued over 700 individual determinants, with lack of social support, waning motivation, and simple forgetfulness emerging as the most frequent barriers to consistent medicine intake [3]. These stark realities point to an urgent need for solutions that not only prompt patients at the right moment but also integrate caregivers into the loop—enabling real-time monitoring and timely interventions.

## II. LITERATURE SURVEY

A number of IoT-enabled medication management systems have been proposed to tackle the challenge of missed doses and keep caregivers informed in real time. For instance, Aparna et al. [4] introduced MediSync, which combines computer vision, cloud services, and rule-based alerts to verify pill removal and maintain accurate inventory. In their three-stage pipeline, a YOLOv4 Darknet model running on Google Colab first detects whether a pill is present in the smart dispenser. It then proceeds to recognise individual pill types to track stock levels and notify users when refills are due. Finally, button sensors tied to the IFTTT API trigger push notifications not only to the patient but also to a designated caregiver whenever a scheduled dose is missed. This layered approach demonstrates how advanced IoT sensors and machine learning can both ensure correct pill intake and offload the monitoring burden from healthcare professionals.

Building on the notion of secure, user-friendly dispensers, another system targets elderly patients with cognitive or sensory impairments by integrating a smart pill dispenser and a mobile application [5]. Here, doctors update prescriptions via the app, pharmacists wirelessly load doses, and patients receive reminders through LED indicators, an LCD panel, an audible buzzer, and push notifications. A robust locking mechanism on each compartment enforces dosing schedules, preventing accidental or premature access. Crucially, this design allows caregivers and physicians to view adherence data remotely, promoting both independent living and timely intervention. In a small-scale trial, seniors reported higher confidence and reduced stress, highlighting the real-world value of marrying physical locks with mobile connectivity in medication adherence solutions.

Cost and accessibility are equally important for broad adoption. Harsha Vardhini et al. [6] developed a smart medicine box for under ₹1 000 (≈ USD 12), aimed at memory-impaired or low-literacy users. An ESP8266 NodeMCU microcontroller orchestrates LDR sensors to detect pill removal and magnet-reed switches to secure the box lid. At scheduled times, small DC motors open the correct compartment; if the LDR sensor registers pill removal, the lid closes automatically. Missed doses are logged and pushed to a web server over Wi-Fi, where caregivers can check adherence status at any time. This affordable system shows how off-the-shelf IoT components can deliver meaningful remote monitoring without imposing financial strain on vulnerable populations.

Finally, Ranjana et al. [7] proposed an automatic medicine reminder and health monitoring system that not only dispenses pills but also continuously tracks vital signs such as blood pressure and ECG at home. Sensor data are compared against clinician-defined thresholds, and alerts are issued to prompt medication intake or recommend seeking medical advice if readings fall outside safe ranges. This integration of health monitoring with medication management helps catch early warning signs of deterioration while reinforcing dosing routines. By combining dosage automation with real-time physiological feedback, the system aims to reduce both human error and clinical workload.

Together, these studies highlight the potential of IoT frameworks to improve adherence through real-time detection, secure dispensing, cost-effective hardware, and integrated health monitoring.

## III. PROPOSED SYSTEM

Figure 1 demonstrates the system overview that illustrates the architecture of an IoT-based smart pillbox integrated with a Flutter mobile application, Blynk IoT platform, ESP32 microcontroller, and Firebase database. This integrated approach ensures real-time monitoring, improves medication adherence, and strengthens patient-caregiver connectivity.

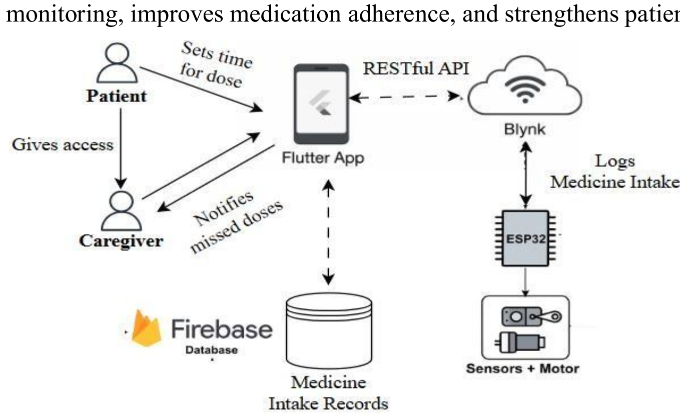


Fig. 1. System Overview

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**System Architecture of Smart Pillbox**

Fig. 2 illustrates the overall system architecture of the smart pillbox, highlighting the key hardware components and their interactions.

