

Development of an IoT-Based Smart Medication Dispenser with Real-Time Monitoring to Improve Patient Medication Adherence

Rafi Abdurrohim^{1*}, Abdullah Hanif², Karyo Budi Utomo³

^{1,2,3}Computer Engineering Technology Study Program, Departemen of Information Technology,

State Polytechnic of Samarinda

abdurrohimrafi@gmail.com^{1*}, abdullahhanif@polnes.ac.id², kbu@polnes.ac.id³

Abstract

Patient medication adherence in Indonesia remains a serious challenge, with reported non-adherence rates reaching 57% among chronic-disease patients, while conventional manual supervision by medical staff is time-consuming and prone to human error. This study aims to design and build a prototype of an Internet of Things (IoT)-based Smart Medication Dispenser equipped with real-time monitoring to improve patient medication adherence in a hospital environment. The system is built around an ESP32 microcontroller integrated with a DS3231 real-time clock for schedule accuracy, an RFID module for staff and patient authentication, a servo motor as the dispensing actuator, an ultrasonic sensor for retrieval verification, a DHT22 sensor for storage-condition monitoring, and a buzzer with an LCD for audio-visual notification. Activity data is transmitted to Google Firebase and displayed on a web dashboard for remote monitoring. The system was evaluated using the black-box testing method across seven functional scenarios covering initialization, staff configuration access, schedule notification, patient verification, retrieval confirmation, and timeout handling. The results show that all tested scenarios executed successfully: the system accurately dispensed medication according to schedule, restricted configuration access to authenticated staff only, and reliably logged and transmitted retrieval status - including "Successfully Taken", "Skipped", and "Not Taken" conditions - to the dashboard in real time. These findings indicate that the developed prototype can serve as a practical and reliable technological solution to support medication-adherence monitoring in clinical settings.

Keywords: Smart Medication Dispenser, Internet of Things, ESP32, Firebase, Real-Time Monitoring, Medication Adherence

1. Introduction

Patient adherence to prescribed medication schedules is a critical factor that directly determines the effectiveness of therapy and clinical outcomes. Non-adherence, however, remains a persistent problem: approximately 57% of chronic-disease patients in Indonesia have been reported to be non-adherent to their treatment schedules, a figure that is echoed by national health survey data showing over half of hypertensive patients facing similar difficulties. This condition is particularly detrimental for vulnerable groups such as elderly patients, and it complicates the overall treatment process that should otherwise run optimally.

In clinical settings such as hospitals, this adherence problem creates a domino effect that increases the workload of medical staff. Manual supervision requires nurses to routinely check on and remind each patient individually, a process that is inefficient, time-consuming, and prone to lapses, especially when the number of patients is not proportional to the available medical staff. Traditional supervision also lacks a real-time notification mechanism: when a patient forgets or is late in taking medication, there is no automatic alert to inform staff immediately, which can delay intervention and worsen a patient's condition. Furthermore, conventional methods do not provide automated activity logs, making it difficult for medical staff to accurately evaluate adherence over time.

To address these issues, an Internet of Things (IoT)-based Smart Medication Dispenser is proposed as an integrated solution that automates the supervision process while providing real-time data. IoT-based automation has been shown in prior studies to help patients take medication on time while simultaneously reducing the workload of caregivers through automated reminder and dispensing processes.

Several related studies have explored automated medication dispensing. Sahlab et al. developed an IoT-based intelligent pill dispenser supporting both mobile and stationary use with time synchronization and remote notification, improving adherence through automatic reminders and intake logging. Cu et al. designed a smart medicine box using an ESP8266, an RTC module, a buzzer, and an infrared sensor coupled with an Android application, although the internal RTC was found to drift over long periods, motivating the use of a more accurate external RTC such as the DS3231. Meghla et al. proposed a dispenser integrated with a diagnosis-oriented web application, while Bhogade combined a load-cell-based pill-level monitor with automatic GSM-based reordering. Guerrero-Ulloa et al. incorporated facial recognition for patient identification, and Bachkar et al. implemented an ESP32-based dispenser communicating through the Blynk platform.

