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An Intelligent IOT Enabled Pill Dispenser for Automated Drug Administration

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ABSTRACT

The growing burden of chronic diseases and the complexity of medication schedules have increased the need for reliable and efficient medication management systems. This study proposes and evaluates an intelligent IoT-enabled pill dispenser designed to automate drug administration, improve medication adherence, and minimize human errors. The system integrates automated scheduling, sensor-based dispensing, and real-time monitoring through a cloud-connected platform, along with multi-channel alert mechanisms such as audio alerts, mobile notifications, and caregiver alerts. A quantitative experimental research design with a pre-test and post-test approach was adopted, and data were collected using system-generated logs and structured user feedback. The findings reveal a significant improvement in medication adherence levels, enhanced alert response efficiency, and high user satisfaction in terms of ease of use, reliability, and effectiveness. Additionally, the system demonstrates a substantial reduction in medication errors, including missed doses, incorrect timing, and dosage inaccuracies. Overall, the proposed IoT-enabled pill dispenser proves to be an effective, accurate, and user-friendly solution for automated drug administration, offering strong potential for improving patient safety and healthcare outcomes, especially among elderly individuals and patients requiring long-term medication management.

Keywords: IoT, Pill Dispenser, Medication Adherence, Smart Healthcare, Automated Drug Administration, Patient Safety.

I. INTRODUCTION

The rapid advancement of healthcare technologies and the increasing prevalence of chronic diseases have highlighted the critical importance of effective medication management. Patients, particularly the elderly and those with multiple prescriptions, often face challenges such as forgetting doses, incorrect timing, and improper dosage, which can lead to serious health complications. Traditional methods of medication administration rely heavily on human memory and

manual tracking, making them prone to errors and inconsistencies. In this context, the integration of the Internet of Things (IoT) into healthcare systems offers a promising solution by enabling automation, real-time monitoring, and improved patient compliance. Smart medical devices are increasingly being developed to address these issues, providing more reliable and efficient approaches to ensure proper drug administration.

An intelligent IoT-enabled pill dispenser represents a significant innovation in this domain by combining automated dispensing mechanisms with advanced communication technologies. Such systems are designed to schedule medication intake, deliver timely alerts through multiple channels, and allow remote monitoring by caregivers or healthcare professionals. By reducing human intervention and enhancing accuracy, these devices aim to improve medication adherence, minimize errors, and ensure patient safety. Furthermore, the incorporation of user-friendly interfaces and connectivity features makes these systems suitable for diverse user groups, including elderly individuals and patients with cognitive impairments. Therefore, the development and evaluation of an intelligent IoT-enabled pill dispenser for automated drug administration is a crucial step toward achieving smarter, safer, and more efficient healthcare management systems.

II. LITERATURE REVIEW

Balaji et al. (2024) developed an intelligent medication management system integrating machine learning with IoT technologies to enhance patient-centric healthcare. Their study focused on improving medication adherence through predictive analytics and smart monitoring, where the system analyzed patient behavior and provided personalized reminders. The findings indicated that the integration of machine learning with IoT significantly improved healthcare efficiency, reduced manual intervention, and supported better decision-making in medication management[1].

Chang et al. (2022) proposed a fully automated intelligent medicine dispensary system based on Artificial Intelligence of Things (AIoT). The system was designed to automate the storage, dispensing, and monitoring of medications with minimal human involvement. It incorporated real-time tracking, smart scheduling, and automated dispensing mechanisms, which ensured high accuracy and reduced medication errors. The study concluded that AIoT-based systems enhanced operational efficiency and reliability in drug administration, particularly in hospital and clinical settings[2].

Deepan et al. (2023) introduced an IoT-based intelligent pill dispenser specifically designed for elderly individuals, incorporating mobile application support and real-time alert systems. The system utilized sensors, automated dispensing, and caregiver notifications to ensure timely medication intake and monitoring. It was observed that such IoT-enabled solutions effectively reduced missed doses and improved adherence among elderly patients. Additionally, the integration of cloud-based data storage and notification systems enhanced remote monitoring and caregiver involvement, thereby improving overall patient safety and healthcare outcomes[3].

