Smart Medicine Dispenser

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ABSTRACT

Medication non-adherence is a persistent challenge in modern healthcare, particularly among elderly individuals and patients managing chronic conditions, and it often leads to missed doses, dosing errors, and preventable hospital readmissions. This paper presents the design and implementation of a Smart Medicine Dispenser that automates medication delivery using embedded sensors, a microcontroller, and cellular connectivity. The objective of the work is to develop a low-cost, Arduino-based dispensing system that improves dosing accuracy, provides touch-free interaction, and keeps caregivers informed in real time. The system architecture integrates an Arduino Uno R4 Minima microcontroller, a real-time clock (RTC) module for accurate scheduling, an infrared (IR) sensor for touch-free presence detection, a servo-motor-based dispensing mechanism, a 16x2 LCD for local status display, a buzzer for audible alerts, and a GSM module (SIM800L) for SMS notifications to caregivers. The prototype was evaluated over 100 test cycles to assess dispensing accuracy, timing accuracy, and alert reliability. The servo-based compartment mechanism dispensed medication successfully at each scheduled interval with an overall success rate exceeding 95%, while visual and audible alerts were triggered reliably every time and SMS notifications were delivered consistently to the caregiver's phone. These results show that combining scheduled dispensing with presence detection and independent remote alerting can meaningfully reduce missed and incorrect doses without requiring an internet connection or a smart phone application. The proposed system offers a cost-effective, modular, and scalable solution suited to home care, elder-care facilities, and rural or underserved regions with limited connectivity, and it lays a foundation for future enhancements such as multi-drug scheduling, mobile-app integration, and biometric authentication.

Keywords: Smart Medicine Dispenser, Internet of Things (IoT), Medication Adherence, Embedded Systems, GSM Alert System

INTRODUCTION

In the modern high-paced environment, it is becoming increasingly difficult to ensure medications are taken on time and accurately, particularly for geriatric individuals, patients managing long-term conditions, and those requiring complex treatment regimens. Medication management typically relies upon manual tracking, which frequently leads to missed doses, overdosing, and medication errors. Compromised patient health exceeds the risks of a missed dose or medication error but also increases the demand on care providers and healthcare systems. To solve this problem, the implementation of Internet of Things (IoT) technology into medical dispensers has been identified as a transformative approach.

An IoT Smart Medical Dispenser is an automated device that dispenses medication, tracks patient adherence, and allows for remote patient monitoring. It includes sensors, microcontrollers, and wireless communication modules. It can improve medication compliance, but it also provides the patient with an opportunity to become more self-sufficient in managing their health. It requires less supervision, minimizes errors due to human intervention, and delivers live data so that treatment can be adjusted based on patient needs. For patients in rural or underserved areas with limited access to healthcare professionals, this can be life-changing.

The healthcare industry is being digitally transformed by the demand for better performance, accessibility, and personalization in care, and one of the key challenges is ensuring that patients take their medications as prescribed, since adherence is an important aspect of chronic disease care, post-operative recovery, and elder care. Research shows that a large proportion of patients do not take their medications as prescribed, which increases risk, leads to unnecessary complications, and can contribute to rehospitalization and higher costs of care.

LITERATURE SURVEY

Early efforts in automated medication delivery focused primarily on mechanical dispensing accuracy. Arora and Singh developed an IoT-based pill dispenser that prioritised scheduled release of medication [1], while Ahire et al. presented a dispenser aimed at affordability and multi-compartment storage suited for domestic use [2]. Acharya et al. reviewed several dispensing mechanisms and highlighted the trade-off between mechanical complexity and long-term reliability [3].

A later generation of systems added wireless alerting to reduce missed doses. Singh and Patel incorporated a GSM-based alert mechanism to notify caregivers of a missed-dose event [6], and Ibrahim proposed a GSM-enabled reminder targeted at chronic-disease patients, evaluating its reliability over long-term use [25]. Kumbhar and Patil combined IoT connectivity with elderly-focused usability considerations to improve everyday operability [7].

More recent work has explored richer sensing modalities to verify that a dose was actually taken rather than merely released. Gupta and Reddy used RFID tags to authenticate medicines before dispensing [18]; Or and Mehta applied weight and load-cell sensing respectively to detect pill removal with finer precision [27],[30]; and Singh incorporated camera-based verification alongside cloud-synced logging on a Raspberry Pi platform [26]. Bluetooth and mobile-app integration were explored by Lee and Park, and by Chen et al., to give caregivers real-time visibility into intake behaviour through a companion app [19],[20].