Roumaissa and Rachid built a pill-management system linking doctors, pharmacists, patients, and caregivers through a mobile application, while Faisal et al. evaluated a real-time blister-pack monitoring intervention in a community pharmacy setting. Karagiannis et al. introduced a low-power portable pillbox with environmental sensing for remote treatment adjustment, and Hassain et al. combined a voice-based reminder with broader IoT health monitoring for elderly patients.

Building on these works, the present study focuses specifically on a hospital-ward context and combines RFID-based dual authentication (for staff configuration and patient verification), adaptive audio-visual notification, and ultrasonic-based retrieval confirmation within a single standalone ESP32 architecture connected to a Firebase-backed monitoring dashboard. Functionally, the developed device dispenses medication according to a schedule configured by staff through a keypad and RFID authentication. When the scheduled time arrives, the system provides layered notification through an LCD screen and a buzzer, then automatically opens medication access using a servo motor. If the medication is not retrieved within a defined time window, the system proactively sends a notification to the web dashboard, allowing staff or family members to perform remote monitoring and further follow-up, so that supervision responsibility is no longer centered solely on the patient but becomes part of an integrated, collaborative care system.

A comparative summary of the key components, communication systems, and mechanisms used across these related studies is presented in Table 1, which was used as a reference in designing a more optimal system architecture for the present study.

Table 1: Comparison of Related Studies

Study	Key Components	Communication	Mechanism	Advantages / Limitations
Sahlab et al. [1]	Mobile & stationary unit, RTC	Wi-Fi / connectivity module	Scheduled dispensing with sync	Improves adherence; limited retrieval verification
Cu et al. [2]	ESP8266, RTC, IR sensor	Android app (local)	IR-based intake detection	Simple and low-cost; internal RTC drifts over time
Meghla et al. [3]	ESP, GSM, gear motor	GSM + web application	Precision mechanical dispensing	Adds diagnosis feature; higher hardware complexity
Bhogade [4]	Load cell, GSM	GSM auto-reorder	Keypad/LCD manual scheduling	Tracks pill stock; no retrieval sensor
Guerrero-Ulloa et al. [5]	Camera (face recognition)	Caregiver mobile app	Visual + audio reminder	Strong identity check; camera raises privacy concerns
Bachkar et al. [6]	ESP32, RTC, servo/stepper, LDR	Blynk platform	Real-time reminder & logging	Similar MCU to this study; lacks dual RFID authentication
This Study	ESP32, DS3231, MFRC522 RFID, HC-SR04, DHT22	Wi-Fi + Firebase	Adaptive schedule, dual RFID auth, ultrasonic retrieval verification	Combines staff/patient authentication with automatic retrieval confirmation and real-time dashboard logging

Based on this background, the research problems addressed in this study are: (1) how to design and build an IoT-based Smart Medication Dispenser capable of dispensing medication automatically and accurately according to a defined schedule; (2) how the system can restrict configuration access to authorized staff only through RFID-based authentication; and (3) how the system can monitor medication-retrieval activity in real time using sensors and reliably transmit the data to a monitoring dashboard. Accordingly, this study aims to design and build an ESP32-based automatic medication dispenser that operates on a fixed schedule, restricts configuration access to authenticated staff, detects patient retrieval activity, and provides audible reminders, while transmitting activity logs to a real-time web dashboard.

2. Research Methods

This research was conducted at Abdoel Moeis Regional General Hospital (RSUD Abdoel Moeis), located in Samarinda, East Kalimantan, Indonesia, over a period of approximately three months from July to September 2025. The hospital was selected because it is a referral healthcare facility that serves inpatient, outpatient, and chronic or elderly patients who require intensive medication-schedule supervision, making it highly relevant to the objective of this research.

The system was developed using the waterfall development method, a classical and sequential software-engineering approach consisting of requirement analysis, design, coding, testing, and maintenance stages, in which each stage must be completed before proceeding to the next. This method was selected because the requirements of the Smart Medication Dispenser prototype had been clearly identified from the outset, and its linear workflow simplifies documentation and evaluation at the end of each stage.

