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PillTrack: IoT para gerenciamento de medicamentos

PillTrack: IoT for medication management

PillTrack: IoT para la géstion de la medicación

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Resumo:
O projeto aborda a criação de um sistema completo e eficiente de gestão de medicamentos, visando assegurar a adesão a tratamentos e melhora de resultados na saúde dos pacientes, especialmente os idosos. O sistema incluirá uma caixa de medicamentos inteligente para notificações de horários de administração e controle de estoque, além de um aplicativo móvel para registro e acesso às informações sobre a rotina medicamentosa dos pacientes por médicos e cuidadores. A metodologia envolverá implementação e teste do sistema em ambiente controlado, seguido de avaliação qualitativa da experiência dos usuários e análise quantitativa dos dados de adesão ao tratamento e resultados de saúde. Espera-se que o sistema melhore significativamente a qualidade de vida dos usuários ao potencializar os resultados de saúde, com benefícios como melhor adesão ao tratamento medicamentoso, redução de erros na administração de medicamentos e melhoria dos indicadores de saúde dos pacientes. Em conclusão do estudo destacará a eficácia da abordagem tecnológica adotada na gestão de medicamentos e seus benefícios para a saúde pública, sublinhando a importância de soluções inovadoras no cuidado com pacientes crônicos, especialmente idosos.

Abstract:
The project addresses the creation of a complete and efficient medication management system, aimed at ensuring adherence to treatment and improving the health outcomes of patients, especially the elderly. The system will include a smart medicine box for notifications of administration times and stock control, as well as a mobile app for recording and accessing information on patients' medication routine by doctors and caregivers. The methodology will involve implementing and testing the system in a controlled environment, followed by qualitative evaluation of the user experience and quantitative analysis of treatment adherence data and health outcomes. The system is expected to significantly improve users' quality of life by boosting health outcomes, with benefits such as better adherence to drug treatment, a reduction in medication administration errors and an improvement in patients' health indicators. In conclusion, the study will highlight the effectiveness of the technological approach adopted in medicines management and its benefits for public health, underlining the importance of innovative solutions in the care of chronic patients, especially the elderly.

Resumen:
El proyecto pretende crear un sistema completo y eficiente de gestión de la medicación para garantizar el cumplimiento del tratamiento y mejorar los resultados sanitarios de los pacientes, especialmente los ancianos. El sistema incluirá un botiquín inteligente para notificar los tiempos de administración y controlar las existencias, así como una aplicación móvil para que médicos y cuidadores registren y accedan a la información sobre la rutina de medicación de los pacientes. La metodología consistirá en implantar y probar el sistema en un entorno controlado, seguido de una evaluación cualitativa de la experiencia del usuario y un análisis cuantitativo de los datos de cumplimiento del tratamiento y los resultados sanitarios. Se espera que el sistema mejore significativamente la calidad de vida de los usuarios al potenciar los resultados sanitarios, con beneficios como una mejor adherencia al tratamiento farmacológico, una reducción de los errores en la administración de medicamentos y una mejora de los indicadores de salud de los pacientes. En conclusión, el estudio pondrá de relieve la eficacia del enfoque tecnológico adoptado en la gestión de medicamentos y sus beneficios para la salud pública, destacando la importancia de las soluciones innovadoras en la atención a los pacientes crónicos, especialmente los ancianos.

7º EnGeTec | 2024
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1. Introduction

According to Eurofarma (2018), it is crucial to follow the doctor's prescription at the correct times, regardless of age. The doctor adapts the treatment based on the individual's body, considering their habits and routines. In consideration of this, this project focuses on the seriousness of medication management by making a proposed technological solution aimed at organizing and monitoring the proper treatment of each medication for the user.

This study is justified by the importance of ensuring correct adherence to medication use, considering the challenges faced by patients in following prescriptions at the correct times. Technology has the potential to minimize forgetfulness and improve medication management, making it a relevant solution for optimizing treatments and reducing complications arising from poor medication administration. In this way, technology is evolving to meet society's needs, keeping pace with its evolution and this leads us to the emergence of the Internet of Things (IoT) with great potential (ALBERTIN, 2017).

Today, the Internet of Things is rapidly becoming a reality, as we can see by looking around that our devices are getting smarter every day (SANTOS, 2018). With this technology, it is possible to automate time-consuming or forgotten tasks. In healthcare, an IoT system becomes a valuable tool for patients and professionals, improving the understanding and management of activities.

