Smart Pill Box Monitoring System for cognitive Impairment with Weight-Based Detection and Vision-Assisted Verification

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Abstract- *Skipping meds causes big problems, especially for older adults or those with memory issues. A new gadget helps by tracking pills through timing cues plus real-time checks. Alarms sound when it is time, repeating if nobody reacts. Instead of guessing, the device notices change in weight to confirm a dose was taken. Cameras add another layer, watching actions to back up the data. A camera setup might be added later to double-check medicine use by watching with smart image tools. When pills get skipped, alerts go out to helpers - those people can log taken doses themselves on a screen too. Testing happens online in a mock version that checks if reminders fire right, spotting when meds are taken, plus how it reacts after. This method works well now - it handles live tracking without big costs while staying flexible for growth.*

Key Words: **Smart pill box, load cell, HX711, ESP32, RTC, medication adherence, cognitive impairment, IoT healthcare, em-bedded systems, weight-based detection., computer vision, AIML, caregiver monitoring, simulation-based validation**

1. INTRODUCTION

Sticking to a medicine routine really matters when handling long-term health conditions [7], [8]. Getting the correct pill at the exact time and amount doctors say keeps things on track. Still, older people - particularly if they have trouble thinking clearly because of illnesses like Alzheimer's or dementia - can find it hard to keep up. Problems remembering might cause them to skip a dose, take one late, or even grab two by mistake. That kind of mix-up could trigger dangerous effects on their body.

Half of those on long-term treatments in wealthier nations do not follow their prescribed plans, reports the World Health Organization [1]. Worse still - people struggling with memory or thinking face even greater challenges. Labelled pill boxes show up a lot, so do notes and family watching over them; yet these tools too frequently fall short when it comes to steady, trustworthy use [9], [11].

Thanks to progress in Internet-connected devices, tools now help people handle their medicine schedules more easily [10]. Usually, these setups depend on detectors

and wireless parts to track when pills are taken. Still, many current options lean on clues like a container being opened or someone saying they took it - neither proves the dose was truly swallowed.

So it happens that a smarter way is needed - something steady enough to nudge people at the right time while quietly making sure pills are actually taken.

2. LITERATURE SURVEY

Back then, medicine alerts relied on basic beeps or clock signals. As IoT grew, so did the tools - now using sensors, live signal transfers, and stored records to shape smarter health support.

From Khan et al. [2], a smart pillbox links to the cloud via Arduino and ESP8266, sending updates on medicine intake. Real-time monitoring works well - yet pressing buttons is required each time. For those struggling to remember things, such steps could become a problem. Interaction stays hands-on, limiting ease for certain users.

Out in the field, Vimal and team [3] built a clever pill box that sends signals far away using LoRa tech. Even though it works well where networks are weak, its method waits for user actions before recording - meaning missed doses might go unnoticed.

Haque and team [4] built a pill tracker using IoT, linked to phones for alerts and logs. Still, every dose needs manual check-in, which trips up if someone overlooks the prompt.

Camera footage helps spot pill-taking by watching hands move, say Phan and team [5]. Though spotting gets sharper this way, the system demands more computing muscle. Costs climb alongside power needs. Everyday use at home becomes tougher under these conditions.

A setup shown by Maria [6] uses weight sensors along with rules or smart methods to spot things more accurately. Even if it works better, linking several sensors and complex computing makes the whole thing harder to manage plus pricier to build.

Looking at those studies, you see a pattern - boxes get opened, people click confirmations, sensors pile up. Most setups depend on signs like these instead of proof someone swallowed the pill. Some fixes miss real verification entirely. Others bring steep prices along with tangled designs.

Built right, such a setup must catch threats without constant oversight. Yet it should run smoothly where people actually work. Not too heavy on steps. Still sharp when needed most.

3. EXISTING SYSTEM

Some smart pillboxes use tiny computers inside them, along with sensors that track when a compartment opens. Yet even with alarms built in, they do not always work well for people who struggle to remember things clearly. Wireless signals let them connect elsewhere, sending data automatically. Though better than paper logs, gaps remain in how they support those with thinking difficulties. Their design often misses real daily challenges faced at home.

