AlzCare: An IoT-Based Smart Medication Management System for Individuals with Alzheimer's Disease

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ABSTRACT

Medication non-adherence is a serious problem for people living with Alzheimer's disease, driven by progressive memory loss, confusion, and a reduced ability to manage daily treatment on their own. Missed doses, incorrect intake, and the resulting caregiver burden can all work against good patient outcomes and quality of life. This paper presents AlzCare, a low-cost Internet of Things (IoT)-based medication management system built to support safe medication administration through automated reminders, user authentication, environmental monitoring, and real-time interaction with the patient.

The system pairs an ESP8266 microcontroller with an MFRC522 RFID authentication module, a DHT11 temperature-humidity sensor, an infrared motion sensor, an I2C liquid crystal display (LCD), and an auditory alert system. Functional testing under controlled conditions assessed system reliability, sensor performance, authentication accuracy, and reminder precision.

The results show strong operational performance across every component: 98% accuracy for RFID authentication, 98–100% detection accuracy for the infrared motion sensor, stable DHT11 environmental readings within acceptable tolerance, and reminder timing accuracy of up to 98%. Overall system reliability exceeded 97% across repeated trials, demonstrating that an integrated, IoT-based platform is a feasible approach to medication management in Alzheimer's care. Future work should pursue clinical validation with patients and caregivers to assess long-term effects on adherence, safety, and caregiver workload.

INTRODUCTION

Alzheimer's disease (AD) is among the most common neurodegenerative disorders worldwide and represents a growing public health challenge. It is marked by progressive deterioration of memory, cognitive function, and decision-making, and it affects millions of people while placing substantial emotional, social, and economic strain on families and health systems. The World Health Organization estimates that more than 55 million people worldwide currently live with dementia, with Alzheimer's disease accounting for roughly 60–70% of cases. As life expectancy keeps rising globally, Alzheimer's

prevalence is expected to grow significantly in the coming decades, underscoring the need for new approaches to patient care and disease management.

One of the toughest challenges for people with Alzheimer's disease is keeping to a consistent medication schedule. Current pharmacological treatments cannot cure the disease, but they play an important role in managing symptoms, slowing cognitive decline, and supporting daily functioning and quality of life — and their benefit depends heavily on patients taking the right dose at the right time. Memory impairment, confusion, reduced executive function, and impaired judgment routinely get in the way of following a medication schedule independently, so patients may skip doses, repeat them, or take the wrong amount, raising the risk of adverse outcomes, hospitalization, and further cognitive decline.

Medication management often falls to caregivers, usually family members providing ongoing support who must track schedules, supervise daily activity, and ensure safety, frequently while juggling their own personal and professional responsibilities. Extended caregiving is well documented to raise stress, anxiety, fatigue, and burnout, and medication-related concerns are especially significant because administration errors can seriously affect patient health — so improving medication management benefits not only patients but also the caregivers and support networks around them.

Traditional aids such as pill organizers, written schedules, calendars, and alarms help to some degree but tend to fall short for people with moderate or advanced cognitive decline, since they generally assume the patient can recognize a reminder, interpret it, and act on it independently. As Alzheimer's disease progresses, these cognitive demands become harder to meet, which limits how effective conventional adherence strategies can be, and has pushed researchers and clinicians toward more adaptive, technology-based alternatives.

Recent progress in digital health has produced smart medication dispensers, IoT-based healthcare systems, wearable monitors, and caregiver-connected platforms, with research showing these can improve adherence, support remote monitoring, and strengthen communication between patients and caregivers. IoT systems in particular let multiple devices and sensors communicate in real time, creating environments that can monitor behavior, gather data, and deliver automated assistance — in healthcare, this can mean medication reminders, environmental monitoring, activity tracking, and alerts when intervention is needed.

