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AI-Powered IoT Based Medicine Dispenser with Face Recognition

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ABSTRACT—

Elderly patients and people with chronic illness often miss doses or take the wrong medicine. This paper presents the design of an AI-powered, Internet of Things (IoT) based medicine dispenser that verifies the patient by face recognition before releasing any medicine. The system is built around an ESP32 microcontroller, a DS3231 real-time clock (RTC), a webcam, four servo-driven compartments, a buzzer, a 16×2 liquid-crystal display (LCD) and Wi-Fi. At each scheduled time the buzzer and display remind the user, the face is captured and matched, and only on a successful match does the corresponding servo open its compartment. The dispensing status is then sent to an IoT cloud platform and a caregiver's mobile application. Several schedules are supported, unauthorised users are refused, and the low-cost design suits homes and care centres. Related work on automated dispensers, IoT adherence monitoring and face-recognition dispensing is reviewed, and the block diagram, circuit diagram, hardware details, algorithm and flowchart of the proposed design are presented.

Index Terms—Smart medicine dispenser, Internet of Things, face recognition, ESP32, medication adherence.

I. Introduction

Taking medicines correctly matters a great deal for treatment outcomes, yet missed doses and wrong-drug errors are common. They are especially frequent among elderly patients, people who take several drugs at different times of day, and people with cognitive decline. A conventional pill organiser is passive: it neither reminds the user nor checks who is taking the medicine, and it tells a caregiver nothing about what happened. Researchers have therefore explored automated dispensers and IoT-based medication management systems to close these gaps [1]–[3], [6].

This project proposes an AI-powered, IoT-based medicine dispenser built around an ESP32 controller. When a dose is due, the device alerts the patient with a buzzer and an LCD message and identifies the patient by face recognition. Only then does it release the correct medicine from a servo-driven compartment, and only to the authorised user. The dispensing status is sent over Wi-Fi to an IoT cloud platform, so intake can be monitored remotely.

Despite this progress, the existing methods leave an important gap. The reviewed dispensers demonstrate automatic release, scheduling, remote monitoring and, in some cases, face recognition, yet none of them is noted as reporting a quantitative evaluation of an authenticated dispenser (Table II). Where face recognition runs, protection against photo and screen-replay attacks, behaviour under network or power faults, and the privacy of stored face data are also rarely addressed in the reviewed material. The urgent problem is therefore a low-cost dispenser that releases a dose only to the authorised patient, confirms that the dose was dispensed and reports the event to a caregiver, because a missed or wrong dose can harm patients who are alone or cognitively impaired. The rest of the paper is organised as follows. Section II reviews related work, and Section III describes the proposed system: its functional requirements, block diagram, circuit diagram, hardware, algorithm and flowchart. Section IV presents the results and discussion, covering the comparison with existing work, the output tests and the limitations, and Section V concludes the paper.

II. Literature Review

Early work concentrated on automatic release and remote supervision. Pak and Park built a smart medication dispenser that emphasises scalability and remote manageability [1], and Panda *et al.* coupled an IoT-based dispenser with an interactive web application so that dispensing could be supervised from a distance [2]. Neither work, however, authenticates the person who takes the medicine.

More recent work adds face recognition to dispensing. Kim *et al.* presented PillGood, an interactive dispenser that uses facial recognition for safe and personalised dispensing [4]. Guerrero-Ulloa *et al.* described an IoT dispenser that offers real-time scheduling, face recognition and mobile notifications [3], while Ranjini *et al.* combine a pill dispenser with facial recognition and health monitoring [5]. From a human-centred viewpoint, Gargioni, Fogli and Baroni reviewed pill and medication dispensers systematically, covering interfaces, development processes and stages of adoption [6].

The ESP32 has been widely adopted as a low-cost Wi-Fi controller for IoT healthcare nodes [7], and cloud platforms such as ThingSpeak and Firebase are commonly used to log device events [8]. Face-embedding methods such as FaceNet [9] and lightweight detectors such as MTCNN [10] are widely

used building blocks for accurate recognition, while research on liveness detection addresses photo and screen-replay attacks [11]. Osterberg and Blaschke review the causes and consequences of poor medication adherence [12], and the World Health Organization identifies it as a major global problem [16]. The IoT paradigm is surveyed in [17], and surveys of IoT in healthcare discuss the security and privacy requirements of such devices [13].