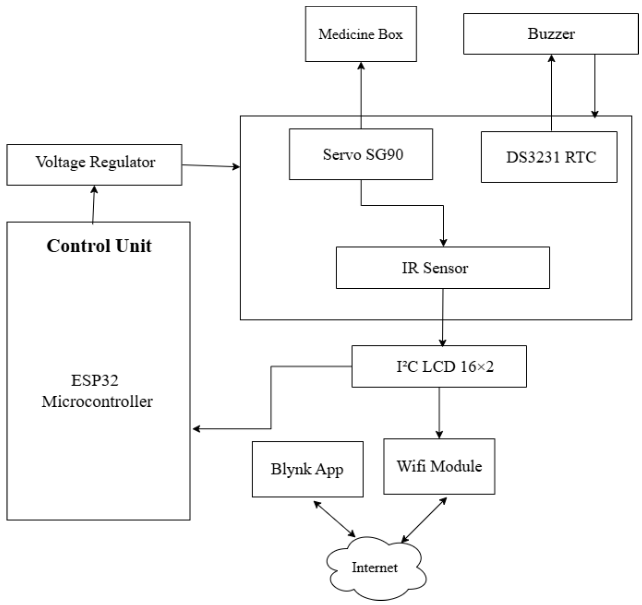


*Fig. 2. Block Diagram of Pillbox*

The hardware components of the Smart Pillbox with their role are explained in the following section: -

ESP32 Microcontroller**:** The ESP32 is the core control unit of the system, responsible for processing data, controlling peripherals, and enabling Wi-Fi connectivity. It handles the timing from the RTC module, sends commands to the servo motor, activates the buzzer, and communicates with the Blynk App. With built-in Wi-Fi and Bluetooth, it enables remote monitoring and notifications through the internet. It operates at 3.3V and supports various interfaces like GPIO, I2C, UART, and PWM.

DS1307 RTC Module: This real-time clock module provides precise and reliable timekeeping. It helps the ESP32 schedule medicine reminders accurately, even during power interruptions due to its internal battery backup. It communicates with the ESP32 via the I2C interface.

SG-90 Servo Motor: The servo motor is used to mechanically open a specific section of the medicine box at the scheduled time. Controlled via PWM signals from the ESP32, it enables the automation of medicine dispensing, improving ease of access for users.

IR Sensor: An infrared sensor is placed near the medicine compartment to detect if the user has picked up the medicine. It acts as a feedback mechanism to confirm medicine intake. Once the medicine is detected, the system can stop the buzzer and log the action.

5V Buzzer: The buzzer provides an audible alert to the user when it's time to take medication. It is activated based on the time schedule provided by the RTC and controlled by the ESP32. It ensures that the user gets notified even if they are not checking the app.

I²C 16x2 LCD Display: This LCD module is used to display real-time system status such as time, medicine alerts, and confirmation messages. It uses the I²C interface to minimize wiring and allows easy communication with the ESP32.

**Working of Smart Pillbox**

Fig. 3 illustrates the step-by-step working of the smart pillbox system designed to automate medication reminders and ensure timely intake. It highlights the step-by-step interaction between the user and the system—from setting reminders via a mobile app to receiving alerts through a buzzer and LCD, and detecting medicine intake using an IR sensor.