Most people rely on sensors attached to pill bottle lids to track when the container opens. Even so, just because the cap moves don't mean a dose was taken. Sometimes individuals lift the lid but skip swallowing the pill. Other times they pull out pills to use at another moment.

Pressing a button or replying via an app often serves as the way people log meds. Still, remembering to do it every time can slip, especially when thinking gets harder. Dependence on routine fades when minds struggle to keep pace.

Most people rely on alert systems like phone pings or loud beeps. Though timing gets easier with such cues, there's no real proof a pill was swallowed. Skipping sounds happens often, putting off meds slips by unnoticed, sometimes checkmarks appear even when nothing went into the mouth - so records lie flat. These signals organize moments but fail at truth keeping.

Camera setups paired with smart algorithms now check if patients take pills correctly. Even though accuracy gets a boost, expenses climb alongside energy needs. Privacy questions pop up along with tangled setup demands. These factors slow down how often people adopt them at home.

Most current setups depend on clues that aren't direct, demand constant input from users, yet they still lean on pricey, complicated tech. The gap shows clearly when simpler, dependable options are missing despite clear demand.

4. PROPOSED SYSTEM

The proposed system is a smart medication monitoring solution that helps patients with cognitive impairment keep track of their medication schedules. It combines scheduled reminders, weight-based detection, vision-assisted verification (for future improvement), and caregiver interaction to make sure patients take their medicine reliably.

At scheduled medication times, the system triggers an alert using a buzzer and visual signals. If the patient does not respond, the system sends repeated notifications at intervals until someone responds or a set time limit is reached.

When the patient takes their medication, the system detects tablet removal by measuring weight changes inside the pill container. This method is more dependable than traditional approaches like lid detection or manual checks. The system figures out if a tablet has been taken by comparing the weight before and after the scheduled time.

To further improve reliability, a vision-based verification module is suggested for future use. In this method, a camera activates only during medication events after detecting tablet removal. The recorded data can be checked with computer vision techniques to confirm whether the patient has actually consumed the medication, which helps tell the difference between taking the tablet and simply removing it.

If there is no response within the set time frame, the system marks the event as a missed dose and notifies the caregiver. The caregiver can manually confirm if the medication was taken using a user interface, especially if the patient is not near the device.

All medication events, including the time, status (taken, not taken, or missed), and type of verification, are logged and stored for monitoring and review. The system's workflow is tested using a web-based simulation environment, which shows reminder activation, intake detection, verification logic, and caregiver interaction.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 05 | May 2026 www.irjet.net p-ISSN: 2395-0072

5. SYSTEM ARCHITECTURE

The proposed system has a layered structure with four main components: the sensing and actuation layer, the processing and control layer, the connectivity layer, and the presentation layer. This modular design allows for flexibility, scalability, and easy future implementation since each layer works independently.

5.1 Sensing and Actuation Layer

This layer detects system events and generates alerts. It uses weight-based sensing to identify when a tablet is removed and includes an alert mechanism with a buzzer and visual indicators. The system continuously checks weight changes during scheduled medication times to see if a tablet has been accessed. Alerts go off at set intervals and repeat if no response is received.

5.2 Processing and Control Layer

The processing layer handles the overall system logic and decision-making. It controls the workflow, including activating reminders, managing repeated alerts, detecting tablet removal, and classifying events (taken, not taken, or missed). The system runs through defined states like idle, alert, detection, and timeout, ensuring orderly and dependable execution.

5.3 Connectivity Layer

This layer allows communication between the system and outside interfaces. Medication events, including timestamps and statuses, are sent to a remote interface for monitoring. It supports real-time updates and sends notifications to caregivers if doses are missed or if there are unusual conditions.

5.4 Presentation Layer

The presentation layer offers a user interface for patients and caregivers. It shows medication schedules, real-time updates, and alerts. Caregivers can monitor patient activities from afar and manually confirm when medication is taken if needed. The interface also keeps a record of past events for tracking and review.