III. Proposed System

The system is intended to run unattended in a home or care centre, and it is designed around six functional requirements: (R1) medicine reminders at scheduled times; (R2) selection of the correct compartment; (R3) face authentication before release; (R4) automatic dispensing; (R5) IoT monitoring of dispensing events; and (R6) multiple schedules with different doses at different times. Each requirement maps to a part of the hardware. The RTC and buzzer serve R1, the schedule table and servos serve R2 and R4, the webcam and recognition module serve R3, and the Wi-Fi link serves R5. R6 is met by storing several schedule entries, each with its own time, compartment and authorised user.

Fig. 1 shows the block diagram of the proposed system, which is organised into input, controller, output/actuation, IoT/communication and power supply sections. The ESP32 is the central controller. It receives inputs from all modules, performs face recognition on the webcam image, checks the time and schedule through the RTC, controls the medicine-dispensing mechanism, handles the buzzer, display and servos, and communicates with the IoT platform over Wi-Fi.

The input section contains the webcam, which captures the user's face for recognition; the DS3231 RTC module, which provides the real time and date; and the PCA9685 servo driver, which controls the servo motors. The output section contains the LCD (0.96-inch or 16×2), which shows the time, medicine information, status and alerts; the buzzer, which alerts the user at the scheduled time; four servo motors (Servo 1 to Servo 4, one for each dosing time), which operate the medicine compartments; and the dispensing mechanism, which releases the scheduled medicine. In the communication section, the Wi-Fi link of the ESP32 reaches an IoT cloud (ThingSpeak, Firebase or Blynk are shown as options), which in turn serves a mobile application for the caregiver. In the power section, a 5 V DC supply powers all modules.

The block diagram also summarises the working sequence: the scheduled time is reached, the buzzer sounds and the alert is displayed, the user's face is captured, face recognition succeeds, the servo opens the compartment, the medicine is dispensed, the status is sent to the IoT cloud or app, and the data is updated for the caregiver. The diagram places face recognition inside the controller block; where recognition actually runs is an open design decision that is discussed in Section IV.