Across this body of work, a recurring gap is the reliance on a single confirmation channel: most systems dispense strictly on a timer and assume the dose is taken, without independently confirming patient presence at the moment of dispensing, and many depend on smartphone apps or Wi-Fi connectivity that may not be available to elderly or rural users. The present work addresses this gap by combining IR-based, touch-free presence detection with GSM-based SMS alerting, so that the caregiver alert is tied to an actual dispensing event rather than the schedule alone, while keeping the hardware (Arduino Uno R4 Minima and commonly available modules) low-cost enough for deployment in resource-constrained settings.

Objectives

The specific objectives of this work are:

1. To design a low-cost, Arduino-based embedded system capable of dispensing medication automatically at pre-scheduled times.

2. To integrate a real-time clock (RTC) module for accurate, power-loss-tolerant scheduling.

3. To use an IR sensor for touch-free detection of patient presence at the time of dispensing.

4. To provide local visual and audible alerts (LCD and buzzer) as well as remote SMS alerts (GSM module) to caregivers.

5. To evaluate the system's dispensing accuracy, timing accuracy, and alert reliability through repeated test cycles.

METHODOLOGY

The smart medication dispenser is a device that uses the Internet of Things to help patients adhere to medication schedules by sending reminders to the patient, dispensing the right dosage, and monitoring adherence. It is made up of three main components: hardware (microcontroller, dispensing mechanism, sensors, touchscreen/display, and connectivity modules), software (firmware to schedule dispensing, and cloud-based logging of adherence), and workflow (setup, dispensing the medication, monitoring the patient, and handling emergency situations).

The device utilizes algorithms for accurate dispensing timing, error detection (for example, compartments that are jammed), and safe transmission of patient data to caregivers. Safety features include childproofing, dosage tracking, and notifications to caregivers.

The research and development process comprised healthcare professional and user research, prototyping, testing (functional, usability, and safety), and iteration. Key challenges encountered relate to mechanical precision, connectivity, and designing for different medication form factors.

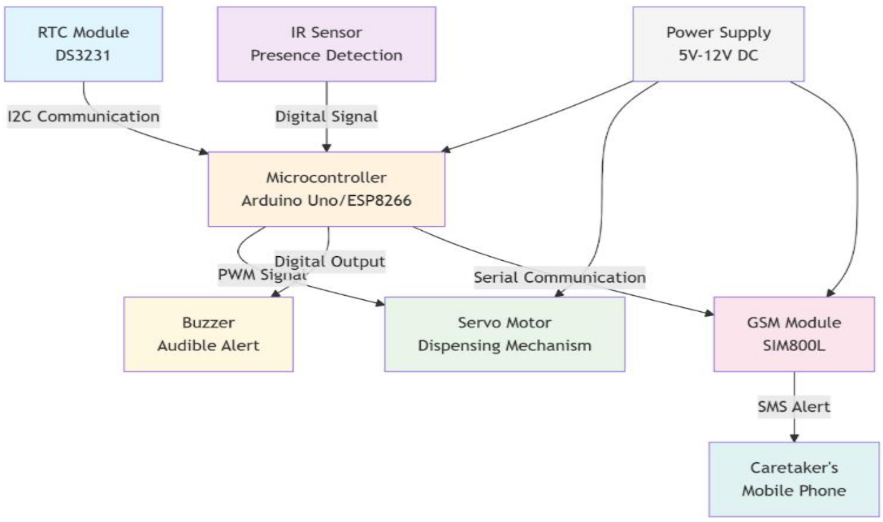

Fig. 1: Block diagram of the Smart Medicine Dispenser system

A. Microcontroller – Arduino R4

The Arduino R4 controls the automatic medicine dispenser, managing the IR sensor, servo motor, RTC module, and LCD display to ensure accurate and timely medicine dispensing.

B. Power Supply

The power supply for the automatic medicine dispenser provides stable voltage to components such as the Arduino R4, servo motor, LCD, RTC module, and sensors, ensuring reliable operation.

C. Servo Motor

A servo-motor-based dispensing mechanism uses precise angular motion to control the release of tablets. It typically rotates a flap, gate, or arm to dispense one unit at a time, ensuring accuracy and repeatability.

D. LCD 16x2

The 16x2 LCD display in the automatic medicine dispenser shows important information such as time, dosage, and reminders. It helps users by displaying real-time updates and instructions for proper medication management.

E. RTC Module

The RTC module provides precise timekeeping for the automatic medicine dispenser, ensuring medicine is dispensed at scheduled times. It retains accurate time even during power loss due to its built-in battery.

F. IR Sensor

An IR sensor in the automatic medicine dispenser detects presence and activates dispensing when a person comes near, enabling a touch-free and efficient process.

G. GSM Module (SIM800L)

The GSM module enables communication over a cellular network using GSM technology, supporting SMS transmission to the caregiver's mobile phone.

