IoT and smartphone app for elderly pill management

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***Abstract*—Technological advancements have greatly improved the quality of life and increased longevity. Meanwhile, the increase in the elderly population for the next years generates some concerns about the quality of life and independence of these people; A prototype for a pill monitoring system has been proposed as part of this project, which aims to contribute to this progress by developing and implementing an Internet of Things (IoT) device for pill management. The prototype allows users to input medication information, set alarms, and monitor doses. The user interface was designed to focus on intuitive and accessible interaction, considering users with low levels of mobile technology proficiency. Additionally, the application generates graphs of patient medication usage to assist healthcare professionals. To control and monitor the medication compartments, the prototype was implemented using the ESP32 microcontroller and Bluetooth or Wi-Fi communication. Regardless of the preliminary stages of development, the functional prototype has great potential to become a valuable tool for the elderly.**

***Index Terms*—Internet of Things, pill administration, medicine management, smartphone application, aged.**

I. Introduction

According to the World Health Organization (WHO), it is estimated that by 2050, the number of people over 60 years old will double, reaching nearly 2 billion, which represents around 21.5% of the global population. The increase in the aged induces a global health concern, which is the increase in the number of people receiving care for chronic diseases and other diseases, such as, mental disturbs, without overloading hospital units. Therefore, many elderly people need to take medication for treating and controlling chronic diseases daily in order to maintain a high level of quality of life. Some factors, such as cognitive decline, memory difficulties, reduced vision, and difficulty handling medication packaging, can compromise medication adherence [1]. In order to provide proper health care to the elderly population, these obstacles must be overcome. Studies indicate that elderly patients with poor medication adherence are more likely to be hospitalized, suffer from deteriorating health, and die earlier. The costs of non-adherence to medication are substantial, with estimates reaching billions of dollars per year [2]. Developing mobile applications and medication case devices with dosage reminders can be an effective strategy for addressing this problem. Such applications and devices should be designed considering the specific needs of the senior, including simple and intuitive interfaces, accessibility features, and functionalities that facilitate tracking and correct administration of medications [3], [4].

Besides there are applications and devices focused on medication management in the market, we argue that (i) applications available in market stores such as Google Play and the App Store still need to improve their accessibility by simplifying the user interface and incorporating features such as audio and video, making instructions clearer and more understandable. Usability is one of the main challenges, especially for the elderly population and those who are not very familiar with the technology [1]. (ii) Medication case devices are either very simple, such as simple plastic cases, or very expensive, costing hundreds of dollars. Medication case devices allow medications to be organized separately in compartments according to the prescribed time and dose by healthcare professionals, facilitating control and avoiding errors in medication administration.

Over the years, advances in healthcare technologies have significantly contributed to improving people's quality of life and increasing longevity. Pill management is essential to the independence of elderly people added to new advances in applications for monitoring diary activities, detecting falls, and implementing preventive measures to improve their quality of life [1]. The applications with IoT and elderly people in scientific literature, recently demonstrated a small advance in the sense of elderly healthcare and concerns about technology usage, mainly with the technology handling [5]. Furthermore, there is an ongoing and continuous development of new solutions addressing various health issues, such as applications for doctors to monitor patients and telemedicine, enabling remote medical care [6].

In this paper, we propose an IoT application to assist the aged in managing their medication efficiently. The application will be integrated with two experimental medication cases that can be controlled by a smartphone. Both cases were designed to function as smart accessibility devices. The suggested approach can prevent polypharmacy and offers various benefits. The elderly, who suffer from cognitive impairment, frailty, multi-morbidity, reside in a long-term care facility, or have specific illnesses such as diabetes, heart disease, neoplasms, metabolic syndromes, and obstructive pulmonary disease, are at a higher risk of experiencing polypharmacy

issues [7]. As life expectancy increases and chronic diseases become more prevalent among the elderly population, the use of multiple medications becomes necessary but also poses a higher risk of complications and side effects [8]. In Section II, the current market devices are discussed, while Section III outlines the features of the prototype. The project methodology and summary are covered in Section IV. Sections V and VI explain the smartphone application and the SP Medication Case prototype, respectively. Section VII presents preliminary results and a brief discussion. Following the conclusion and future work, the references.

II. Related Work

Methods for medication administration can be classified into four groups, according to the classification proposed in [9]:

1) Pill holders: are boxes or containers to carry medications with different compartments;
2) Alarm-based aids: pill holders attached to a timer.
3) Pill monitoring devices: home-based medication dispenses medication and some of them have voice and text alarms, some of them can be connected to the internet and send messages to mobile phones.
4) Mobile phone-based solutions: Using these systems, patients have to manually enter their medications and set reminders and dosages on their mobile phones and PDAs.