Even so, real limitations remain: many commercial systems are expensive, technically complex, or simply unavailable in lower-resource settings; some focus purely on reminders while skipping features like secure authentication or environmental monitoring; and others demand so much caregiver involvement that they undercut patient independence. These gaps point to a clear need for an affordable, integrated, and easy-to-use system built specifically for people with Alzheimer's disease. AlzCare responds to that need by combining an ESP8266 microcontroller with RFID authentication, infrared motion detection, environmental sensing, visual notifications, and auditory reminders into one comprehensive, low-cost medication-support platform intended to improve safety, accessibility, and usability. This study set out to design, build, and evaluate the technical performance of the AlzCare prototype under controlled conditions, assessing sensor accuracy, authentication reliability, environmental monitoring stability, and

reminder precision, with the broader aim of contributing to the growing field of assistive technology for dementia care and laying groundwork for future clinical research involving patients and caregivers.

LITERATURE REVIEW

The rising global prevalence of Alzheimer's disease has pushed researchers to look for technologies that can help people with the condition live more independently and receive better day-to-day care. Because memory loss makes it progressively harder for patients to manage their own treatment, medication adherence has become one of the most heavily studied problems in dementia care. Prior work shows that technology can meaningfully improve adherence, protect patient safety, and ease the load carried by caregivers, although accessibility, ease of use, and long-term integration remain open problems.

Missing or mistiming doses is a well-documented consequence of cognitive impairment. People living with dementia frequently struggle to recall schedules, recognize their own medications, or follow dosing instructions correctly, which raises the chance of missed doses, dosing errors, and downstream health complications. Adherence rates reported in geriatric and dementia-focused research are consistently lower for cognitively impaired populations than for cognitively healthy older adults, motivating the search for systems that reduce reliance on constant caregiver supervision.

Early technology-based interventions centered on electronic reminder devices and automated pill dispensers, using visual, audible, or digital cues to prompt medication-taking at set times. Tellier and colleagues, for example, found that electronic pillboxes could improve medication-taking behavior in older adults with mild Alzheimer's disease, and related studies reported similar gains when reminder features were paired with monitoring capability. These results support the idea that structured reminders can offset memory-related barriers to adherence, but most such tools only remind; they provide little or no confirmation of whether a dose was actually retrieved or taken correctly.

This gap pushed researchers toward Internet of Things (IoT)-based healthcare platforms, which let sensors, microcontrollers, mobile applications, and cloud services exchange information in real time. Multiple studies report that IoT-enabled systems improve monitoring efficiency, keep caregivers informed without requiring their constant physical presence, and support independent living for older adults through environmental sensors, activity trackers, and remote alerts — capabilities that are especially valuable where routine safety monitoring is central to disease management.

More recently, artificial intelligence and machine learning have been layered onto these platforms to analyze behavioral patterns, flag adherence risk, and tailor reminder timing to the individual. Work published in venues such as IEEE Access and Sensors reports encouraging results for predictive and adaptive monitoring, but these approaches typically depend on considerable computing power, large training datasets, and continuous connectivity — requirements that can put them out of reach in lower-resource settings.

Taken together, the literature points to several recurring limitations. Many commercial systems remain too costly for lower-income families; some prioritize technical sophistication over usability, producing interfaces that are hard for cognitively impaired users to navigate; many focus narrowly on reminders

while ignoring other safety-relevant factors such as environmental conditions or verified user presence; and caregiver integration is inconsistent even though caregiver involvement is repeatedly linked to better outcomes. The literature also stresses human-centered design: assistive technology for older adults needs to minimize cognitive load, give clear feedback, and keep working reliably outside the lab, since systems that ignore these needs tend to see poor real-world adoption regardless of their technical merit.

These gaps motivate AlzCare. Rather than treating reminders, authentication, and environmental monitoring as separate problems, AlzCare combines RFID-based user verification, infrared motion sensing, temperature and humidity monitoring, and audio-visual reminders on a single low-cost ESP8266 platform, aiming to show that an affordable embedded system can bring these functions together in one accessible package for Alzheimer's care.