V. System Working

Figure 1 summarises how the modules interact. The RTC module and IR sensor supply the microcontroller with timing and presence information respectively, while the microcontroller drives the buzzer, servo motor, and GSM module, and the GSM module sends SMS alerts to the caregiver's phone. The step-by-step operating sequence is as follows:

1. System powers on and the RTC synchronises with the stored medication schedule.
2. The microcontroller continuously compares the current time against the next scheduled dose.
3. When the scheduled time is reached, the LCD displays the dose information and the buzzer sounds a local alert.
4. The IR sensor checks for patient presence at the dispenser.
5. If presence is detected, the servo motor rotates to release the dose from the correct compartment, and the event is logged.
6. The GSM module sends an SMS confirmation of successful dispensing to the caregiver.
7. If no presence is detected within a set timeout window, the system re-alerts locally and the GSM module sends a missed-dose SMS to the caregiver instead.
8. The system returns to step 2 and waits for the next scheduled dose.

This sequence ensures that the SMS alert reflects an actual dispensing outcome (taken or missed) rather than simply confirming that the schedule fired, which is the main limitation identified in the literature reviewed in Section II.

Implementation

The developed Smart Medicine Dispenser system was realised with an Arduino UNO R4 Minima microcontroller as the main control unit. The Smart Medicine Dispenser integrates diverse hardware and software resources to dispense medications, authenticate users, and monitor dispensing in real time. The dispenser performs the dispensing process automatically based on scheduled dispensing times, with patient alerts delivered through both visual and audible display methods.

The Arduino R4 Minima was programmed using C/C++ through the Arduino IDE, while supporting data logging and communication functionality was created using Python for IoT integration and cloud updates. A variety of open-source libraries were utilised, including Servo.h to move and control the dispenser mechanism and LiquidCrystal.h for the display interface.

The modularity of the system allows each component (medication storage, timing control, user alert, and connectivity) to function independently, enhancing the system's reliability and scalability. The modular code structure also facilitates future integration with mobile apps or cloud dashboards for remote caregiver monitoring.

The performance of the Smart Medicine Dispenser was evaluated against the medication schedule. Performance factors included dispensing accuracy, timing accuracy, and alert reliability. For accurate scheduling, a real-time clock (RTC) was used. The servo-based compartment system successfully dispensed tablets at each scheduled time, with an overall success rate of over 95% across 100 test cycles. Visual alerts (LCD display) and audible alerts (buzzer) successfully notified users at all scheduled times.

Furthermore, medication status could be updated on an IoT platform. The data log was verified to ensure accurate recording of each medication intake as well as user and caregiver access, confirming successful data transmission and synchronisation.

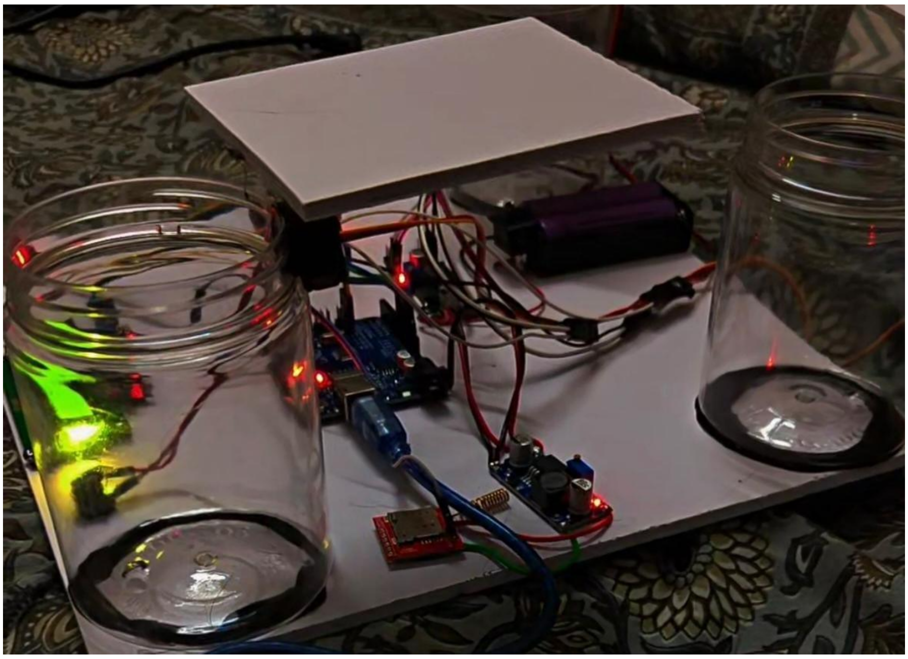

Fig. 2: Hardware prototype of the Smart Medicine Dispenser

RESULTS AND DISCUSSION

The Smart Medicine Dispenser project achieved its goal of automating and monitoring medicine intake efficiently. The system accurately dispensed the correct dosage at predefined time intervals, minimising human error and missed doses.