A. Cases in the market

Currently, there are multiple medication cases available on the market. One option is a simple model that contains two compartments capable of holding between 2 and 4 pills, depending on their size. Although the most widely used medication case has some restrictions for those with visual impairments and does not have extra features like storing critical information or sending alarm alerts to a user's smartphone, there is an alternative case with seven compartments that can be used to distribute medications throughout the week, just like the first case mentioned. Moreover, the E-pill device is available in the market and can assist individuals with daily medication use. It features a timer with a vibrating alarm that can be set up to four times per day and four compartments that can hold up to eight medications each, depending on their size. The corresponding compartment number for each scheduled medication is also displayed on the screen. Despite this, the portability of the product is a positive aspect, as it is compact enough to be carried in pockets. However, it is important to note a limitation of the device: the lack of accessibility elements for individuals with visual impairments, as there is no tactile or auditory feedback to assist them in using the device. The last device examined is called MedaCube[1], which incorporates advanced internet connectivity features. The equipment has 16 compartments – 10 regular-sized and 6 large-sized, allowing for the configuration of up to 20 alarms per day. The main distinction of this device compared to others is its ability to automatically dispense medications in the appropriate dosage and send notifications via email or voice to caregivers if the medications are not consumed. Additionally, MedaCube securely stores information in the cloud, such as the prescribed medication schedule, medication history, missed dose reports, contact information, and visual references of the pills. Furthermore, the equipment is not easily portable and represents one of the most expensive devices currently available on the market, making it particularly challenging to acquire due to its foreign origin. Despite this, it presents itself as a promising alternative for those who require additional support in medication management and have the resources to make such an investment. Research suggests that the correct administration of medication is crucial in managing complex medication schedules. For senior individuals, mobile applications are highly effective in improving medication adherence. These apps send reminders and alerts about the correct time to take medications, which is especially helpful for older people who have to manage multiple chronic conditions and take medications on a daily basis [10].

[1]https://www.medacube.com/

B. Mobile application

The use of mobile apps can offer benefits to caregivers as it lessens their workload. Among caregivers who used a mobile app to monitor the health of their aged patients, reports indicate that they felt more confident in their role and had a reduced workload. This technology can be a valuable tool in ensuring accurate medication and proper care for the senior [10].

1) Four medication management apps identified: The Cuco-Medication alert has the ability to track treatment adherence, manage medication inventory, and involve caregivers. The medication library is extensive, with over 29,000 listed items. However, there are opportunities for improvement, such as including medication photos and integrating with virtual assistants. MyTherapy Medication Reminder shares many features with Cuco, but the inclusion of a usage report is a distinguishing factor. The absence of a registered caregiver or responsible person and the lack of a premium plan can be seen as negative points. The accessibility for the aged is weak. Lastly, it is worth noting that MyTherapy is backed by academic research and adheres to strict European privacy laws. Pill Reminder Tracker for Meds has similar functionalities to MyTherapy, adding a premium plan. The medication interaction checker is a particular feature, allowing users to identify potential interactions between different medications, contributing to the prevention of adverse effects. Regardless the accessibility for the aged is also considered weak. Mango Health has the fewest number of functionalities, with the main limitation being the lack of a calendar and a premium plan. Analogous to the rest, its accessibility for the aged is weak, too.

2) Main features: The ability to add and set alarms and receive medication reminders are crucial features for our target audience. Elderly individuals who take several medications daily find these features especially helpful because they assist

them in remembering to take their medications at the appropriate time.

III. Analysis Result

After analyzing related work and reviewing existing applications, we identified the requirement to improve the application that will be integrated with the smart case.

1) The system can monitor a patient's medication usage and send reminders to promote adherence.
2) Connectivity allows for communication with mobile devices to collect patient information and medication data, as well as provide relevant information to caregivers.
3) The application interface should be simple and intuitive for easy use by elderly patients or those unfamiliar with technology.
4) Features of the planning tool include medication reminders, customizable medication plans, and notifications for healthcare professionals when medications need refilling or are low.
5) The medication case should be easily portable and convenient to use in various environments, particularly when the patient is away from home for a few days.
6) The device should provide personalized medical monitoring solutions customized to the patient's specific needs.
7) The device plans to integrate with the Echo Dot, allowing for voice commands to perform tasks currently done in the app.

The aim of the study was to ensure that the device meets the patient's needs securely and effectively. To achieve this goal, the medication case and mobile application have been designed to enhance the patient's quality of life and provide them with more control over their healthcare management. Additionally, ensuring the privacy and security of elderly people, who may have limitations when it comes to using digital technology, is a crucial consideration. Therefore, in future work, this critical point must be explored.

IV. Methodology

This section details the methodology used in the prototype and plans to integrate it with the Echo Dot. Firstly, we identified the system requirements, followed by defining the smart case's architecture and development procedures. Figure 1 provides an overview of the smart case, mobile application, and web system.

A. System Architecture

The architecture of the project is structured in multiple layers, which deviates slightly from the typical two or three-tier architectures. The layers are organized as follows:

- The User Interface Layer is the part of the system that directly interacts with the user. It should be intuitive and user-friendly, giving the user access to all the functionalities of the mobile application.
- The Mobile Application Layer implements the core functionalities of the application, such as alarm control and user information management.