The problem revolves around the difficulty that many patients, especially the elderly, have in strictly following prescribed treatments, either through forgetfulness or lack of discipline, which compromises the effectiveness of medicines and can aggravate health conditions. With this, combined with medical knowledge, an IOT can act in preventive medicine, improving quality of life and patient satisfaction (MASSOLA; PINTO, 2018). According to data referenced by the Cardiology Society of the State of São Paulo (KATZ; FEITOSA; PINTO; FELIX, BORTOLOTTO, 2020) “it is estimated that half of the 3.2 billion medical prescriptions made annually in the USA are not followed correctly”. In this way, the creation of an assistive system makes a big difference to recovery and prevents forgetfulness that causes worsening of conditions that require treatment.

Thus, the use of the system can significantly improve medication adherence. With easy access to medication information and automatic notifications, users are encouraged to follow medical guidelines, reducing forgetfulness and increasing the long-term effectiveness of treatments.

Access to the system allows for a more specific analysis by caregivers and doctors of patients' adherence to treatment, and in the case of elderly patients, who are more likely to forget doses and schedules, the creation of the application becomes even more positive, since it tends to solve these problems, contributing to improving the quality of care, ensuring the correct administration of medicines, thus making the project unique and innovative with automation in the problem addressed.

In this article, we will use React Native (FACEBOOK, 2015) to develop the application; Firebase (GOOGLE, 2014) to store the data; C++ to build the system's programming (STROUSTRUP, 1985); UML 2 (GUEDES, 2018) to document the project's diagrams.

2. Fundamentação Teórica

In this chapter, we will cover the main theories, concepts and technologies that underpin the development of this project.

2.1. Difficulties in effective medicines management

One of the fundamental principles for good recovery and treatment is direct communication between patients and doctors, allowing them to achieve the best results together in the fight against disease. Short consultation times and poor communication increase the propensity for distancing and hyper-

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

formality in dialog, which contributes to these problems (PIXEL DIAGNÓSTICO, 2020). In other words, a detailed medical history can act as a map to prevent future health problems (UNIMED CAMPINAS).

It is therefore possible to use resources that facilitate this monitoring. In order to have more time to listen to and monitor their patients, doctors can rely on software technologies to manage patient information in one place.

A survey carried out by students at the University of São Paulo (USP) with healthcare professionals and the reactions most often cited by professionals included terms such as “seriousness”, “worsening”, “worry”, “harmful” and “death”, reflecting the effects of poor adherence to treatment for both patients and professionals (FERREIRA; CAMPOS, 2023).

That's why we came up with the PillTrack application, which will not only help patients to take their medication correctly according to their doctor's prescription, but will also enable direct interaction between doctor and patient, through detailed reports made available by the application, which will have access to information straight from the box. To understand how the PillTrack project will work, keep reading, as our system will be more detailed in the following chapters.

2.2. PillTrack: IoT for medicines management

PillTrack has been designed to help with the effectiveness and management of medication, especially for those who are elderly and find it difficult to take their medication correctly according to the prescription, because they take too much medication or because their memory fails.

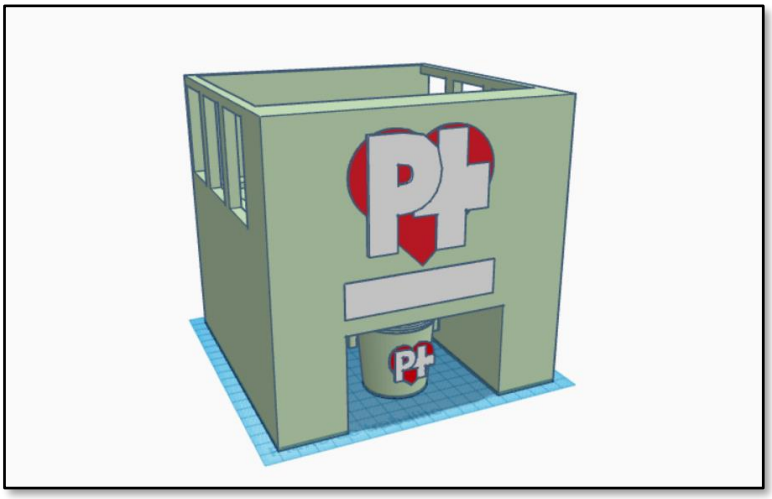
Basically, it consists of a 3D machine-printed smart medicine box that notifies the patient when they need to take their medication and monitors the stock of pills, as well as recording information about the medication routine, so that doctors and caregivers can be sure that the patient is following the prescription correctly.

The box uses the ESP32 microcontroller that connects to the application via *Wi-Fi*, which guarantees real-time updates. It is therefore possible to say that the PillTrack smart medicine box has come to facilitate adherence to treatment, reducing failures in the medication routine, especially for those who are elderly and need special attention and tend to have a routine with multiple prescriptions on a daily basis.

