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PILLZ: SMART PILL DISPENSER SYSTEM FOR SENIOR CARE

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Abstract

The Smart Pill Dispenser System functions as a modern system which enables elderly users and patients to handle their medicine schedules effectively. The system combines Raspberry Pi with infrared sensor, servo motor and mobile application using Firebase as a real-time monitoring platform. The dispenser runs its automated pill distribution process through timed rotations of the specific pill slot to guarantee proper dosage. The mobile application receives information from an infrared sensor when it detects pill consumption. The system activates an alert by sending notifications for the user when the pill remains unretrieved. The mobile app enables remote monitoring which enables caregivers and family members to check medication adherence patterns. Firebase provides users with automatic data synchronization capabilities that allow device-to-device data accessibility. Real-time alerts and IoT integration with automation in the Smart Pill Dispenser system promote medication adherence which decreases the chance of patients missing their doses or taking them twice. The proposed solution seeks to develop a dependable system that simplifies medication administration specifically for elderly patients and people dealing with persistent health conditions.

Keywords: Smart Pill Dispenser, IoT, Raspberry Pi, Firebase Realtime Database, elderly care, automated pill dispensing, infrared sensor, mobile application, remote access, scheduling, wireless connectivity.

INTRODUCTION

Medication compliance is a significant feature of chronic illness management, particularly in the elderly, who could be reliant on multiple drugs daily. However, medication regimen non-compliance is also a very prevalent occurrence, leading to severe illness, increased hospitalization, and deterioration of overall well-being. Forgetfulness, cognitive impairment, and the complexity of the drug regimen are primary reasons contributing to this problem. The traditional methods, such as pillboxes and reminder alarms, provide limited assistance because they lack monitoring capabilities and do not prevent missed or improper doses. Therefore, there is a pressing need for a highly advanced, user-friendly, and automated system for drug management to ensure adherence and patient safety.

Through the new technology in Internet of Things (IoT), smart pill dispensers offer a possible solution to non-adherence medication. They integrate sensors, real-time tracking, and automatic dispensing to deliver the correct drug at the correct time to patients. Furthermore, cloud-based systems also allow caregivers and healthcare providers to remotely track taking medication, adding more support and intervention when necessary. Along with Raspberry Pi, sensors, and Firebase, a smart pill dispenser system can effectively manage medication timetables, remind users through smartphone notifications, and mitigate the risks of skipped or improper doses.

This research endeavors to create and innovate a smart pill dispenser for care of the elderly, with live monitoring for increased medication adherence. The project further evaluates the efficiency of the system in dispensing pills and warning users effectively. With the mission of avoiding pitfalls of traditional medicine management practices, this project envisions improving autonomy and well-being among the elderly and providing caregivers with relief of mind. Finally, the suggested system is an organized and technology-based solution whose purpose is to improve medication compliance as well as healthcare outcomes in the elderly group.

LITERATURE REVIEW

Medication adherence is a key concern, particularly among the elderly and visually impaired, who struggle to keep their medications in check. The application of technology in the healthcare industry has introduced several smart pill dispensers that aim to address these issues. This section presents previous relevant works on automated drug dispensing systems and their assistance towards enhancing adherence, accessibility, and overall efficiency in healthcare.

2.8.1 Smart Medicine Planner for Visually Impaired People (Al Haider et al., 2020)

The Smart Medicine Planner (SMP) system is designed to assist people who are visually impaired in managing their medication schedule. The system includes an automatic refilling function, a voice-assisted smart medicine box (SMB), and alarms, providing greater autonomy and adherence to treatment courses. The SMP system meets the United Nations Convention on the Rights of Persons with Disabilities, focusing on accessibility and autonomy.

The primary objectives of this project are to design an automated dispenser system, including a voice command recognition feature, integrate a user-friendly smart medicine box, and facilitate interaction by voice because it assists people in utilizing the dispenser easily without requiring visual input.

Unlike the smart pill dispenser project, the SMP system aims only for visually impaired individuals, whereas the smart pill dispenser has its accessibility provided to older patients and medication-restricted patients. The use of voice-command medication selection, automatic prescription refills, and smartphone reminder apps can further improve medication adherence. Both systems aim towards user-friendliness and independence, letting the patient control their health better.

2.8.2 Microcontroller-Based Smart Tablet Dispenser (STD) for Elderly Persons (Balaji et al., 2022)

Smart Tablet Dispenser (STD) is designed for elderly patients who tend to forget drug timings. It has a touchscreen interface, smartphone application, and microcontroller-based dispensing system. The system avoids overdose or underdose from the patients and provides remote access by caregivers. Key features of the system are:

- Automated Dispensing: Utilizes servo motors and microcontrollers to release medication at scheduled intervals.
- Alert System: Incorporates a red-light warning as well as user-definable reminders to remind users of missed doses.
- Caregiver Monitoring: Remote monitoring of medication adherence through mobile application.