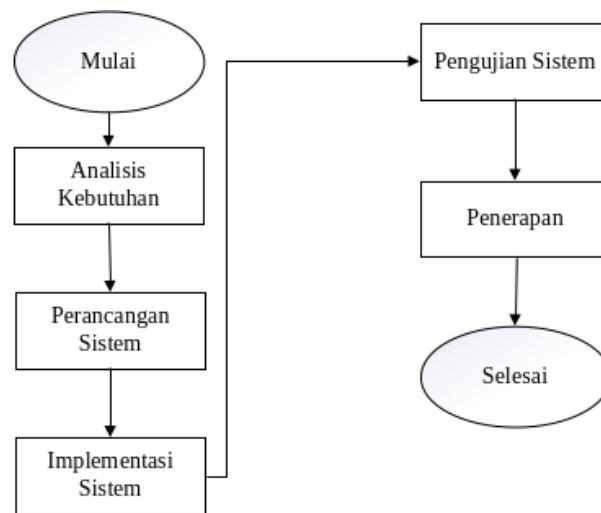


Fig. 1: Research Development Flow

The hardware and software components used in the development and testing of the system are summarized in Table 2.

Table 2: Tools and Materials

No.	Component	Function
1	ESP32 Development Board	Acts as the main processing unit that controls the RTC, sensors, servo motor, and LCD, and provides Wi-Fi connectivity for real-time data transmission to the dashboard.
2	RTC DS3231	Maintains accurate time even when the device is powered off; essential for schedule-based dispensing logic due to its low drift and temperature stability.
3	RFID Module (MFRC522) + Cards	Provides authentication so that only staff cards can access the configuration menu, while patient cards are used to acknowledge scheduled notifications.
4	Sensor DHT22	Measures ambient temperature and humidity around the medication storage compartment to help preserve medication quality.
5	Ultrasonic Sensor HC-SR04	Detects hand movement at the dispenser opening to automatically verify and log medication retrieval.
6	Servo Motor SG90	Opens and closes the dispenser compartment automatically when a schedule or verification event is triggered.
7	LCD 16x2 (I2C)	Displays time, environmental readings, device status, and reminder notifications to the user.
8	Keypad 4x4	Used for manual input such as schedule configuration and device reset by authenticated staff.
9	Buzzer	Provides an audible reminder when the scheduled medication time arrives.
10	Power Supply / Adapter (5V)	Provides a stable power source for all system components.
11	Google Firebase Realtime Database	Serves as the cloud backend that stores activity logs and schedules and powers the real-time web dashboard.

The overall system architecture, illustrating the interaction between the ESP32 microcontroller, sensors, actuators, and the Firebase-based cloud backend, is shown in Fig. 2.

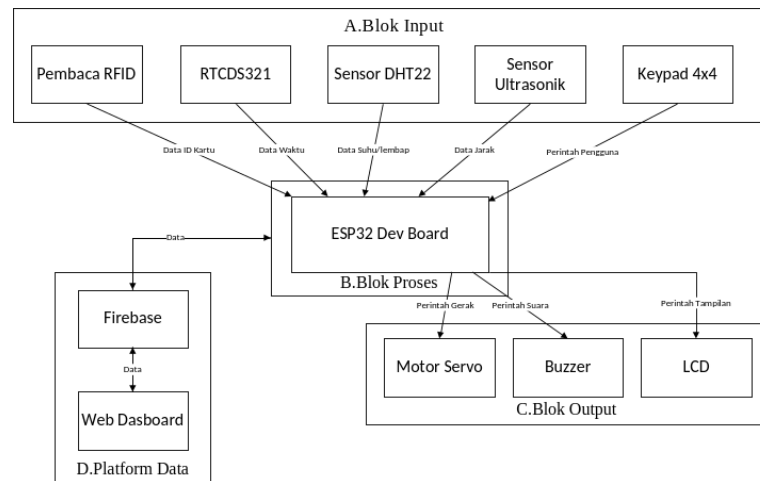


Fig. 2: System Architecture Block Diagram

Based on this architecture, the system operates through five main functional components. First, the ESP32 acts as the central processing unit, reading inputs from the RFID reader, DHT22 sensor, and ultrasonic sensor, while controlling the servo motor, buzzer, and LCD as outputs. Second, the DS3231 RTC module keeps track of accurate time for schedule execution even when the device is powered off, since timing is the core parameter for dispensing logic. Third, the RFID module (MFRC522) differentiates between staff and patient cards, so that only an authenticated staff card can unlock the configuration menu, while a patient card is used solely to acknowledge and open the dispenser during a scheduled notification. Fourth, the ultrasonic sensor (HC-SR04) is placed at the dispenser opening to detect hand movement when medication is retrieved, allowing the system to log a successful retrieval automatically rather than relying on a manual confirmation button. Fifth, all activity data - including dispensing schedules, retrieval status, and environmental readings - is transmitted over Wi-Fi to the Firebase Realtime Database and rendered on a web dashboard for remote monitoring by medical staff or family members.