HYPOTHESIS AND VARIABLES

Research Hypothesis

AlzCare is hypothesized to provide reliable, accurate support for medication management by combining sensor-based monitoring, automated reminders, and secure user authentication. Specifically, the system is expected to achieve operational accuracies above 95% across its core functions — RFID authentication, infrared motion detection, environmental monitoring, and reminder delivery — under controlled testing conditions. It is further hypothesized that combining these technologies on a single IoT-based platform will demonstrate the feasibility of a low-cost, scalable assistive system for Alzheimer's medication management.

Research Objectives

1. Design and develop an IoT-based medication management system using embedded hardware and sensor technologies.
2. Evaluate the accuracy and reliability of RFID-based user authentication.
3. Assess the performance of infrared motion sensing for patient presence detection.
4. Determine the stability and accuracy of environmental monitoring using temperature and humidity sensors.
5. Evaluate the precision of the automated reminder system.
6. Assess the overall operational performance and integration of the AlzCare prototype.

Variables

Independent Variable: the implementation and operation of the AlzCare system, including its RFID authentication, infrared motion detection, environmental monitoring, and automated reminder functions.

Dependent Variables:

- RFID authentication accuracy (%)

- Infrared sensor detection accuracy (%)
- Temperature measurement accuracy (°C)
- Humidity measurement accuracy (%RH)
- Reminder timing precision (%)
- Overall system reliability (%)

Controlled Variables: to keep testing conditions consistent, the following were held constant across all trials:

- Hardware configuration and component specifications
- Power supply voltage
- Sensor placement and operating distance
- Testing environment and ambient conditions
- Software version and programmed parameters
- Number of testing trials performed for each component

Success Criteria

The AlzCare prototype was considered successful if each major subsystem achieved at least 95% performance accuracy across repeated trials, and if the fully integrated system operated stably without significant functional failures.

MATERIALS AND METHODS

System Design and Architecture

AlzCare was designed as an IoT-based medication management platform to support adherence among people living with Alzheimer's disease, bringing sensing, authentication, monitoring, and notification functions together in one embedded architecture. The design targeted reliable reminders, secure authentication, environmental monitoring, and real-time interaction with the patient, all while keeping cost and implementation effort low.

An ESP8266 microcontroller sits at the center of the architecture, coordinating every connected component. Its inputs are an MFRC522 RFID authentication module, a DHT11 temperature-and-humidity sensor, and an infrared (IR) motion sensor; its outputs are an I2C liquid-crystal display (LCD) and a piezoelectric buzzer that provide visual and audible feedback. The RFID module confirms a user's identity before granting access to the station. The DHT11 sensor continuously reports the environmental conditions around the stored medication. The IR sensor detects when a user is present near the medication station, and the LCD and buzzer deliver reminder notifications on a predefined schedule, with the ESP8266 processing incoming sensor data and triggering the appropriate action, as shown in Figure 1.

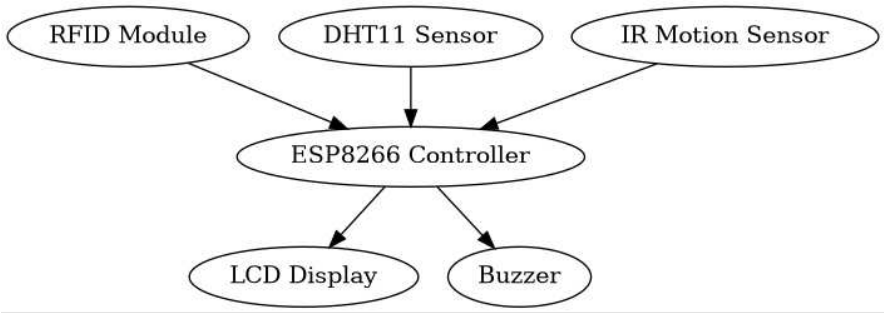


Figure 1. AlzCare system architecture: RFID, DHT11, and IR inputs feed the ESP8266 controller, which drives the LCD display and buzzer.