Although both the smart pill dispensers and STD leverage mobile apps for reminder purposes, the STD comes with a more sophisticated notification system in the form of visual reminders and remote monitoring by caregivers. The smart pill dispenser can capitalize on these features through the inclusion of real-time reminders for forgotten doses and a database accessible to caregivers to maximize adherence and safety for patients.

2.8.3 IoT-Enabled Medicine Dispenser for Pills and Liquid Medication (Hassan et al., 2024)

This study sets out an IoT-based medication dispenser that improves medicine adherence among geriatric patients with the integration of Raspberry Pi and Arduino UNO to dispense medicine precisely and monitor remotely. The system provides improved compliance on time to help avoid missed medication doses and compliance monitoring for more accurate caregiving. The machine is linked with an online portal through which caregivers remotely observe adherence. The important advantages of the system are:

- Automated Dispensing & Monitoring: Leverages Raspberry Pi and Arduino UNO for precise dosage management.
- Real-Time Caregiver Access: Remote monitoring of medication schedules and usage by caregivers.
- Future Enhancements: The study suggests AI integration for personalized medication reminders and energy-efficient designs for broader accessibility.

As opposed to conventional smart pill dispensers that rely on human user operation, this IoT-based system exploits automated dispensing and AI-enabled tracking. Utilizing the same machine learning techniques and real-time monitoring features in the smart pill dispenser project can propel medication adherence and enhance individualized health management.

2.8.4 Automatic Pill Dispenser for Elderly Medical Adherence: A Survey (Divya et al., 2024)

The survey provides a comprehensive analysis of automatic pill dispensers, with a particular focus on their integration with IoT to improve elderly patient medication adherence.

It focuses on the following primary areas:

- IoT Capabilities: Describes how connected devices improve adherence and monitoring.
- Technological Evolution: Describes past and existing pill dispenser technologies.
- Challenges & Limitations: Identifies common sensor precision issues and user engagement issues.
- Future Directions: Suggests advancements in AI-based medication tracking and real-time monitoring of adherence.

The integration of IoT-based automation and real-time monitoring of adherence is a big leap over traditional smart pill dispensers, which are typically reminders and not automation. The smart pill dispenser project can be augmented with these IoT advancements by adding sensor-based monitoring, cloud connectivity, and AI-based reminders to the system, making it more efficient and easier to use.

In conclusion, the reviewed literature demonstrates significant advancements in smart medication dispensers, particularly automated dispensing, real-time monitoring, and caregiver accessibility. The SMP system is designed for voice interaction and visual impairment accessibility, while the STD is designed for elderly patients with touchscreen screens and alert systems. The IoT-based medicine dispenser offers advanced automation through Raspberry Pi and Arduino, offering a more efficient compliance monitoring system. Lastly, the automatic pill dispenser survey points toward the importance of IoT integration and AI-based medication management.

Based on these studies, the smart pill dispenser project can be enhanced by adopting real-time adherence tracking, AI-based reminders, and IoT-based automation. The improvements will not only address elderly medication adherence challenges but also pave the way for future healthcare technology advancements.

METHODOLOGY

This study's research approach follows the sequential methodology of the waterfall model that consists of five primary stages: requirement gathering, system design, implementation, testing, and documentation.

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In the requirement gathering stage, the first step was gathering information about medication non-adherence problems among elderly adults. Research was conducted to identify significant issues such as forgetfulness, inability to operate conventional pill dispensers, and the need for caregiver monitoring. Based on these, the hardware and software requirements were designed. The hardware components included Raspberry Pi, infrared sensor, servo motor, while software development relied on Python for Raspberry Pi programming, Firebase for cloud storage, and Android Studio for mobile app development.

In the system design phase, the system architecture was designed to ensure the free interaction between hardware and software components. Hardware design was focused on integrating Raspberry Pi with sensors and actuators to enable pill dispensing and alert mechanisms. Software architecture was designed to ensure the free communication between the dispenser, Firebase database, and mobile app. The Android app user interface was designed with a simple and elderly-friendly design to ensure ease of use.