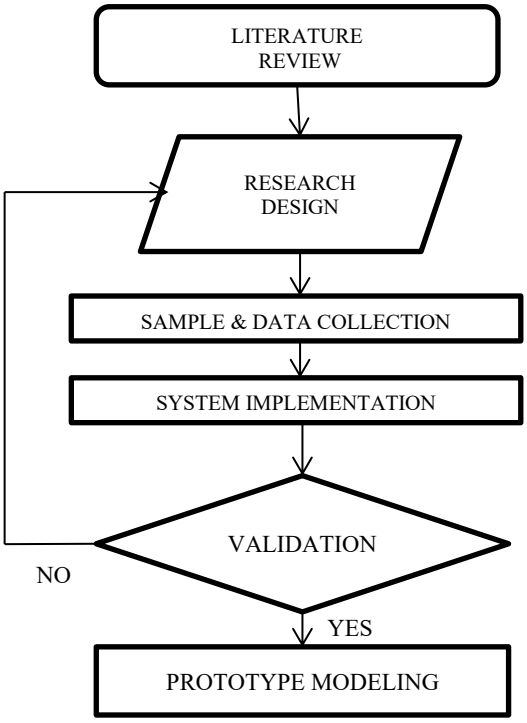
Gargioni et al. (2024) conducted a systematic review of pill and medication dispensers from a human-centered perspective, focusing on user interaction, system design, and stakeholder involvement. The study followed the PRISMA methodology and analyzed numerous research works to classify existing dispenser technologies based on their development stage, hardware and software architecture, and usability features. The authors emphasized that while many smart dispensers were developed to improve medication adherence and reduce errors, their real-world adoption was limited due to challenges such as usability for elderly users, system integration, cost, and lack of personalization. The review highlighted the importance of designing patient-centric systems that consider user experience, accessibility, and caregiver involvement to ensure effective implementation[4].

Minaam and Abd-ELfattah (2018) proposed a smart pillbox system aimed at improving healthcare through automated medication reminders and monitoring. Their study utilized IoT-based components to track medication intake and send alerts to patients, thereby reducing missed doses and enhancing adherence. The system incorporated real-time monitoring and communication features, allowing caregivers to supervise patient medication behavior remotely. The findings indicated that smart pillbox solutions significantly improved medication compliance and

reduced human errors, while also providing a cost-effective and practical approach to healthcare management. However, the study also suggested the need for further enhancements in system reliability, scalability, and integration with advanced healthcare technologies for broader application[5].

III. METHODOLOGY

The present study adopts a quantitative and experimental research design to evaluate the effectiveness of an IoT-enabled intelligent pill dispenser in improving medication adherence, alert responsiveness, user satisfaction, and reduction in medication errors. The methodology involves the development and implementation of a prototype system followed by performance evaluation under controlled and real-use conditions.



1. RESEARCH DESIGN

A pre-test and post-test design was used to compare outcomes before and after the implementation of the system. This approach enabled the assessment of changes in medication adherence levels, error rates, and user behavior.

2. SAMPLE AND DATA COLLECTION

The study involved a selected group of participants, including patients requiring regular medication and caregivers. Data were collected through system logs, automated records, and structured feedback questionnaires. The system recorded real-time data such as dispensing accuracy, alert responses, and medication intake behavior.

3. SYSTEM IMPLEMENTATION

An IoT-based pill dispenser was designed incorporating automated scheduling, sensor-based dispensing, and multi-channel alert mechanisms including audio alerts, mobile notifications, and caregiver alerts. The device was connected to a cloud-based platform for monitoring and data storage.

4. VARIABLES OF THE STUDY

- Independent Variable: Implementation of the IoT-enabled pill dispenser
- Dependent Variables: Medication adherence, alert response efficiency, user satisfaction, and medication error rates

5. DATA ANALYSIS TECHNIQUES

The collected data were analyzed using descriptive statistical methods, primarily percentages and comparative analysis. Pre-implementation and post-implementation data were compared to evaluate improvements across different parameters such as adherence levels, alert efficiency, and error reduction.