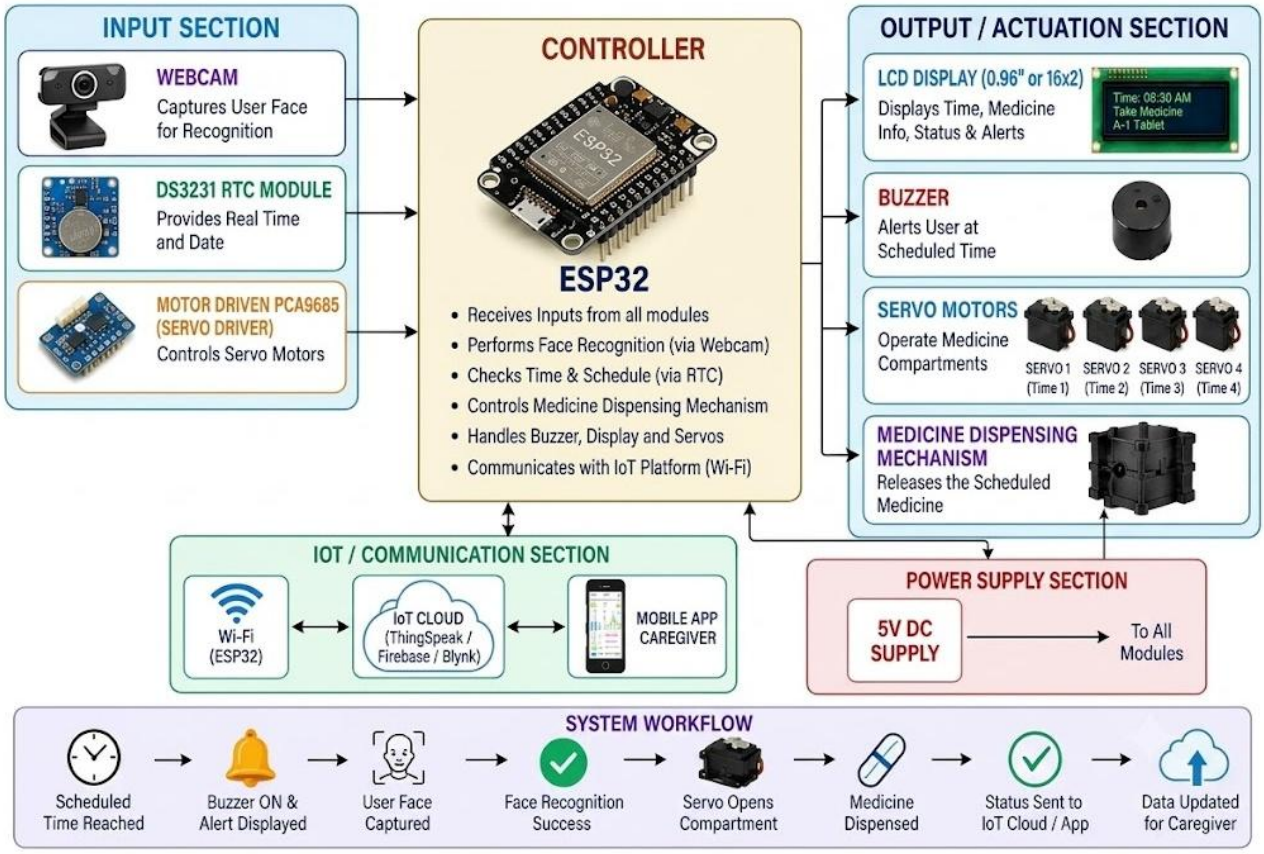


Fig. 1. Block diagram of the proposed system, showing the input, controller, output/actuation, IoT/communication and power supply sections.

Fig. 2 shows the circuit diagram. The controller is an ESP32 (ESP-WROOM-32 module with a CP2102 USB-to-serial bridge), powered from the 5 V supply. The 16×2 LCD with its I²C backpack, the DS3231 RTC and the PCA9685 servo driver share the two-wire I²C bus (serial data line SDA and serial clock line SCL), so each must have its own bus address. The DS3231 [14] normally answers at 0x68 and the PCA9685 [15] at 0x40 by default, while common LCD backpacks use 0x27 or 0x3F. The buzzer is driven from general-purpose input/output (GPIO) pin 25 and returns to ground. The four MG90S servo motors, one for each dosing time (Servo 1 to Servo 4), are connected to the first four channels of the PCA9685, which generates their pulse-width-modulation (PWM) signals.

A host laptop with a USB webcam, drawn at the top of the circuit diagram, is linked to the ESP32 over USB/serial. This corresponds to the host-based recognition option discussed in Section IV. The diagram also repeats the system operation flow, from the scheduled time (RTC) through face recognition and servo dispensing to the status update on the IoT cloud or app, and it shows a common ground for all modules.