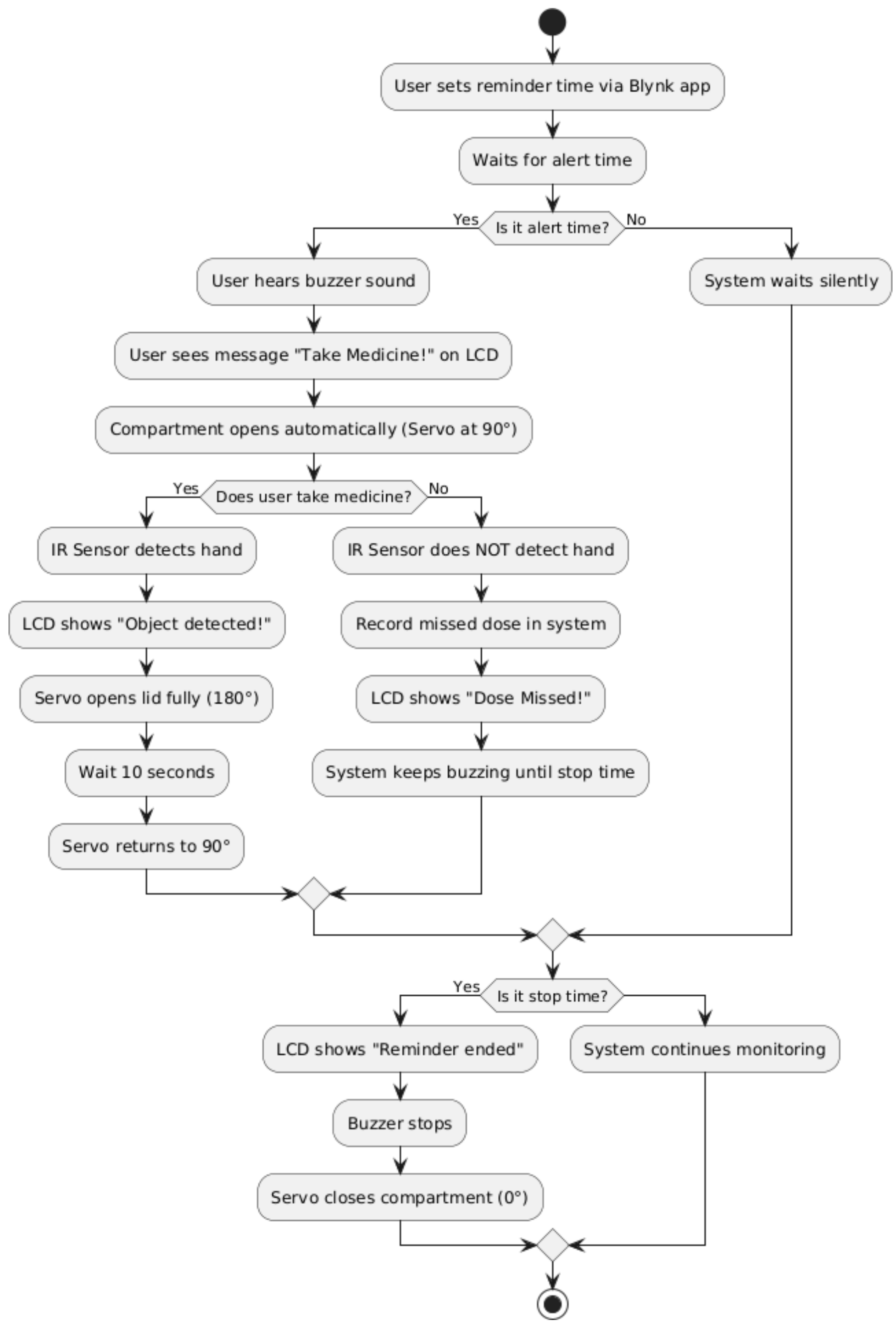


*Fig. 3. Flow Chart of Working of Smart Pillbox*

The system records missed doses if no interaction is detected, enhancing adherence tracking. This solution is particularly useful for elderly individuals, patients with chronic illnesses, or those with memory impairments who require regular medication and caregiver support.

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## IV. IMPLEMENTATION

### Hardware Implementation

The hardware circuitry of the system has been simulated and designed using Proteus software, as illustrated in Figure 4. Figure 5 demonstrates the IoT model of Pillbox with labelled hardware components.