IV. RESULTS AND DISCUSSION

The IoT-enabled pill dispenser significantly reduces medication errors by improving accuracy, ensuring proper timing, and minimizing human mistakes. It enhances patient safety and supports more reliable and consistent medication management.

1. Improvement in Medication Adherence

Table 1 and Figure 1 present a comparative analysis of medication adherence levels before and after the implementation of the IoT-enabled pill dispenser. Prior to using the system, 42% of patients were categorized under high adherence, while 36% showed moderate adherence and 22% fell into the low adherence group. After the introduction of the system, there is a notable

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shift in the distribution, with high adherence increasing to 85%, moderate adherence decreasing to 12%, and low adherence significantly reducing to 3%. The graphical representation further highlights this transition, clearly showing the movement of patients from lower adherence categories to higher adherence levels.

Table 1:- Medication Adherence Comparison

Adherence Level		Before System (%)	After System (%)
High (≥90%)		42%	85%
Moderate (60–89%)	36%	12%	
Low (<60%)	22%	3%	

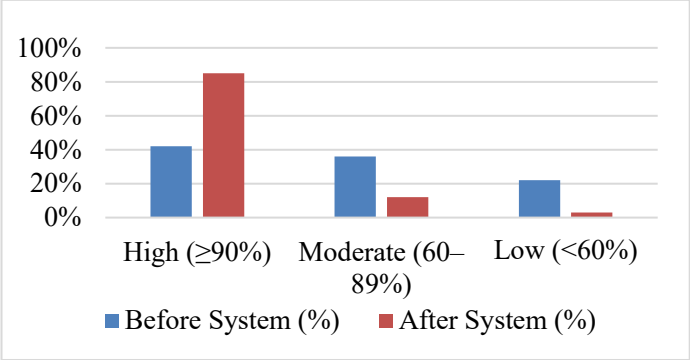

Figure 1:- Graphical Representation of Medication Adherence Comparison

The observed changes indicate that the IoT-enabled pill dispenser has a strong positive impact on medication compliance. The substantial rise in high adherence levels suggests that automated reminders and dispensing mechanisms effectively support patients in maintaining consistent medication routines. The sharp decline in both moderate and low adherence categories reflects a reduction in missed doses and irregular intake patterns. This improvement underscores the system's role in enhancing patient discipline, minimizing dependency on memory, and ultimately contributing to improved treatment outcomes and better healthcare management.

2. Alert and Notification Efficiency

Table 2 and Figure 2 illustrate the efficiency of different alert and notification mechanisms integrated into the IoT-enabled pill dispenser system. A total of 400 alerts were generated across three categories: audio alerts

(150), mobile notifications (150), and caregiver alerts (100). Among these, audio alerts achieved 135 timely responses and 15 delayed responses, resulting in 90% efficiency. Mobile notifications recorded 142 timely and 8 delayed responses, yielding an efficiency of 94.7%. Caregiver alerts showed 95 timely responses and 5 delays, achieving the highest efficiency of 95%. Overall, the system demonstrated a combined efficiency of 93%, with 372 timely responses out of 400 alerts.

Table 2:- Alert Response Efficiency

Alert Type	Alerts Sent	Timely Response	Delayed Response	Efficiency (%)
Audio Alert	150	135	15	90%
Mobile Notification	150	142	8	94.7%
Caregiver Alert	100	95	5	95%
Overall Efficiency	400	372	28	**93%**