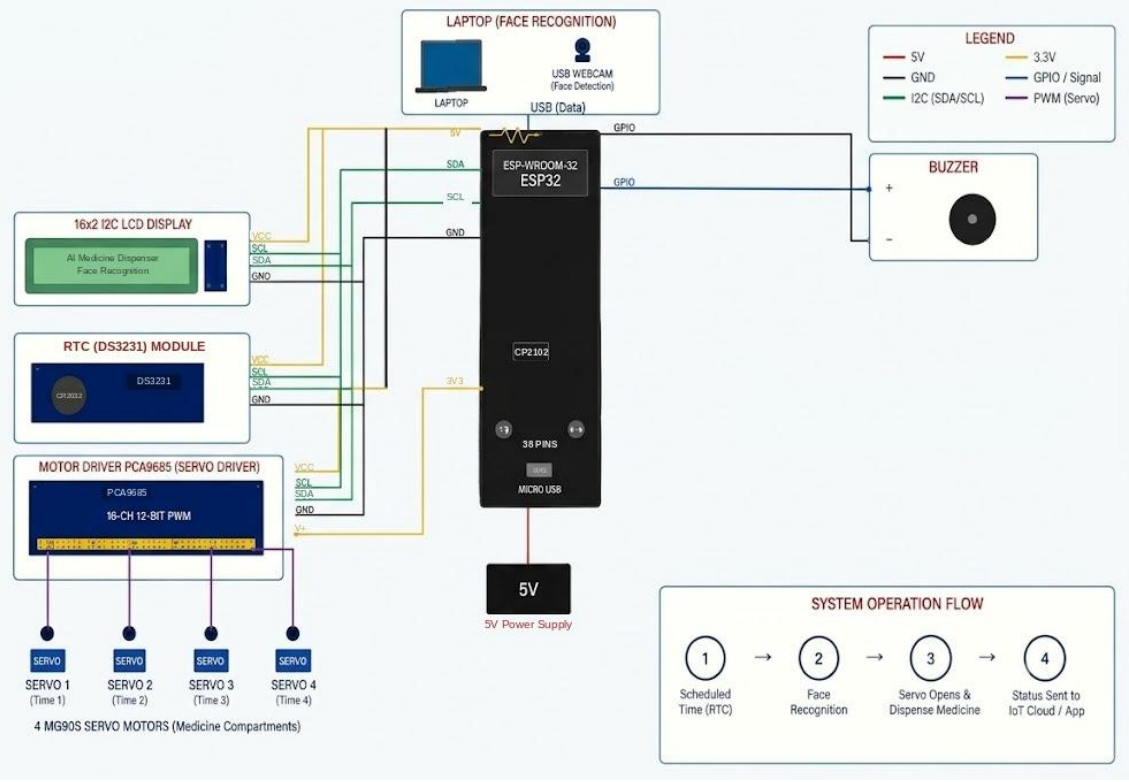


Fig. 2. Circuit diagram of the proposed dispenser: ESP32 controller, I²C devices (LCD, DS3231 RTC, PCA9685), buzzer, four MG90S servos, host laptop with webcam, and 5 V supply.

Table I lists the main components and their key specifications. The block and circuit diagrams show a 5 V supply; in the hardware plan this supply is obtained from a 12 V DC, 2 A adapter that is stepped down to 5 V by a DC-DC regulator.

TABLE I. HARDWARE COMPONENTS

Component	**Key specification**
Webcam	5 MP; autofocus; low-light capable
DS3231 RTC	3.3–5 V; high timekeeping accuracy
Power supply	12 V DC, 2 A adapter with a 5 V DC-DC regulator
Servo motor	MG90S; ~180°; 4.8–6 V (four units)
PCA9685 driver	16-channel, 12-bit PWM; I²C
ESP32 DevKit	3.3 V logic; Wi-Fi/Bluetooth
LCD	16×2 (32 characters)
Buzzer	~5 V; low power

The working of the device, summarised by the flowchart in Fig. 3, is as follows. On start-up the system initialises the ESP32, RTC, LCD, servo motors and Wi-Fi connection, and loads the stored medicine schedule, which records the scheduled time, the required compartment and the authorised user. In normal operation the controller keeps comparing the RTC time with the schedule. When a dose falls due, the buzzer sounds and the LCD shows the medicine details. The camera then captures the user's face, and the recognition step compares it with the authorised user's stored template.

If the face is not recognised, the system allows a limited number of retries (N_{max}). When the limit is reached, dispensing is cancelled and an alert is sent. If the user is authenticated, the controller drives the servo of the scheduled compartment, and the medicine is released. The dose is then marked as served, the event (user, compartment and time) is published over Wi-Fi to the IoT platform, and the controller returns to standby to watch the RTC for the next scheduled dose.