On the software side, the dispensing logic follows an adaptive scheduled routine combined with an emergency/timeout-handling routine. During normal operation, the ESP32 continuously compares the current RTC time against up to three configured schedules per day. When a match occurs, the buzzer and LCD activate a "WAKTUNYA OBAT" ("Time for Medication") notification. If a valid patient RFID card is scanned within the notification window, the servo motor opens the dispenser and the ultrasonic sensor begins monitoring the compartment for a retrieval gesture; a successful detection is logged as "Successfully Taken" to Firebase. If the notification is not acknowledged within three minutes, the system automatically stops the notification and logs the event as "Skipped". If the dispenser has been opened but no retrieval is detected within one minute, the servo closes automatically and the event is logged as "Not Taken". Configuration access - for setting new schedules or resetting the device - is only granted when a valid staff RFID card is scanned, after which the keypad and LCD are used to input or modify the schedule, which is then synchronized to Firebase.

To support the configuration and monitoring functions, the Firebase Realtime Database was structured into three main nodes: a "schedule" node storing up to three configurable dispensing times per day together with their active/inactive status; a "logs" node recording every dispensing event with a timestamp and a status field ("Successfully Taken", "Skipped", or "Not Taken"); and a "telemetry" node storing the latest temperature and humidity readings from the DHT22 sensor. This structure was designed to keep read and write operations lightweight, which is important given the limited processing and memory resources of the ESP32, while still providing the web dashboard with all the information needed to render the schedule panel, the adherence chart, and the environmental-status panel described in Section 3.

From a user-interaction perspective, the system defines two primary actors: medical staff and patients. Medical staff interact with the device to configure schedules, refill medication, and reset the system, all of which require RFID authentication before the keypad and LCD configuration menu becomes accessible. Patients interact with the device only during an active notification window, where scanning a valid patient card and subsequently retrieving the medication completes the interaction cycle. This clear separation of roles at the authentication layer is what enables the system to enforce access security while keeping the patient-facing interaction as simple as a single card tap, which is particularly important for elderly or cognitively impaired users who are the primary beneficiaries of this system.

System evaluation was conducted using the black-box testing method, in which the system is tested based on given inputs and observed outputs without inspecting the internal code structure. This approach was chosen because it directly validates whether the system's functional requirements - dispensing accuracy, access security, and real-time monitoring reliability - are met from the end-user perspective, which is the primary concern of this study.

3. Result and Discussion

3.1. System Implementation

The hardware components were assembled into a compact standalone unit consisting of the ESP32 control circuit, the RFID reader, the DHT22 and ultrasonic sensors, the servo-driven dispenser mechanism, and the LCD-and-keypad interface, as shown in the final prototype in Fig. 3. On the software side, the ESP32 firmware was developed using the Arduino IDE, implementing the adaptive scheduling logic, the RFID-based dual-authentication routine, and the Firebase communication routine described in Section 2. Each status update - including dispensing events, retrieval confirmations, and timeout events - is structured as a JSON payload and pushed to the Firebase Realtime Database, from which the web dashboard reads and renders the data in real time.



Fig. 3: Final Prototype of the Smart Medication Dispenser

The web dashboard provides a main monitoring view summarizing daily operational status, a medication-schedule panel that reflects any configuration changes made through the physical device, and an adherence chart that visualizes the patient's retrieval history over time, as illustrated in Fig. 4. When staff configure a new schedule through the keypad, the update is synchronized to the "Medication Schedule" panel on the dashboard in real time, confirming that the IoT communication between the physical device and the server functions correctly.