5.5 Vision-Based Verification (Future Extension)

In the future, a camera-based verification module can be added to the system. This module activates during medication events and uses image analysis to confirm actual consumption. This addition will improve the system's reliability by clearly distinguishing between tablet removal and intake.

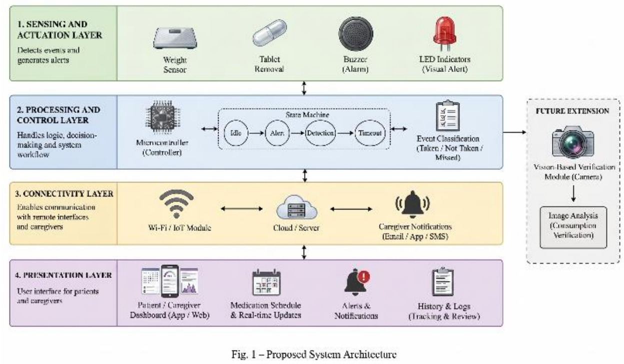

Fig-1: Proposed System Architecture

6. HARDWARE IMPLEMENTATION

The proposed system can be set up using a variety of low-cost and common hardware components. The design supports weight detection, alert generation, and connectivity for real-time monitoring. The hardware setup might be developed in the future as an extension of the current simulation-based system.

6.1 Weight Sensing Module

A load cell measures the weight of the pill container. The analog signal from the load cell is amplified and converted into digital form using an HX711 analog-to-digital converter. This allows for precise measurement of small changes in weight when tablets are removed.

6.2 Real-Time Clock Module

A real-time clock (RTC) module, like the DS3231, can be added to keep accurate timing for medication schedules. This ensures that alerts trigger at set intervals, even after system restarts or power outages.

6.3 Processing Unit

A microcontroller, such as the ESP32 or something similar, can manage system tasks. This includes processing sensor data, controlling alerts, and handling communication. The controller runs the logic for medication detection and overall system function.

6.4 Alert Mechanism

The system can have a buzzer and LED indicators to notify users at scheduled times. The visual and audio alerts make sure the user receives medication reminders.

6.5 Connectivity Module

Wireless communication, such as Wi-Fi, can transmit medication data to a remote interface. This enables caregivers to monitor patient activities in real time.

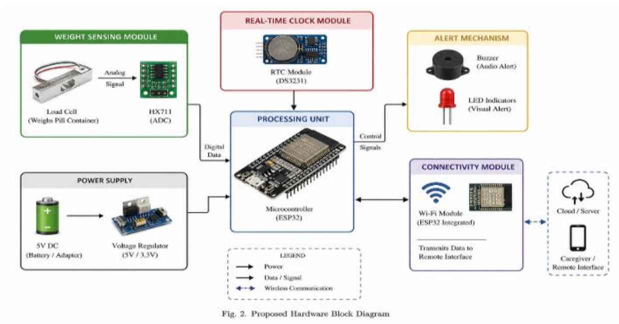

Fig-2: Proposed Hardware Block Diagram

TABLE -1: Proposed Components and Specifications

Component	Model / Type	Key Specifications	Purpose in System
Load Cell	Strain Gauge Load Cell	Capacity: 1–5 kg; Sensitivity: ~1.0–2.0 mV/V; Accuracy: ±0.03% FS	Measures pill container weight
ADC Module	HX711	24-bit ADC; Gain: 32/64/128; Supply: 2.6–5.5 V	Converts analog load cell signal to digital
Real-Time Clock (RTC)	DS3231	Accuracy: ±2 ppm; Battery backup; I2C interface	Maintains precise medication timing
Microcontroller	ESP32	Dual-core, 240 MHz; Wi-Fi + Bluetooth; 3.3 V logic	Controls system logic and communication
Buzzer	Active Buzzer	Voltage: 3–5 V; Sound level: ~85 dB	Provides audio alerts
LED Indicator	Standard LED	Voltage: 2–3 V; Current: 10–20 mA	Provides visual alerts
Connectivity Module	Wi-Fi (ESP32)	IEEE 802.11 b/g/n; Range: ~50–100 m	Enables data transmission to remote interface

7. SOFTWARE IMPLEMENTATION

For a validation and system implementation purpose, a software-based simulation approach is adopted. The implementation is divided into two main parts, including system logic simulation and a web-based interface for the users.