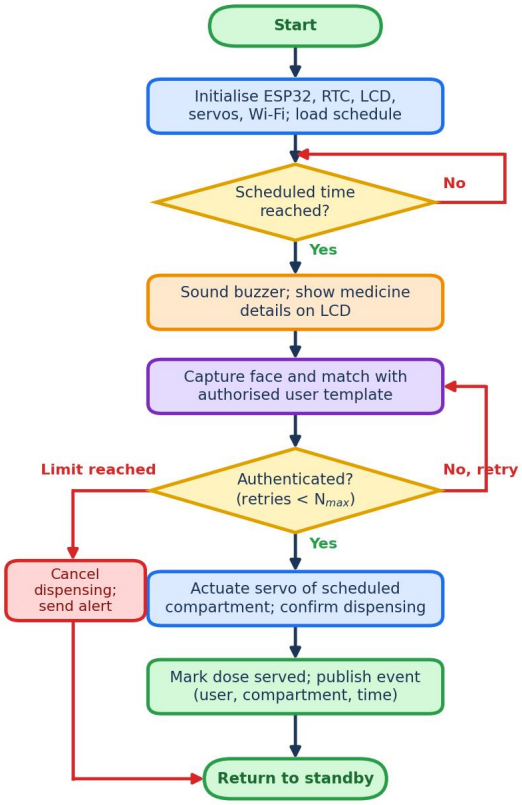


Fig. 3. Flowchart of the working sequence from the scheduled time to the IoT update.

IV. Results and Discussion

Table II compares the surveyed works with the functions that this project targets. The entries are derived from each work's title and summary. A dash means "not stated in the material reviewed", not necessarily absent, so the table should be checked against the full texts.

TABLE II. FEATURE COMPARISON OF THE REVIEWED WORKS

Ref.	Year	Focus	Auto	IoT	Face	Multi	Eval.
[1]	2012	Scalable, remote dispenser	✓	✓	–	–	–
[2]	2018	IoT dispenser + web app	✓	✓	–	–	–
[3]	2020	Scheduling, face recog., notifications	✓	✓	✓	✓	–
[4]	2022	Interactive, facial recognition	✓	–	✓	–	–
[5]	2026	Face recog. + health monitoring	✓	–	✓	–	–
Proposed	2026	ESP32; face auth. + IoT	✓	✓	✓	✓	Planned

Auto = automatic dispensing; IoT = IoT remote monitoring; Face = face recognition; Multi = multiple schedules; Eval. = quantitative evaluation.

Automatic dispensing is common to all the reviewed works, and IoT-based remote monitoring appears in the earlier works [1]–[3]. Face recognition appears in [3]–[5], while multiple schedules are reported in [3]. None of the reviewed works is noted as reporting a quantitative evaluation of an authenticated dispenser. The proposed system combines face authentication, servo-based dispensing and IoT reporting on a low-cost ESP32 platform, and it is to be evaluated quantitatively through output tests on the implemented prototype.

The prototype has been implemented properly, and its output is verified through a set of functional tests. The tests check that the buzzer and LCD alert at the scheduled time, that only an authorised face triggers the correct servo, that the medicine is released from the correct compartment, and that the event reaches the IoT platform. Compared with the existing systems in Table II, the proposed design aims to bring authenticated release, scheduled dispensing and event reporting together in a single low-cost unit. Whether it achieves this remains to be shown by testing.

Several engineering issues remain open in the current design. First, the ESP32 has no USB host, so a generic USB webcam cannot be attached to it directly. The design needs either an ESP32-CAM or a host, such as a PC or single-board computer, that performs capture and recognition, and this choice also decides where recognition runs. The circuit diagram adopts the host option. Second, embedding-based face recognition is demanding for an ESP32-class device, so its accuracy and latency must be measured rather than assumed. Third, the servo-power pin of the PCA9685 and the 16×2 I^2C LCD, which Fig. 2 draws on the 3.3 V line, should be supplied from the 5 V rail, because MG90S servos are rated for 4.8–6 V and such LCD modules are commonly specified for 5 V. The supply arrangement therefore needs to be checked in the final wiring, together with servo inrush current and the common ground.

Face recognition may show demographic and lighting bias, a single biometric cannot replace clinical oversight, and the device does not verify that the medicine is swallowed. A successful release shows only that a compartment was operated, not who took the medicine. Medical-device regulation and clinical validation are outside the scope of this work. Future work includes a mobile application with cloud medication history, low-stock alerts, liveness detection, pill-identity verification by vision or weight, and multi-user profiles.

V. Conclusion

This paper presented the implementation of an automated medicine dispensing apparatus combining real-time scheduling, biometric facial authentication, multi-compartment servo actuation, and cloud-based IoT tracking. Governed by an ESP32 processor interfaced with an external vision pipeline, the system ensures that prescribed dosages are dispensed exclusively to verified patients at designated intervals, reducing medication errors. The structural organization, electrical interfacing, hardware inventory, and decision algorithms were systematically described.

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