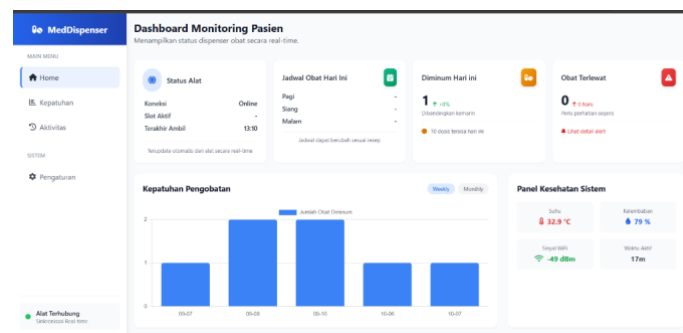


Fig. 4: Web Monitoring Dashboard

3.2. Functional Testing Results

Functional testing was carried out using the black-box method to verify that every core feature of the system - from initialization to dashboard reporting - operates correctly. Seven test scenarios simulating real operational conditions were designed and executed; the results are summarized in Table 3.

Table 3: Functional Test Scenarios and Results

No.	Test Scenario	Expected Result	Actual Result	Conclusion
1	System initialization: device powered on and connected to Wi-Fi.	LCD displays "System Ready" and the device successfully connects to the Wi-Fi network.	Device connected to Wi-Fi and LCD displayed the status as expected.	Passed
2	Configuration mode: staff scans an RFID card to enter setup mode.	System enters SETUP mode and the servo opens the dispenser for refilling.	System responded to the staff RFID card, the servo opened, and the LCD entered the configuration menu.	Passed
3	Schedule notification: system reaches a configured medication time.	Buzzer sounds periodically and the LCD displays a "Time for Medication" message.	The buzzer and LCD were active and provided notification as scheduled.	Passed
4	Patient verification: patient scans an RFID card during an active notification.	Notification stops, the dispenser opens, and the LCD displays a retrieval instruction.	Notification stopped, the dispenser opened, and the LCD displayed the instruction message.	Passed
5	Retrieval verification: patient retrieves medication from the dispenser tray.	Ultrasonic sensor detects the hand and a "Successfully Taken" log is sent to Firebase.	The sensor successfully detected the hand and the data was recorded in Firebase.	Passed

No.	Test Scenario	Expected Result	Actual Result	Conclusion
6	Failure scenario (notification timeout): notification ignored by the patient for 3 minutes.	Notification stops, dispenser remains closed, and a "Skipped" log is sent to Firebase.	After 3 minutes, the notification stopped and the "Skipped" data was recorded in Firebase.	Passed
7	Failure scenario (retrieval timeout): dispenser open but medication not retrieved for 1 minute.	Dispenser closes again and a "Not Taken" log is sent to Firebase.	After 1 minute, the servo closed and the "Not Taken" data was recorded in Firebase.	Passed

As shown in Table 3, all seven functional test scenarios were executed successfully. Each core feature of the Smart Medication Dispenser prototype responded as expected, indicating that the system satisfies the functional requirements defined during the design stage. Fig. 5 documents the LCD response when a valid staff RFID card is scanned to enter configuration mode, showing that the device correctly transitioned into the setup menu.



Fig. 5: LCD Display Upon Entering Configuration Mode

3.3. Discussion

The testing results validate that the core workflow of the system - from device initialization, network connection, and schedule execution to final reporting - functions as designed. In particular, the system successfully managed the full user-interaction cycle: it provided timely audio-visual notifications when a schedule was reached, validated patient identity through RFID authentication, actuated the servo motor to grant medication access, and, most importantly, verified actual medication retrieval using the ultrasonic sensor rather than relying on an unconfirmed timer alone.

The significance of these results is further reflected in the system's ability to handle abnormal scenarios. Successful handling of timeout conditions - automatically logging a "Skipped" status when a notification is ignored, or a "Not Taken" status when the dispenser is opened but medication is not retrieved - demonstrates that the underlying program logic is robust. This shows that the device functions not merely as an alarm, but as an intelligent monitoring tool capable of distinguishing between different adherence conditions. Every final status from all tested scenarios was also successfully transmitted and recorded in real time on the Firebase dashboard, confirming that the end-to-end IoT functionality of the system works reliably.

With respect to the research problems defined in Section 1, the results confirm that: (1) an IoT-based Smart Medication Dispenser capable of dispensing medication automatically and accurately according to a defined schedule was successfully designed and implemented using the ESP32 microcontroller and the Firebase platform; (2) the MFRC522 RFID module and the corresponding firmware logic successfully distinguished between staff and patient cards, ensuring that only an authenticated staff card could access the configuration menu, as validated in scenario 2 of Table 3; and (3) the ultrasonic-sensor-based retrieval verification, combined with reliable transmission of "Successfully Taken", "Skipped", and "Not Taken" statuses to the Firebase dashboard, demonstrated that the system can perform real-time monitoring reliably, as validated in scenarios 5 through 7 of Table 3.