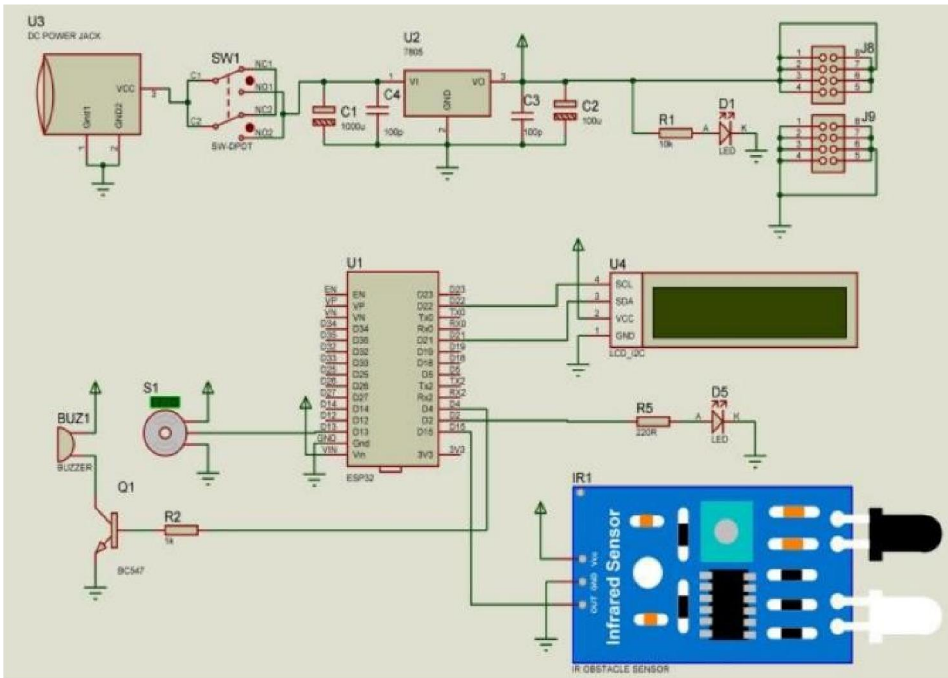


*Fig. 4. Circuit Diagram made using Proteus Software*

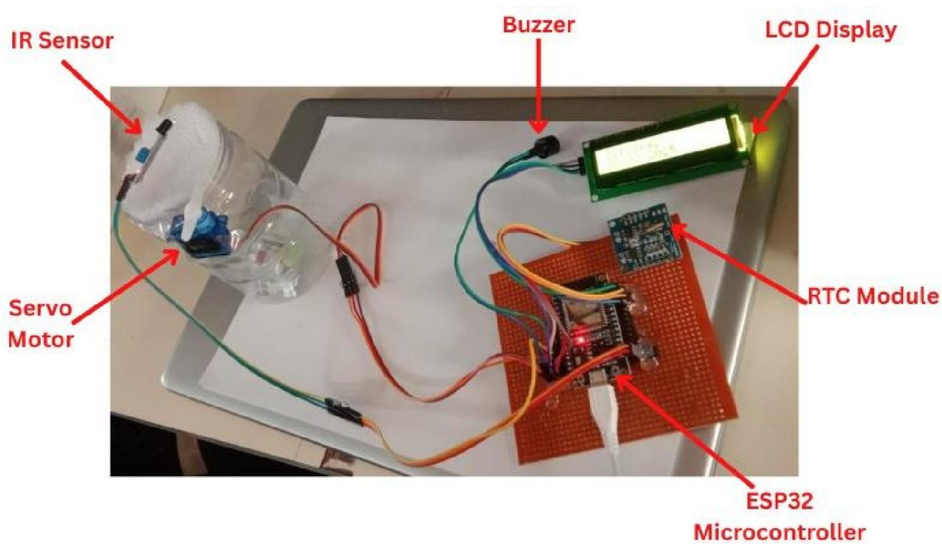


*Fig. 5. Physical Connection of Smart Pillbox*

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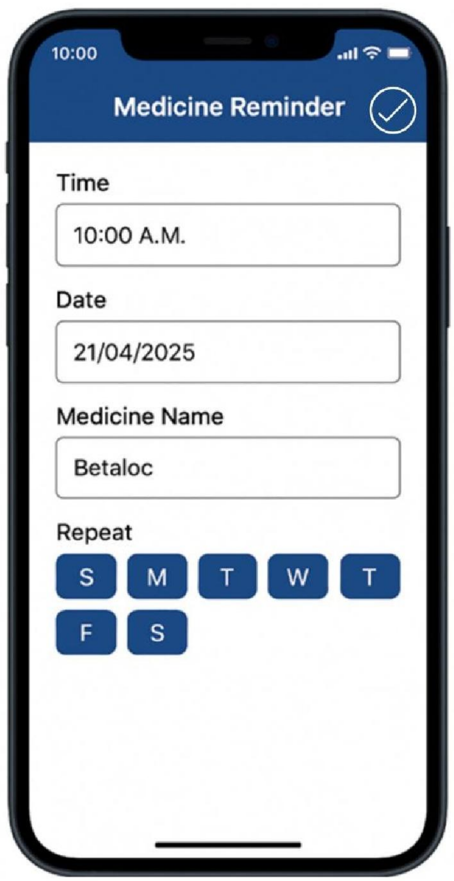
**Software Implementation**

Figure 6 demonstrates a prototype of flutter application screen when the user logged in as patient. The patient has to fill all the details related to the medicines and successfully schedule the medicines in order to get timely alerts for the medicines. At the scheduled time, the app ensures that the IoT Smart Pillbox gets activated and open the dispenser using the Servo motor.