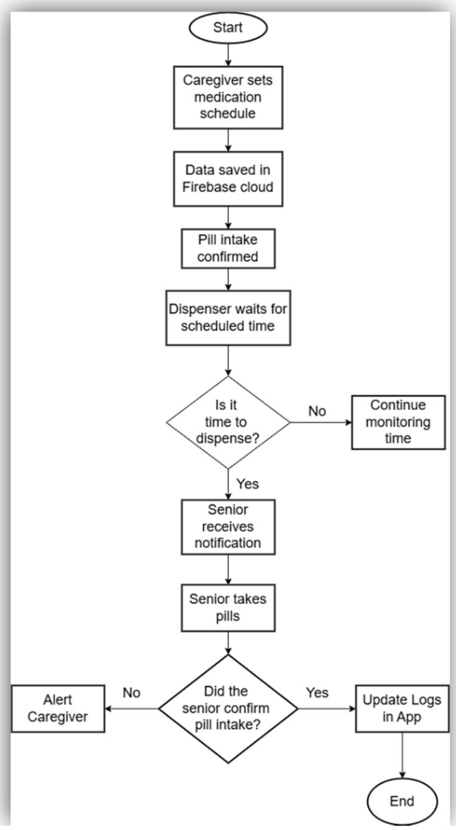

Figure 1: Flowchart of overall system of Smart Pill Dispenser

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The overall system flowchart in Figure 1 demonstrates how users input information that leads to pill dispensing through the smart pill dispenser system. The mobile application enables caregivers to establish medication schedules that Firebase stores as part of its database. The system examines the database periodically to confirm whether the current time matches a scheduled pill. The system activates the dispenser mechanism at the time point to release the pill. The infrared sensor verifies whether the pill has been consumed and generates alerts to notify both the senior user and their caregiver when someone fails to take the medication. The system runs this sequence of operations for each scheduled medication while delivering notifications when patients forget to take their medications.

The third phase, which is the implementation phase focused on making the system by combining the hardware components and coding the software. The Raspberry Pi was programmed to control the dispensing system with the aid of a servo motor, while Firebase stored and managed user data. The mobile application was designed to allow users and caregivers to schedule medications and be reminded accordingly.

Pill dispensing, delivery of alerting notifications, and system behavior were also tested during system testing phase to determine the precision and consistency of pill dispensing, notification delivery, and system response in general. Simulations were conducted to ensure that the system would respond correctly when users missed doses, or the device ran out of pills.

Lastly, there was the documentation process, whereby every detail about the project from hardware setup to software development to system performance was recorded. Through this process, future enhancements and debugging can easily be done. Documentation also covered test case results, user testing results, and a user manual for installation and operational guidelines. Proper documentation ensures that future updates can be made following the documented development process and system functionality.

RESULT AND DISCUSSION

Results and discussion section presents the test results for the smart pill dispenser system and discusses its effectiveness in addressing medication compliance among elderly users. The different tests conducted were for measuring the accuracy of pill dispensing, sensitivity of infrared sensors, effectiveness of the notification process, and user experience.

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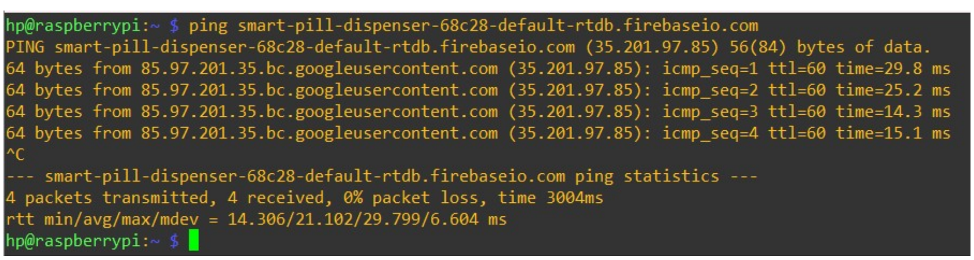
The main observation was that the servo motor-based dispensing device released the correct dose at the right time. The system ensured precise pill release, which minimized drug errors. The infrared sensor correctly detected whether a pill was taken and gave reminders in case a user missed a dose. Firebase enabled real-time updates, through which caregivers could monitor medication adherence using the mobile application.

The notification system was also tested in different scenarios, including when the user had already taken the pill, missed the dose, or attempted to manually dispense medicine. The results of the test showed that the system always issued reminders through the mobile app in case a missed dose was detected. One drawback that was pointed out was dependence on an active internet connection to synchronize data in real-time. In areas that are not well connected, there was some delay in app updating, which could affect timely reminders for medication. User experience was also taken into account to assess the usability of the system. The interface was easily understood by most participants, and they welcomed the various forms of notification, such as visual and text alerts. Some users recommended inclusion of voice notifications for visually challenged users, which can be looked at for future enhancements. Moreover, the Android-only compatibility of the system restricted access for iOS users, which is an area that can be improved.