From a practical standpoint, the results also suggest that the proposed system is feasible for deployment in a real hospital ward. The use of low-cost, widely available components - ESP32, DS3231, MFRC522, HC-SR04, and DHT22 - keeps the bill of materials relatively affordable compared to commercial IoT medication-management platforms, while the reliance on a standard Wi-Fi connection and the Firebase free-tier backend means that no dedicated server infrastructure is required for initial deployment. This affordability is particularly relevant for public hospitals such as RSUD Abdoel Moeis, where budget constraints often limit the adoption of proprietary medical IoT devices. At the same time, the modular hardware design - in which each sensor and actuator is connected to the ESP32 through clearly separated functions - makes the system relatively easy to maintain and to extend with additional sensors or actuators in future iterations. Compared with the related studies summarized in Table 1, the system developed in this study distinguishes itself by combining two features that are rarely implemented together: dual-role RFID authentication that separates staff configuration access from patient retrieval acknowledgment, and ultrasonic-sensor-based confirmation of actual medication retrieval rather than relying solely on a timer or a manually pressed confirmation button. Studies such as Bhogade [4] and Bachkar et al. [6] provide reliable scheduling and reminder functionality but do not verify whether the medication was physically removed from the compartment, while Guerrero-Ulloa et al. [5] achieve strong patient identification through facial recognition at the cost of additional hardware complexity and potential privacy concerns. By contrast, the approach adopted in this study - a lightweight ultrasonic sensor paired with RFID-based role separation - offers a practical

middle ground between security, retrieval verification, and implementation cost, making it well suited to a resource-constrained hospital-ward deployment such as the one targeted in this research.

Despite these positive results, several limitations were identified. First, the real-time monitoring and data-transmission functions depend on the availability and stability of the Wi-Fi network at the installation site; if the connection is interrupted, activity logs cannot be transmitted until connectivity is restored. Second, the current prototype relies entirely on an external power adapter and has no backup power source, so it cannot operate during a power outage. Third, although RFID authentication restricts access, the system cannot fully guarantee that the person retrieving the medication is the intended patient, since an RFID card could potentially be used by another individual. These limitations point toward promising directions for future development, such as adding a carousel-style multi-compartment mechanism to support polypharmacy, integrating a GSM module (e.g., SIM800L) as a backup communication channel for critical notifications, incorporating a rechargeable battery with a power-management module for continuity during outages, and adding a secondary biometric verification layer, such as a fingerprint sensor, to strengthen patient identity validation.

4. Conclusion

Based on the design, implementation, and testing process described in this study, an IoT-based Smart Medication Dispenser prototype was successfully developed using the ESP32 microcontroller as the main processing unit and the Google Firebase platform as the backend. The system successfully executed all of its intended core functionalities: providing audio-visual schedule notifications, securing configuration access through RFID authentication, dispensing medication automatically, and verifying medication retrieval using an ultrasonic sensor. The IoT functionality of the system was also proven reliable, as all activity data - including successful-retrieval status, skipped-schedule status, and device telemetry - was consistently transmitted and displayed in real time on the web monitoring dashboard. These findings indicate that the developed system successfully addressed the research problems formulated for this study and can serve as a practical technological solution to improve the efficiency of medication-adherence monitoring in clinical environments. Future development is recommended to focus on multi-compartment dispensing for polypharmacy management, backup communication via a GSM module, backup power integration, and additional biometric verification to further strengthen the reliability and security of the system.

Acknowledgment

The authors would like to express their gratitude to the management and medical staff of RSUD Abdoel Moeis, Samarinda, for granting access and providing valuable input during the field observation and testing stages of this research. The authors also thank the academic supervisors and the Informatics Engineering study program of [Institution Name] for their guidance throughout the design, implementation, and evaluation of this prototype.