Hardware Components

The prototype uses commercially available parts chosen for their reliability, affordability, and suitability for embedded healthcare use. Table 1 summarizes the major hardware used.

Component	Function
ESP8266	Main controller
RFID RC522	User authentication
DHT11	Temperature and humidity sensing
IR Sensor	Motion detection
LCD (16×2, I2C)	Information display
Buzzer	Audio reminders

Table 1. Hardware components and specifications.

The ESP8266 was chosen as the main controller for its processing capability, low power draw, and built-in support for future wireless expansion. User authentication runs through the MFRC522 RFID module, which provides secure, contactless identification. The DHT11 sensor supplies both temperature and relative humidity readings for environmental monitoring, while an infrared motion sensor handles patient presence detection. Visual notifications appear on a 16×2 I2C LCD screen, and a piezoelectric buzzer generates the audible reminder alerts. The complete circuit was assembled on a breadboard, shown in Figure 2, and checked for correct electrical connectivity, stable voltage, and reliable communication between components before testing began.

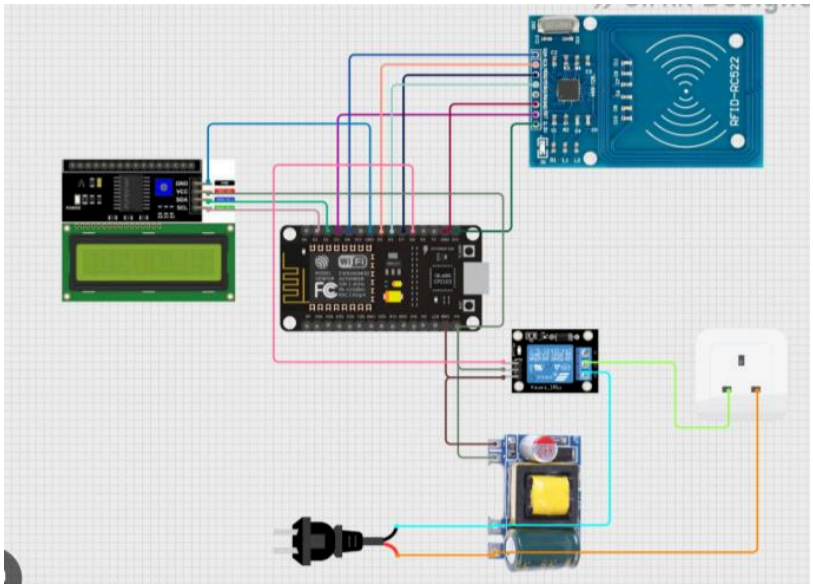


Figure 2. Circuit diagram of the AlzCare prototype.

Software Development

The system software was written in C++ using the Arduino IDE and organized with modular programming practices to keep it easy to maintain, debug, and extend. It was built to perform five core functions: RFID authentication and access verification; continuous temperature and humidity acquisition; infrared-based patient presence detection; medication reminder scheduling and activation; and visual and auditory notification delivery.

When a user presents an RFID tag, the system checks the detected identifier against the authorized credentials stored in the microcontroller's memory, granting access to recognized users and rejecting unauthorized attempts. Environmental readings are collected continuously from the DHT11 sensor and shown on the LCD. The IR sensor tracks movement near the medication station so the system can respond to the user's presence, and scheduled reminders trigger the buzzer while displaying the relevant medication instructions on the LCD screen. Figure 3 illustrates this operational sequence.