7.1 System Logic Simulation

The primary logic is embodied in a Complex type workflow that emulates reminder generation, tablet detection, and response handling. The overall setting for this system is the medications schedules. Finally, at the scheduled moment, the system triggers an alerting mechanism (buzzer simulation). In the absence of a response, the alert is repeated at set intervals for a predetermined period. The repeated notification can also guarantee that missed doses are kept to a minimum. The logic behind this weight variation is supposed to emulate the removal of tablets. The weight values before and after the scheduled event are compared to find out if the tablet has been accessed or not. If the change is above set thresholds, the system deems the event a tablet removal event. The system then enters the verification stage, which is achieved by detecting when the tablet is removed. Finally, upon detection of tablet removal, the system switches into a verification stage; a vision-based verification module, where the camera is triggered in an attempt to verify the actual consumption, is considered as a future enhancement. This is done currently through predefined scenarios or by providing sample inputs. If there is no indication of tablet removal within the defined window of time, the system registers the missed dose and fires the caregiver notification. The caregiver can manually confirm the removal of medication through the user interface if the need arises. All events are recorded with timestamps and categorized as taken, not taken, and missed for further processing.

7.2 Web-Based Interface

To visualize the system behaviour and simulation results, a web-based dashboard is developed using standard web technologies like HTML, CSS, and JavaScript. Other data represented includes schedules for taking medications, on-time alerts, and current system statuses. The dashboard provides different visual indicators for different results:

Green: Medication is Taken

Red: Missed dose

Yellow: Yet to be or verification phase

Caregivers can also check on the patient's activity remotely and manually update the status of medication if necessary. Forensic Evidence Theories

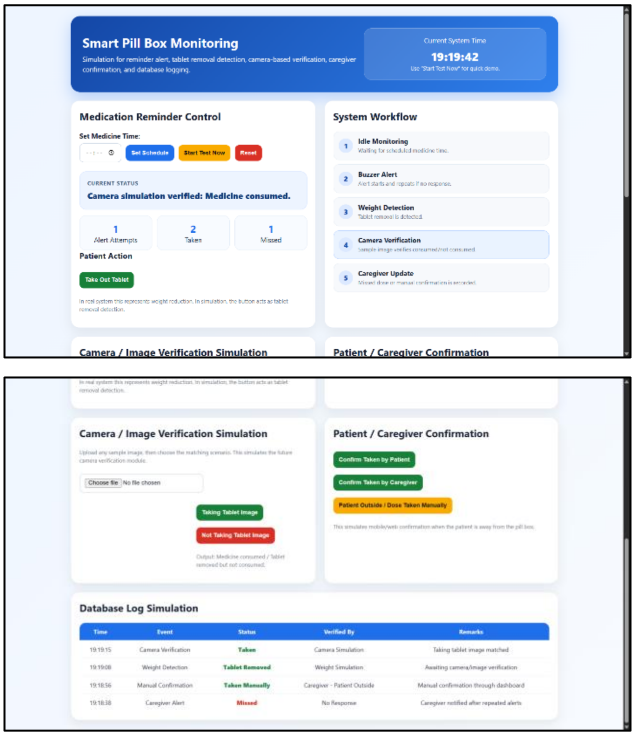

Fig-3: Web Dashboard Interface

8. METHODOLOGY

The methodology for the proposed system includes its weight-based detection capabilities, managing alerts, and decision-making based on various workflows. For this purpose, the system uses a structured approach so that proper medication monitoring can be ensured.