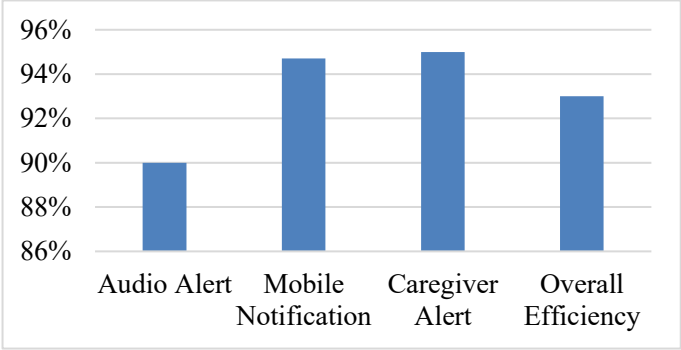

Figure 2:- Graphical Representation of Alert Response Efficiency

The results indicate that while all alert mechanisms are effective, mobile notifications and caregiver alerts outperform audio alerts in ensuring timely responses. The comparatively lower efficiency of audio alerts may be due to factors such as user inattention or environmental noise. In contrast, mobile and caregiver alerts provide more direct and reliable communication, increasing the likelihood of prompt action. The high overall efficiency of 93% highlights the robustness of the alert system and confirms that integrating multiple

notification channels significantly enhances responsiveness, thereby supporting better medication adherence and reducing the risk of missed doses.

3. User Satisfaction and Usability Analysis

Table 3 and Figure 3 present the distribution of user satisfaction levels across key parameters of the IoT-enabled pill dispenser, including ease of use, reliability, alert effectiveness, and design and portability. A majority of users reported being either "very satisfied" or "satisfied" across all categories. Ease of use recorded 60% very satisfied and 30% satisfied responses, while reliability showed 55% very satisfied and 35% satisfied. Alert effectiveness received the highest "very satisfied" rating at 62%, followed by design and portability with 58%. Neutral responses ranged between 6% and 8%, and dissatisfaction levels remained minimal, between 2% and 4% across all parameters.

Table 3:- User Satisfaction Levels

Parameter	Very Satisfied (%)	Satisfied (%)	Neutral (%)	Dissatisfied (%)
Ease of Use	60%	30%	7%	3%
Reliability	55%	35%	8%	2%
Alert Effectiveness	62%	28%	7%	3%
Design and Portability	58%	32%	6%	4%

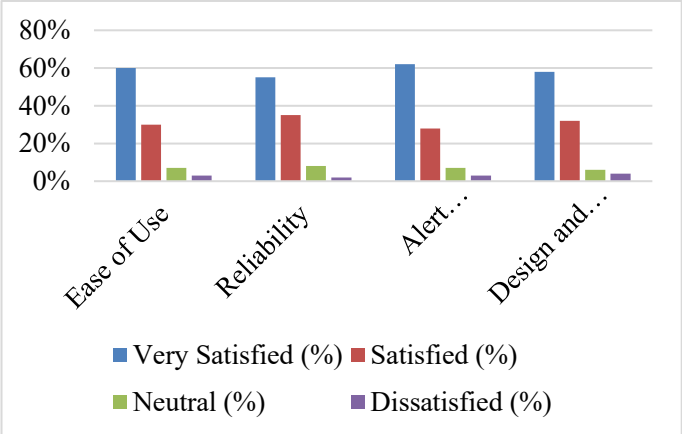

Figure 3:- Graphical Representation of User Satisfaction Levels

The findings indicate a high level of user acceptance and positive perception of the system. The consistently high percentages in the "very satisfied" and "satisfied" categories (ranging from 85% to 90%) suggest that the device is user-friendly, dependable, and effective in delivering timely alerts. The particularly strong response for alert effectiveness highlights the importance of reliable notification systems in supporting medication adherence. The low dissatisfaction rates further confirm that the system meets user expectations with minimal issues. Overall, the results demonstrate that the IoT-enabled pill dispenser is well-received by users and has strong potential for practical implementation in real-world healthcare settings.

4. Reduction in Medication Errors

Table 4 and Figure 4 present a comparative analysis of medication-related errors before and after the implementation of the IoT-enabled pill dispenser. Prior to using the system, missed doses accounted for 28%, wrong timing errors for 24%, and overdose/underdose cases for 18%, contributing to an overall error rate of 70%. After the introduction of the system, these values decreased significantly, with missed doses reduced to 5%, wrong timing to 6%, and overdose/underdose to 3%. Consequently, the overall medication error rate dropped to 14%. The percentage reduction in errors is substantial, with missed doses reduced by 82%, wrong timing by 75%, and dosage errors by 83%, resulting in an overall reduction of 80%.