References

- [1] N. Sahlab et al., "Development of an Intelligent Pill Dispenser Based on an IoT-Approach," *Advances in Intelligent Systems and Computing*, vol. 1026, pp. 33-39, 2020, doi: 10.1007/978-3-030-27928-8_6.
- [2] G. Cu, D. Chan, A. G. Chua, and E. G. Ramin, "A Smart Medicine Pill Box for Improving Medication Adherence," 2021.
- [3] R. T. Meghla et al., "An Internet of Things (IoT)-based Smart Automatic Medication Dispenser with an Integrated Web Application for Patient Diagnosis," in *Proc. 2022 5th Int. Conf. on Computer and Informatics Engineering (IC2IE)*, 2022, pp. 16-21, doi: 10.1109/IC2IE56416.2022.9970073.
- [4] S. Bhogade, "Design and Development of IOT Based Intelligence Pill Box," *Int. J. for Research in Applied Science and Engineering Technology*, vol. 8, no. 10, pp. 545-549, 2020, doi: 10.22214/ijraset.2020.31949.
- [5] Gleiston Guerrero-Ulloa, M. J. Hornos, C. Rodríguez-Domínguez, and Ma. M. Fernández-Coello, "IoT-Based Smart Medicine Dispenser to Control and Supervise Medication Intake," 2020, doi: 10.3233/AISE200021.
- [6] Y. B. Bachkar, A. Dattatray Tekale, and N. Santosh Pawar, "IoT-Based Automatic Medicine Dispenser Using ESP32 Microcontroller," *Int. Research J. of Modernization in Engineering Technology and Science (IRJMETs)*.
- [7] B. Roumaissa and B. Rachid, "An IoT-Based Pill Management System for Elderly," *Informatica (Slovenia)*, vol. 46, no. 4, pp. 457-468, 2022, doi: 10.31449/inf.v46i4.4195.
- [8] S. Faisal et al., "Implementation of a Real-Time Medication Intake Monitoring Technology Intervention in Community Pharmacy Settings: A Mixed-Method Pilot Study," *Pharmacy*, vol. 9, no. 2, p. 105, 2021, doi: 10.3390/pharmacy9020105.
- [9] D. Karagiannis, K. Mitsis, and K. S. Nikita, "Development of a Low-Power IoT Portable Pillbox for Medication Adherence Improvement and Remote Treatment Adjustment," *Sensors*, vol. 22, no. 15, 2022, doi: 10.3390/s22155818.
- [10] M. M. Hassain, A. Rahman, Md. N. I. Harun, Md. A. I. Emon, and Md. T. Alam, "Voice Activated Medicine Reminder Box with IoT Health Monitoring for Old People and Hospital," *European J. of Engineering and Technology Research*, vol. 10, no. 2, pp. 22-30, 2025, doi: 10.24018/ejeng.2025.10.2.3252.
- [11] I. Nuryanti and M. I. Prakoso, "Desain Smart Medicine Box dengan Notifikasi Berbasis Telegram Bot dan Mikrokontroler ESP32," *Jurnal Teknologi dan Sistem Komputer*, vol. 10, no. 3, pp. 301-308, 2022, doi: 10.14710/jtsiskom.2022.301.
- [12] M. T. Mokhtar, M. K. A. Zaini, and M. M. Rahman, "IoT-Based Medication Reminder System with Automatic Dispensing Mechanism," *Int. J. of Advanced Computer Science and Applications*, vol. 11, no. 8, pp. 432-437, 2020, doi: 10.14569/IJACSA.2020.0110855.
- [13] S. M. M. Rahman and M. S. Islam, "IoT-Based Smart Medication Reminder System for the Elderly and Chronically Ill Patients," *Int. J. of Computer Applications*, vol. 183, no. 1, pp. 17-21, 2021, doi: 10.5120/ijca2021919807.
- [14] M. H. Rashid and T. Ahmed, "Development of an IoT-Based Smart Pill Dispenser System for Elderly People," in *Proc. 2021 Int. Conf. on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT)*, 2021, pp. 1-6, doi: 10.1109/3ICT53559.2021.9581717.
- [15] R. S. Pressman, *Software Engineering: A Practitioner's Approach*, 7th ed. New York, NY, USA: McGraw-Hill, 2012.
- [16] R. B. Pradipta et al., "Medication Non-Adherence Among Chronic Disease Patients in Indonesia," [journal/report details], 2025.