8.1 Weight Measurement and Calibration

For detection of removal of tablets, the system uses the weight-based approach. First, calibration is done in two stages. First, the variation in the baseline weight of the empty pill container is recorded to eradicate offset errors. Then, a special reference value is taken into account concerning the expected variations in the tablet weight. This calibration process ensures that the changes in weight, however small they may be, can be accurately detected and differentiated from noise.

8.2 Threshold-Based Detection Algorithm

Threshold-based detection mechanisms determine tablet removal. The tablet-removal process is determined by using a threshold-based detection system, and at the scheduled medication time, the initial weight is noted as; This gives the initial weight at the time of scheduled medication as:

$$\Delta W = W_{before} - W_{after}$$

If the weight difference calculated is more than a predefined threshold T_w (the minimum expected tablet weight), the tablet is deemed removed.

If,

$\Delta W \geq T\ w$, then Tablet removed

$\Delta W < T\ w$, then No tablet is removed.

The threshold value is selected in a way that sensitivity and stability are balanced so that actual tablet removal is sure to be detected while any false detection due to noise is minimized.

8.3 Alert and Reminder Mechanism

On the predefined times for medication, an alert is activated using a buzzer and visual indicators. Thereafter, the alert is repeated at predefined intervals for a certain duration, if the user is inactive. If there is no interaction during the specified window of time, the alert is temporarily stopped and then restarted after a short delay. The system operates this way until a user responds, or the event becomes recognized as a missed-dose incident.

8.4 System Operation Workflow

The overall operation of the system is as follows in sequence; System is initialized and then enters idle monitoring mode. Constantly monitors time and system conditions; At scheduled time, it takes initial weight (W_{before}) , Starts buzzer and indicator as alert signals. Also, records changes in weight over a period of time. If $W \geq T\ w$, it is confirmed that the tablet has been removed. Starts verification stage (vision-based module – future). Its value is set to 1, and the pill is marked as a missed dose if a weight change is not detected within the specified time. Sends notification to the caregiver if necessary. Writes to log file (timestamp, status). The last step is to go back to the idle state until the next cycle starts.

8.5 Vision-Based Verification (Future Work)

To improve on system reliability, a vision-based verification module is proposed. After Tablet removal is detected, a Camera can be turned on to analyze users' actions through computer vision methods. This source also helps to distinguish between removing a tablet and its real consumption.

9. RESULTS AND DISCUSSION

To that end, a web-based simulation was performed to validate the system's workflow regarding whether reminders are set, the course of action following repeated alert reminder signals, the recognition of tablet removal, and the caregivers' behaviour in interacting with the system. The scenarios differed in the time taken for a response and the manner in which the tablets were removed.

Different test scenarios were factored in, and they included normal tablet intake, delayed response, and missing the tablets. The system behaviour when using weight variation to confirm a tablet removal and when considering alert mechanisms was analyzed.

To identify tablet removal, the threshold-based detection approach was used based on weight values before and after the scheduled event. The threshold T_w was chosen based on the expected variations in the tablet weight to ensure the detection was reliable and that noise and a small variation in the tablet weights have minimum impact on the detection procedure.

Results demonstrate the system's capacity to differentiate between tablet removal and missed doses in simulated environments successfully. The repeated alert proves to be a good mechanism to notify the users more than once (4), ensuring that a case of missed medication is unlikely (ibid). Besides, the caregivers are also notified to add more reliability in situations where the patient is not responding.

The proposed workflow presents a solution to this by eliminating the need for manual input and by creating a framework for monitoring medication. Compared to conventional methods of lid-based or button confirmation, the weight-based approach can provide more reliable confirmation of tablet access.