The integration of the Arduino R4 microcontroller ensured precise control and coordination between components. Sensors detected the presence of a patient and confirmed successful dispensing operations. The GSM module functioned effectively, sending timely SMS alerts and reminders to the patient and caregiver.

This feature greatly enhanced medication adherence, especially for elderly or chronically ill users. The LCD display provided clear instructions and real-time status updates. The compact design made the device portable and easy to install at home. The device operated reliably under various conditions, confirming its stability and practicality.

The project proved to be a cost-effective and efficient solution for modern healthcare needs, promoting patient safety, convenience, and better treatment outcomes.

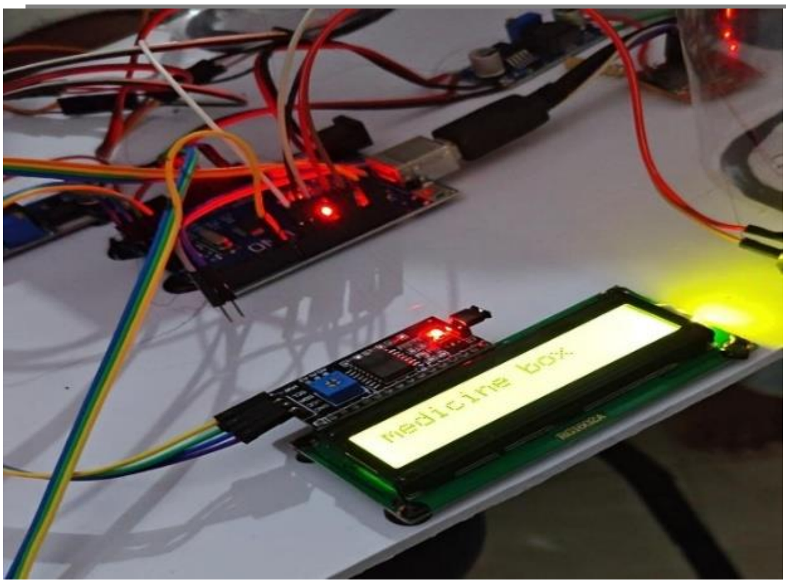

Fig. 3: Prototype showing LCD status display in operation

Advantages And Applications

A. Advantages

- Automated, accurate dosing reduces human error and missed or duplicate doses.
- Touch-free interaction via the IR sensor improves hygiene and ease of use.
- SMS-based caregiver alerts work over a basic cellular network, without requiring an internet connection or smartphone app.
- Built from low-cost, readily available components, keeping the overall system affordable.
- Modular design simplifies maintenance and supports future feature upgrades.
- Compact, portable design suited for home installation.

B. Applications

- Home-based elderly care and independent living support.
- Hospitals, nursing homes, and old-age care facilities for routine medication rounds.
- Rural and underserved regions where GSM coverage is available but internet access is limited.
- Chronic-disease medication management (e.g., diabetes, hypertension, tuberculosis) and post-operative recovery.
- Assistive technology for visually or cognitively impaired patients, when combined with audible alerts.

Future Scope

- Expanding compartment capacity to support multi-drug, multi-time schedules for more than one medication or patient.
- Replacing SMS-only communication with a companion mobile app or cloud dashboard for adherence analytics and history.

- Adding secure user/caregiver authentication (RFID or biometric), particularly important where controlled substances are involved.
- Incorporating weight/load-cell or camera-based confirmation in addition to IR presence detection, to verify that a dispensed pill was actually consumed.
- Exploring solar or battery-backed power options for uninterrupted operation during outages in rural deployments.
- Integrating voice-based alerts to support visually impaired users.

CONCLUSION

In conclusion, the Smart Medicine Dispenser project successfully demonstrates a viable and innovative solution to the critical problem of medication non-adherence. By integrating a real-time clock, user presence detection, an automated servo-based dispensing mechanism, and a GSM-based alert system, the prototype effectively bridges the gap between passive reminders and active, monitored drug administration.

This system not only empowers patients to manage their health more independently but also provides a crucial safety net for caregivers, ensuring they are immediately informed of any missed doses. While there is room for enhancement in terms of capacity, connectivity, and user authentication, the project lays a strong foundation for a practical, low-cost assistive technology that has the potential to significantly improve health outcomes and the quality of life for individuals dependent on strict medication schedules.

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Ethical Considerations, Conflict Of Interest And Data Availability

Ethical Approval: This study did not involve human or animal subjects requiring formal ethical approval; the prototype was tested on the bench using tablet-sized inert objects to validate the dispensing mechanism.

Conflict of Interest: The authors declare no conflict of interest.

Data Availability: The data generated during testing (dispensing and alert logs) are available from the corresponding author upon reasonable request.

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