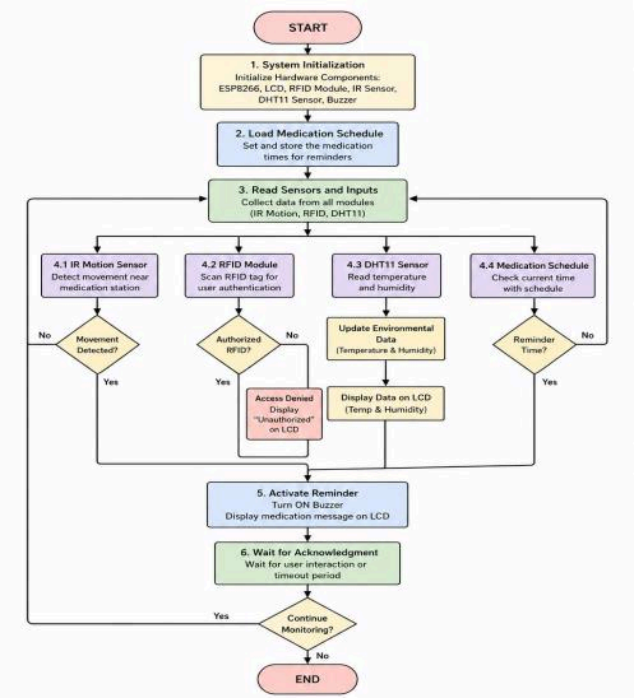


Figure 3. System operation flowchart covering initialization, sensor monitoring, authentication, and reminder activation.

Experimental Procedure

System evaluation took place under controlled laboratory conditions to characterize both the performance of individual components and the reliability of the integrated system. Testing covered authentication accuracy, environmental monitoring stability, motion-detection reliability, and reminder timing precision.

RFID Authentication Testing. The RFID module was put through repeated authentication trials using both authorized and unauthorized tags. Each scan attempt was logged as successful or unsuccessful based on whether the system correctly identified the presented tag, and authentication accuracy was calculated as the percentage of correct identifications out of the total number of attempts.

Infrared Sensor Testing. The infrared motion sensor was tested across multiple trials involving controlled movement within its operating range. Each trial recorded whether the movement was detected, and detection accuracy was calculated as the proportion of correctly registered movement events.

Environmental Monitoring Testing. The DHT11 sensor's temperature and humidity readings were logged at regular intervals under stable indoor conditions. Stability was assessed by looking at the variation between repeated readings, and the measured values were compared against expected environmental conditions to estimate accuracy and consistency.

Reminder System Testing. The buzzer's notification behavior was evaluated by comparing programmed activation times against observed activation events, with reminder precision calculated as the percentage of notifications delivered at the correct scheduled time.

Integrated System Testing. After the individual components were evaluated, all modules were run together to assess system integration and operational stability. The prototype ran continuously while communication between the sensors, authentication module, and output devices was monitored, and any failures, delays, or unexpected behavior were logged and analyzed.

Data Analysis

Collected data were analyzed with descriptive statistics, producing accuracy, reliability, and consistency metrics for each subsystem. Authentication and detection accuracies were calculated with Equation (1):

Accuracy (%) = (Number of Correct Responses / Total Number of Trials) × 100 … (1)

Reminder precision was calculated by comparing successful reminder activations against the total number of scheduled reminders, and environmental sensor performance was assessed through repeated measurements and error estimation, summarized in Table 2.

Component	Expected (%)	Measured (%)	Abs. Error (%)	Remarks
DHT11 Temperature Sensor	100	98.8	1.2	Minor deviation from sensor tolerance
DHT11 Humidity Sensor	100	96.0	4.0	Slight variation under stable indoor conditions
RFID (MFRC522) Authentication	100	98	2	Errors from tag alignment and scanning distance
IR Motion Sensor	100	99	1	Highly stable, minimal false readings
Buzzer Timing System	100	100	0	Fully synchronized with programmed intervals
LCD Output System (I2C)	100	100	0	Stable output, no observed failure
ESP8266 System Stability	100	97–99	1–3	Minor fluctuations during continuous operation

Table 2. Sensor error analysis.