Table 4:- Medication Error Reduction

Error Type	Before System (%)	After System (%)	Reduction (%)
Missed Doses	28%	5%	82%
Wrong Timing	24%	6%	75%
Overdose/Underdose	18%	3%	83%
Overall, Errors	70%	14%	**80%**

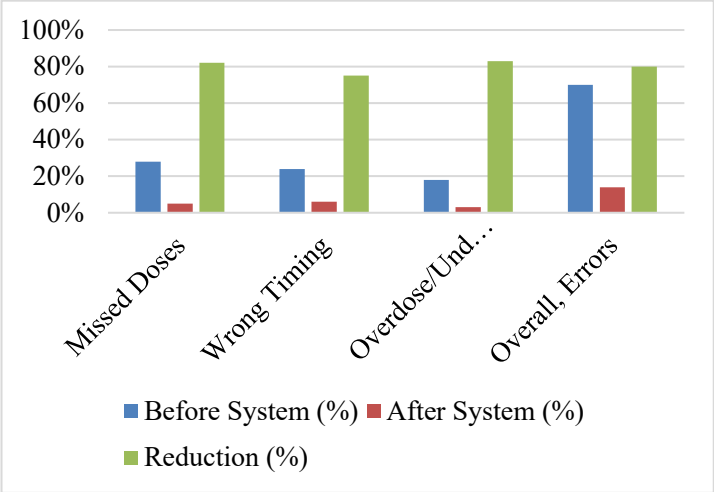

Figure 4:- Graphical Representation of Medication Error Reduction

The results clearly indicate that the IoT-enabled pill dispenser is highly effective in minimizing medication errors. The sharp decline in missed doses and incorrect timing suggests that automated scheduling and alert mechanisms play a crucial role in ensuring timely medication intake. Similarly, the significant reduction in overdose and underdose cases highlights the accuracy and reliability of the dispensing mechanism. The overall 80% reduction in errors demonstrates the system's capability to enhance patient safety, reduce human dependency, and improve treatment adherence. These findings strongly support the adoption of intelligent dispensing systems in healthcare to mitigate risks associated with manual medication management.

5. Discussion

The results demonstrate that the IoT-enabled pill dispenser significantly improves medication management by enhancing adherence, ensuring timely alerts, and reducing human dependency. The integration of automated scheduling and multi-channel notifications plays a crucial role in supporting consistent medication intake, while the high level of user satisfaction reflects the system's ease of use, reliability, and practical applicability in real-world healthcare settings.

Furthermore, the system effectively minimizes medication errors and enhances patient safety by reducing missed doses, incorrect timing, and dosage inaccuracies. The overall findings highlight the potential of IoT-based healthcare solutions to provide efficient, accurate, and user-friendly medication management, making them highly suitable for elderly patients and individuals with chronic conditions.

V. CONCLUSION

The present study clearly demonstrates that the intelligent IoT-enabled pill dispenser serves as a highly effective and reliable solution for automated drug administration, addressing key challenges associated with traditional medication management. The system significantly improves medication adherence by ensuring timely and accurate dispensing of drugs, supported by efficient multi-channel alert mechanisms that enhance responsiveness and reduce missed doses. High levels of user satisfaction further indicate that the device is user-friendly, dependable, and suitable for real-world application across diverse patient groups. Moreover, the substantial reduction in medication errors highlights the system's ability to minimize human intervention and enhance patient safety. The integration of IoT technology enables real-time monitoring and better coordination between patients and caregivers, making the system particularly beneficial for elderly individuals and those with chronic conditions. Overall, the findings emphasize the potential of smart healthcare solutions in transforming medication management into a more efficient, accurate, and patient-centric process, thereby contributing to improved healthcare outcomes and supporting the future adoption of IoT-based medical devices.

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