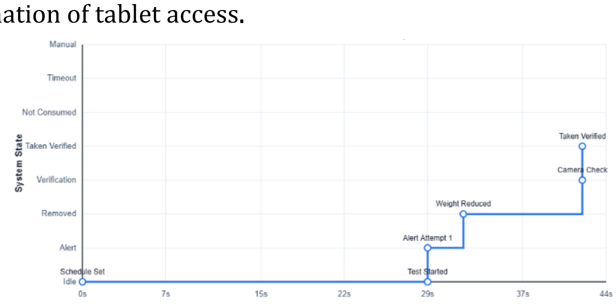

Chart- 1: Simulated Detection Performance of the Proposed Medication Monitoring Workflow (dose taken)

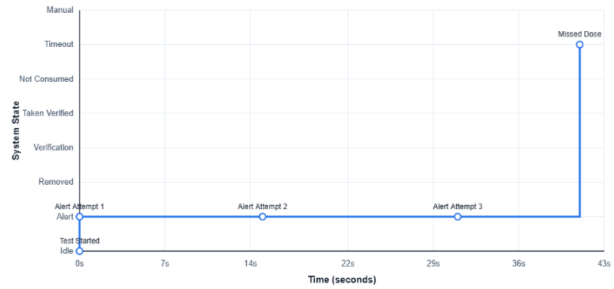

Chart- 2: Simulated Detection Performance of the Proposed Medication Monitoring Workflow (missed dose)

Time	Event	Status	Verified By	Remarks
20:00:47	Caregiver Alert	Missed	No Response	Caregiver notified after repeated alerts
19:59:57	Camera Verification	Not Taken	Camera Simulation	Not taking tablet image matched
19:59:55	Weight Detection	Tablet Removed	Weight Simulation	Awaiting camera/image verification
19:59:44	Camera Verification	Taken	Camera Simulation	Taking tablet image matched
19:59:41	Weight Detection	Tablet Removed	Weight Simulation	Awaiting camera/image verification
19:53:33	Caregiver Alert	Missed	No Response	Caregiver notified after repeated alerts

Fig-4: Simulation Results(web-based)

The comparative analysis suggests that direct indicators are either absent or there is a need for significant complexity and costs. The proposed system is meant to offer a compromise solution that benefits from simplicity, reliability, and scalability. The system can be enhanced with the introduction of the vision-based verification module (future work), which improves the reliability of the system by eliminating the ambiguity between tablet removal and actual consumption.

Table 2 shows a comparison between the proposed system and the existing ones based on the detection method, reliability, and complexity of the system.

TABLE 2: Comparative Analysis

System	Method	User Input	Intake Verification	Cost	Limitation
Khan et al. [2]	Lid/cloud	Required	No	Medium	Indirect detection
Vimal et al. [3]	Pull sensor	Low	No	Medium	Removal only
Haque et al. [4]	Button/app	Required	No	Low	Depends on user

Phan et al. [5]	AI vision	Low	Yes	High	Cost/complexity
Proposed	Weight + vision simulation	Low	Partially/Proposed	Low	Hardware future work

The simulation results are a proof of concept for the proposed system's ability to work with real-world medication scenarios. Therefore, the identified reminder mechanisms, detection logic, and caregiver interaction form a comprehensive monitoring solution.

However, for now, the evaluation is limited to simulation-based validation. Real-world performance would differ when it comes to hardware accuracy, environmental setup, and user performance.

X. CONCLUSION AND FUTURE WORK

This paper presented the architectural design of a Smart Pill Box Monitoring System that aims to enhance medication adherence for patients with memory-related cognitive disabilities. The entire scheme will work on planned reminders, weight detection, and a well-defined workflow to ensure reliable monitoring of medication intake.

With this, a threshold-based detection approach is established to recognize the variations in weight to identify if the tablets were removed and is defined as: To detect the removal of tablets, a threshold-based approach is initiated on the variation of weights and is formulated as follows.

Validation of the system is done through a simulation-based approach, showing the system's capabilities on activating reminders, a mechanism for repeated alerts, detecting intakes, and its interaction with caregivers. The proposed workflow offers a more reliable alternative to the existing workflow, which depends mainly on manual user inputs.

On the whole, the system can serve as a practical and cheaper alternative of medication monitoring, which can be deployed for the real-world scenarios, after hardware implementation.