The performance of each subsystem was then compared to gauge overall prototype effectiveness, producing an integrated reliability score based on the successful operation of all major components, illustrated in Figures 4 through 6. This dataset was used to determine whether the AlzCare prototype met the predefined success criterion of at least 95% operational accuracy across all major subsystems.

RESULTS AND DISCUSSION

Results

The AlzCare system was evaluated through a series of controlled experiments on both the individual subsystems and the integrated prototype. Results show consistent operational reliability across all hardware components, spanning authentication, sensing, and notification.

The RFID authentication module (MFRC522) reached a 98% success rate across repeated scanning trials, illustrated in Figure 4; the small share of failures traced mainly to minor misalignment between tags and the reader or brief signal interference, while unauthorized access attempts were consistently and correctly rejected. The infrared (IR) motion sensor achieved roughly 99% detection accuracy with consistent results across trials, shown in Figure 5, reliably detecting user presence within its effective range with very few false positives or missed detections.

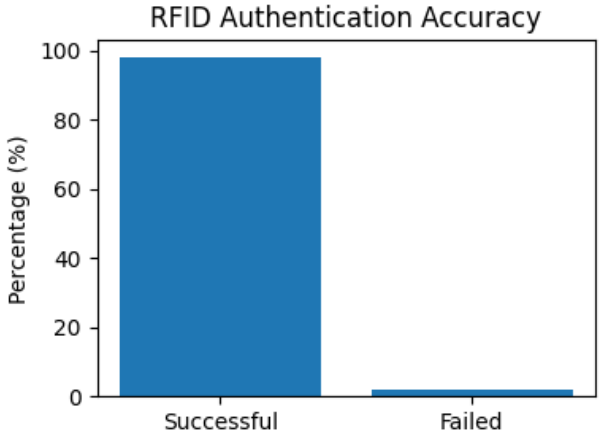


Figure 4. RFID authentication accuracy across repeated scanning trials.

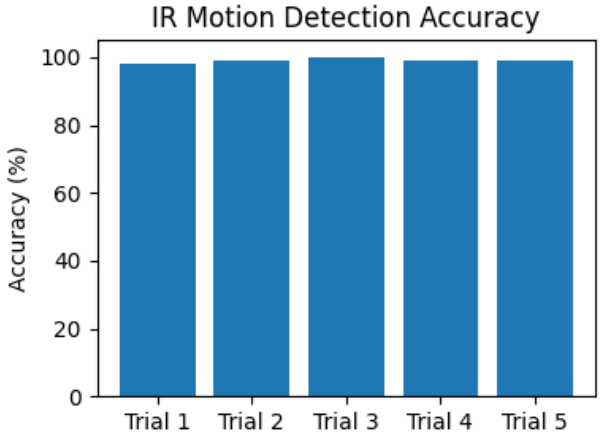


Figure 5. Infrared motion detection accuracy across five test trials.

The DHT11 environmental sensor produced stable readings under controlled indoor conditions, with an average temperature deviation of about ±1.2°C and an average humidity deviation of about ±4%, both within acceptable limits for embedded environmental monitoring. The buzzer-based reminder system hit 100% timing accuracy, triggering alerts at every scheduled interval, and the LCD display consistently delivered real-time feedback with no observed errors or communication failures. With everything integrated, overall system reliability ranged between 97% and 99% depending on test conditions and subsystem interaction, illustrated in Figure 6, and no critical failures occurred during continuous operation testing.

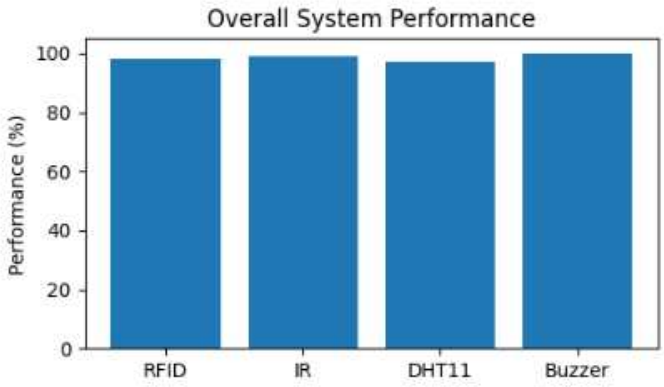


Figure 6. Overall performance comparison across the RFID, IR, DHT11, and buzzer subsystems.