Figure 7 demonstrates a prototype of flutter application screen when the user is logged in as Caregiver. The caregiver remotely monitors the medicine intake of the user. The caregiver is given the access by the patient so as to ensure secure data privacy. Before giving the access, the caregiver is authenticated using Firebase Auth package.



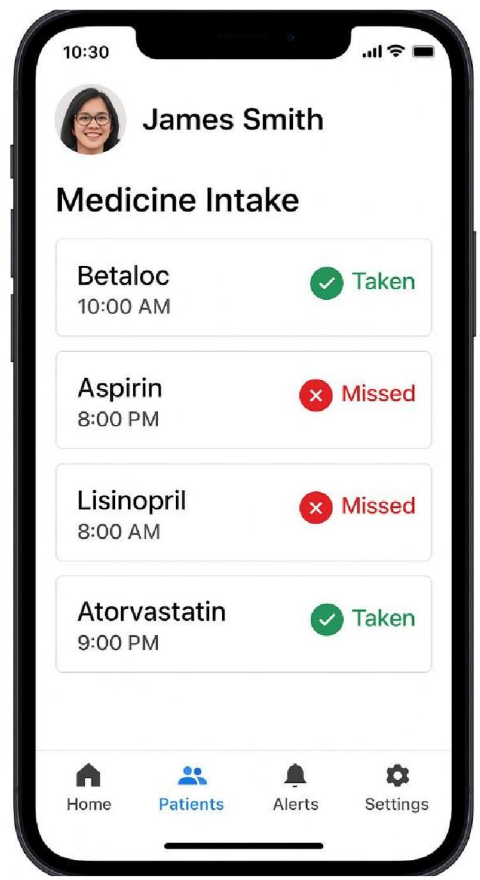




*Fig. 6. Patient-Medicine Scheduler Fig. 7. Caregiver-Medicine Intake Monitoring*

**COST ANALYSIS**

The developed smart pillbox is a cost-effective system where only 1220 BDT is needed to implement it. This project was accomplished by authors own financial contribution and it was not sponsored by anyone. The cost of each of the components used in the proposed work is shown in Table I.

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TABLE I : APPROXIMATE COST ANALYSIS

| Equipment Name | Quantity (pcs) | Unit Price (BDT) | Cost (BDT) |
|---|---|---|---|
| ESP32 Microcontroller | 1 | 350 | 350 |
| DS1307 RTC Module | 1 | 50 | 50 |
| 16 X 2 I2C Module | 1 | 130 | 130 |
| IR Sensor | 1 | 30 | 30 |
| 5V Buzzer | 1 | 10 | 10 |
| SG-90 Servo Motor | 1 | 80 | 80 |
| 16 X 2 LCD Display | 1 | 20 | 20 |
| Jumper wire + Breadboard | 1 | 50 | 50 |
| Installation Cost | | | 500 |
| Total Cost | | | 1220 |

## V. CONCLUSION

In conclusion, this IoT-based Smart Pillbox has demonstrated a practical, end-to-end solution for improving medication adherence by combining automated dispensing, real-time intake monitoring, and caregiver notifications through a familiar smartphone interface. Looking ahead, we can further boost adherence by designing an even more intuitive UI—think large, high-contrast buttons, clear icons, and optional voice prompts that guide elderly users through each step without confusion. Introducing light gamification elements—such as points for on-time doses, achievement badges, or gentle progress charts—can transform routine pill-taking into a motivating daily ritual. Future enhancements might also include adaptive reminders powered by simple AI (which learns your most missed doses and adjusts alerts accordingly), multi-language support, seamless integration with wearable health trackers, and periodic "check-in" quizzes or fun mini-games that reinforce the importance of staying on schedule. By blending accessibility, engagement, and smart automation, this project lays the groundwork for a truly patient-centered medication management system that grows and improves alongside its users.

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