Further work will be based on extending the system toward the real-world implementation and considering the enhancement of the reliability under the practical conditions. The hardware prototype will be constructed from the most appropriate sensing components to validate the performance of the system in real environments. Enhancements in detection accuracy can be achieved through better signal processing techniques including noise filtering and adaptive thresholding. Finally, integration of a mobile or web-based application with real-time notifications and remote management of the schedule will enhance the usability of the system by patients and caregivers.

A vision-based verification module will subsequently be introduced to verify that the tablets have indeed been taken and not just removed through computer vision techniques. This will help further verify the system's reliability.

Further improvements may include cloud-based data storage and analytics for long-term monitoring, as well as multi-sensor integration to reduce false dictions. Lastly, the systems will also be subjected to real-world validation with users, most specifically among the elderly patients, to assess its general usability and performance in practical healthcare contexts.

XI. REFERENCES

[1] World Health Organization, Adherence to Long-Term Therapies: Evidence for Action. Geneva, Switzerland: WHO, 2003.

[2] A. Khan et al., "A Smart Medical Box for Medical Professionals and Patients for Helping Them to Avail Timely Medication," in Proc. IEEE Int. Women in Engineering (WIE) Conf. on Electrical and Computer Engineering (WIECON-ECE), Chennai, India, Dec. 2024, pp.321-325, doi:10.1109/WIECONECE64149.2024.10914895.

[3] S. Vimal et al., "A Smart Pill Dispenser with Real Time Alerts, Remote Access, and Enhanced Safety," in Proc. Int. Conf. on Computing and Intelligent Reality Technologies (ICCIRT), 2024, pp. 39–43, doi: 10.1109/ICCIRT59484.2024.10921885.

[4] Md. S. S. Haque et al., "Design and Implementation of an IoT-based Smart Pillbox for Improving Medical Adherence," in Proc. 17th Int. Conf. on Electronics Computer and Computation (ICECCO), Kaskelen, Kazakhstan, Jun. 2023, doi: 10.1109/ICECCO58239.2023.10147144.

[5] H. T. T. Phan et al., "IoT and AI-Enabled Smart Pillbox for Medication Reminder and Intake Monitoring in the Elderly," in Proc. 10th Int. Conf. on Research in Intelligent Computing in Engineering (RICE), 2025, doi: 10.1109/RICE67503.2025.11439972.

[6] A. Maria, "AI Medication Adherence System Using an IoT Smart Pill Box," Technical Report, Immaculate College for Women, Cuddalore, India, 2024.

[7] L. Osterberg and T. Blaschke, "Adherence to medication," New England Journal of Medicine, vol. 353, no. 5, pp. 487–497, Aug. 2005.

[8] B. Vrijens et al., "A new taxonomy for describing and defining adherence to medications," British Journal of Clinical Pharmacology, vol. 73, no. 5, pp. 691–705, May 2012.

[9] D. S. Abdul Minaam and M. Abdelfattah, "Smart drugs: Improving healthcare using smart pill box for medicine reminder and monitoring system, Future Computing and Informatics Journal, vol. 3, no. 1, pp. 1–5, 2018.

[10] A. Al-Fuqaha et al., "Internet of Things: A survey on enabling technologies, protocols, and applications," IEEE Communications Surveys and Tutorials, vol. 17, no. 4, pp. 2347–2376, 2015.

[11] R. Turjamaa, S. Kapanen, and M. Kangasniemi, "How smart medication systems are used to support older people's drug regimens: A systematic literature review," Geriatric Nursing, vol. 41, no. 6, pp. 677–684, 2020.

[12] T. Patel et al., "An in-home medication dispensing system to support medication adherence for patients with chronic conditions in the community setting," JMIR Formative Research, vol. 6, no. 5, p. e34906, 2022.

[13] S. K. Saha et al., "An IoT based smart medicine dispenser model for healthcare," in Proc. Int. Conf. on Computer, Communication, Chemical, Materials and Electronic Engineering (IC4ME2), 2021, pp. 1-5.

[14] Espressif Systems, ESP32 Technical Reference Manual, v5.1,2023.[Online].Available:https://www.espressif.com/documentation Accessed: Apr. 2026.