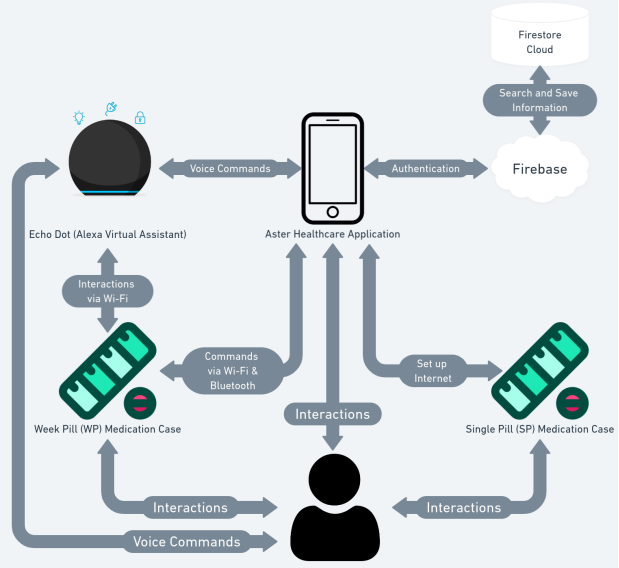

Fig. 1. Project Overview

- The Communication Layer manages communication between the mobile app and smart medication case via Bluetooth or Wi-Fi, depending on convenience and efficiency.
- The layer responsible for data storage and processing not only holds user data, such as profile information but also stores medication history and alarm settings. Additionally, the AI-powered assistant offers users valuable information, such as usage statistics.

V. Smartphone Application

The mobile app was built with Dart[2] and Flutter[3] for agile and efficient screen creation and rule definition. This is due to Flutter's ability to create custom widgets and its hot reload architecture, which allows developers to see interface changes in real-time. As shown in Figure 2, the application displays the information collected by the smart medication case and provides those other functionalities mentioned earlier.

To define the application screens, essential wireframes were created at the beginning. Wireframes depict the user interface elements, including buttons, menus, input fields, and information displays. In the initial sketches, 28 screens were designed for the application, aiming to make it user-friendly for older adults. To achieve this goal, distinct screens were created thinking of the specific needs of older adults while also accommodating adult users. This approach is justified by the fact that older adults may have more difficulties with complex interfaces, thus specific screens were created to better serve them. As a result, the application becomes more accessible and user-friendly for all users.

VI. SP Case

A prototype IoT device named SP Case was assembled employing ESP32-V1, a 20x4 LCD display, an I2C Adapter

[2]https://dart.dev/
[3]https://flutter.dev/docs

Fig. 2. Main Screen

Module, a RTC DS1307, LEDs, resistors, tactile switches, a power switch, and PLA filament for case fabrication. After evaluating the features of the proposed SP case and comparing it to similar products on the market, it is clear that the SP case offers exceptional value. It boasts internet connectivity, an alarm system, reporting capabilities, and multiple compartments to store medications. The creation of the SP case prototype marks a major step forward in the quest for effective pill management technology. The case was crafted using PLA filament, a thermoplastic synthetic polymer made from renewable resources. Many details were taken into account during the development process, including the addition of Braille characters for easy compartment identification, LED indicators in each compartment to distinguish medications taken at specific times, a display to showcase the schedule and medication information, and alarms for each compartment.

VII. Results and Discussions

The solution integrates Firestore Cloud and is compatible with Android and iOS devices. This study's main focus is on designing, defining prototypes, and assembling cases for the application. The most important contribution is to provide a new solution for the difficulty of aged people handling digital technology and its features in this area. There are many gaps in this context to settle and improve the application for the solution of pill management applied to aged people. Future investigations can provide more detailed prototypes and complement them with additional information including the privacy and security mentioned earlier. However, there are several limitations in the preliminary prototype that must be addressed in the future. It is important to note that certain cases on the market do not provide internet access or generate tracking reports, as mentioned in Section II-A. It is also noteworthy that a few cases have reported privacy and security concerns. The lack of accessibility in the majority of the products analyzed is worrying, particularly when considering the needs of elderly individuals who may face cognitive impairment and multiple chronic diseases, known as multimorbidity, which can exacerbate their functional limitations. As a result, new applications have been developed, including the one proposed in this paper, which prioritizes the needs of the elderly to enhance their quality of life and promote independence.

VIII. Conclusion and Future Work

Our aim is to enhance the health and quality of life of users, particularly the elderly, through efficient medication management. The effectiveness and safety of our solution is still being validated as it is in the experimental phase. As we move towards testing with the elderly population, we prioritize security and privacy measures for user data. We are pleased to announce that we have successfully completed the prototype and application, meeting our objective. However, Section VII outlines the need for further refinements and testing before considering it as a proof of concept for large-scale production in the future. Shortcomings and advancements in this field require the continuity of this work and research.

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