Discussion

These results show that AlzCare performs reliably as an integrated IoT-based medication management prototype. The 98% accuracy observed for RFID authentication indicates the system is well suited to controlled-access applications requiring secure identification, and the small margin of error is consistent with known RFID limitations around tag orientation, reading distance, and electromagnetic interference.

The infrared motion sensor's near-perfect detection performance (≈99%) confirms it is suitable for real-time presence detection in assistive healthcare settings, which matters for medication reminder systems, where incorrect detection could cause missed or repeated alerts; the consistency observed suggests the sensor is well matched to short-range human activity monitoring in a controlled environment.

The DHT11 results show acceptable, if imperfect, accuracy for environmental monitoring. The minor deviations in temperature and humidity are expected given the inherent limitations of low-cost digital sensors and do not meaningfully affect system functionality, since in this project environmental monitoring is meant to supply supportive contextual data rather than clinical-grade measurement.

The buzzer's perfect timing accuracy under test conditions indicates that the microcontroller's internal timing and software scheduling were implemented correctly — a critical detail, since timely alerts are central to reminder effectiveness. Integration testing confirmed that all modules worked together without

communication conflicts or major performance loss, and the 97–99% combined reliability range suggests the architecture is stable and scalable for further development.

Compared with IoT-based medication management systems reported in the literature, AlzCare compares favorably, particularly in how it combines authentication, environmental sensing, and reminder mechanisms within a single low-cost platform. Unlike the clinical studies referenced earlier, however, this evaluation is limited to technical validation under controlled conditions and does not include long-term trials with patients or caregivers. That absence of real-world clinical testing is a key limitation: conclusions about improvements in medication adherence or caregiver burden cannot be drawn directly from this experimental data, and future work should prioritize user-based evaluation in clinical or home settings to assess usability, long-term reliability, and behavioral impact.

Despite these limitations, the results support the technical feasibility of AlzCare as an integrated IoT healthcare prototype. Reliable sensing, secure authentication, and automated reminders working together demonstrate the potential of low-cost embedded systems for medication management, suggesting that architectures like AlzCare can serve as a foundation for future assistive healthcare technologies, particularly where affordability and simplicity are essential design constraints.

CONCLUSION

This study presented AlzCare, an IoT-based smart medication management system built to support medication-related tasks for people living with Alzheimer's disease. It brings RFID-based authentication, infrared motion detection, environmental monitoring, and automated reminders together on a single low-cost ESP8266 platform.

Experimental evaluation showed high operational reliability across every subsystem tested: 98% accuracy for RFID authentication, roughly 99% detection accuracy for the infrared motion sensor, acceptable environmental monitoring performance from the DHT11 sensor with only minor deviations, and 100% timing accuracy for the reminder and alert system. Overall system reliability ranged from 97% to 99%, indicating stable integration of hardware and software. These results confirm the technical feasibility of a compact, low-cost IoT architecture for medication management, though the evaluation was limited to laboratory testing and did not include clinical trials or long-term studies with patients or caregivers, so no conclusions can yet be drawn about direct improvements in adherence or caregiver burden.

Future work will extend the system toward real-world deployment and clinical validation to assess usability, long-term reliability, and behavioral outcomes in home-care settings, potentially adding mobile application integration, cloud-based monitoring, and adaptive, algorithm-driven reminders. Overall, AlzCare illustrates how embedded IoT systems can offer scalable, accessible assistive healthcare solutions, particularly in resource-limited settings where affordability and reliability are essential.

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