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hp@raspberrypi:~ $ ping smart-pill-dispenser-68c28-default-rtdb.firebaseio.com
PING smart-pill-dispenser-68c28-default-rtdb.firebaseio.com (35.201.97.85) 56(84) bytes of data.
64 bytes from 85.97.201.35.bc.googleusercontent.com (35.201.97.85): icmp_seq=1 ttl=60 time=29.8 ms
64 bytes from 85.97.201.35.bc.googleusercontent.com (35.201.97.85): icmp_seq=2 ttl=60 time=25.2 ms
64 bytes from 85.97.201.35.bc.googleusercontent.com (35.201.97.85): icmp_seq=3 ttl=60 time=14.3 ms
64 bytes from 85.97.201.35.bc.googleusercontent.com (35.201.97.85): icmp_seq=4 ttl=60 time=15.1 ms
^C
--- smart-pill-dispenser-68c28-default-rtdb.firebaseio.com ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3004ms
rtt min/avg/max/mdev = 14.306/21.102/29.799/6.604 ms
hp@raspberrypi:~ $
```

Figure 2: Latency (Ping Test)

Figure 1 shows the ping test of Raspberry Pi has successfully connects to smart-pill dispenser-68c28-default-rtdb.firebaseio.com through its IP address 35.201.97.85 on a Google Cloud server. The four ICMP echo requests sent through the test experienced a successful reception which produced zero packet loss to indicate a steady and dependable connection. The average response duration for round-trip time (RTT) measurements fell within the range of 14.3 ms to 29.8 ms at 21.1 ms while indicating low latency performance. Response 64 times experience normal variation because of network congestion together with routing paths and server load conditions. The successful pings show that both the internet connection and DNS resolution work properly to enable smooth data communication with Firebase Realtime Database. The database's stable performance is essential for applications that need real-time data synchronization in IoT projects and cloud-based services. Additional network diagnostic services must be conducted to solve identified latency problems or packet loss occurrences.

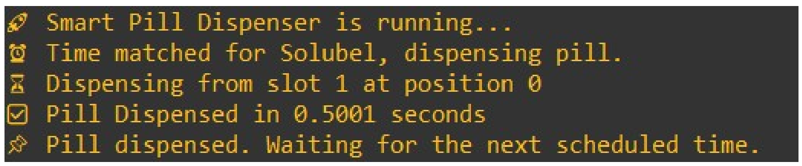

Figure 3: Data transfer speed

The data transfer speed (throughput) test for the Smart Pill Dispenser on Figure 2 determined the duration needed for Raspberry Pi to exchange data with Firebase during operations. The system operated efficiently by detecting the programmed dispensing time and then started the pill dispensing sequence. The system executed communication and performed the operation within 0.5001 seconds according to the recorded results. During operation the dispenser successfully recognized the correct pill slot before delivering the medication promptly. Application performance proved stable throughout the test period because transmission delays and network issues did not occur. The stable nature of the Raspberry Pi-to-Firebase connection demonstrates its ability to process real-time database updates. The system's speed can be optimized through three methods which consist of Wi-Fi signal enhancement, Ethernet connection switch and batch updates to Firebase database. The system shows successful performance during standard operations which maintains both quick and dependable medicine distribution to users.

Overall, the result indicated that the smart pill dispenser performed effectively in improving the dispensing of medication by dispensing it on time and reminding users and caregivers. The system operated effectively under normal conditions, but integration of solutions for vulnerabilities such as internet reliance and platform compatibility would further make the system accessible and usable.

CONCLUSION

This research aimed to develop an intelligent pill dispenser system for elder care, addressing the problem of medication adherence with an automated and easy-to-use solution. By integrating Raspberry Pi, sensors, and Firebase technology, the system was capable of real-time pill monitoring, reminders, and accurate drug dispensing. The project was successful in demonstrating that the implementation of IoT-based systems enhances medication adherence, reduces missed doses, and contributes to patient safety.

The findings of this study confirm that the combination of advanced technologies and easy-to-use interfaces significantly improves the effectiveness of elderly medication management. The system's pill presence detection ability and real-time alert feature through a mobile application ensured timely drug compliance, averting the risks associated with forgetfulness or cognitive impairment. The research further reveals the importance of accessibility and ease of use in the design of smart devices for healthcare, which renders the devices more suitable for the elderly.

Despite its utility, there were some drawbacks to the project, the most prominent being its Android-only application, which precluded the use of the system for iOS users. Additionally, requiring an active internet connection for the real-time synchronization of data rendered it impractical for areas with low connectivity. Addressing these drawbacks in future iterations will increase the accessibility and reliability of the system.

Future enhancements need to include an automatic refill reminder system using weight or ultrasonic sensors that will alert users when the medication stocks are running low. Ensuring the application is compatible with iOS and utilizing cross-platform frameworks like Flutter or React Native will enable broader usage. Moreover, integrating the smart pill dispenser with other IoT devices like Amazon Alexa, Google Assistant, and smartwatches will provide a more integrated and simpler medication management experience.

In conclusion, this research contributes to healthcare innovation through the provision of a practical, low-cost, and technology-enabled solution for elderly medication compliance. The intelligent pill dispenser system not only raises patients' independence levels but also provides caregivers with a reliable tool to efficiently monitor and manage medication schedules.

Through continued innovation and the resultant improvements, this system can be a widely embraced solution for elderly care, significantly improving their quality of life and overall well-being.

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