The 3D modeling of PillTrack is shown below:

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

Figure 1 - PillTrack 3D modeling

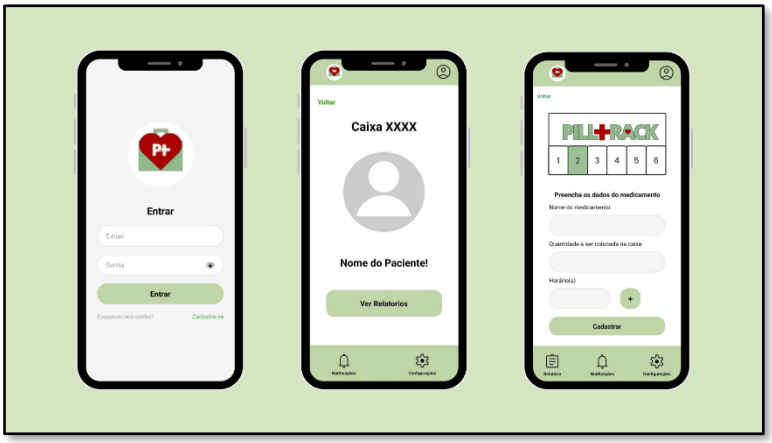


Source: From the authors (2024).

As you can see in the image, we have a 3D modeling prototype, which was designed to make it easier to keep track of medication schedules. On the sides of the boxes, entrances have been designed for inserting the medication. On the front, there is a space for the LCD display, which will show the time, the name of the box and the compartment in which the motor is being activated. Finally, at the bottom, there is a space for the cup in which the medicines will be dispensed automatically.

The application was developed using React Native, which is compatible with Android and iOS users, allowing them to set alarms for the times of their respective medications and to receive notifications and view the medication administration history.

Figure 2 - PillTrack application



Source: From the authors (2024).

3. Method

In this section, we will explore the methods, materials and technologies that were fundamental to the creation of the PillTrack medication management system.

But first, it is necessary to understand what kind of methodologies are integrated into our project, such as qualitative methodologies, which are mainly used to understand motivations, thoughts ideas and opinions through insights, and quantitative methodologies, which are considered practical because they translate numerical data, seeking conclusive answers on different topics (QUALIBEST, 2020).

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

3.1.1 ESP32

Developed by Espressif Systems, the ESP-32 is an efficient, low-cost microcontroller that is excellent for IoT, entertainment and home automation projects, supporting WIFI, Bluetooth and other types of connection (MAKIYAMA, 2023).

That said, ESP-32 is ideal for IoT projects as it has the capacity to connect to the internet and other devices, with a dual-core processor and 500 KB of SRAM, which allows it to run complex programs (PEREIRA, 2020). So the ESP-32 has 36 digital pins with 16 usable as PWM, and carrying inputs and outputs, where inputs, like pressing a button, send signals to the microcontroller, and can activate outputs such as LEDs and motors. (ELETRÔNICA ÔMEGA, 2021).

For the PillTrack project, it will be used to monitor medication use in real time, connecting the application, the database and the smart medicine box via *Wi-Fi*. It will be possible to send information on medication use from the moment the patient takes the medication according to the doctor's prescription and receive notification of each daily dose. The following image shows an ESP-32 for demonstration purposes:

Figure 3 – ESP32

Source: RoboCore (2024).

3.1.2 Display LCD

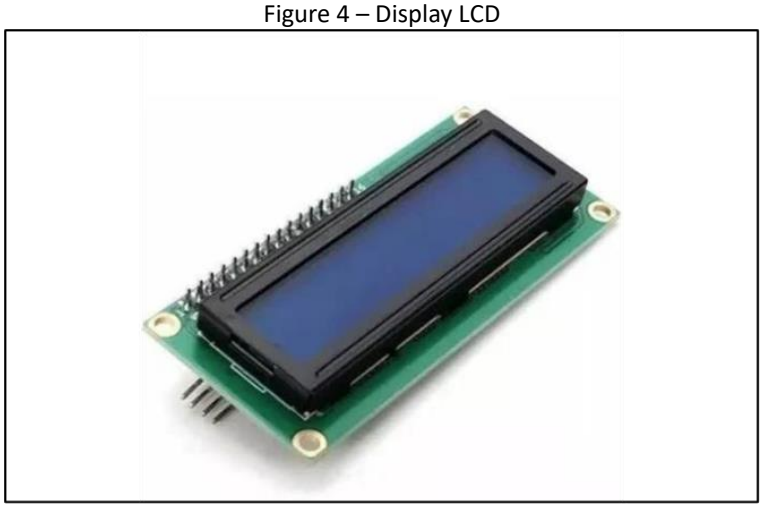
Created by engineer George Heilmer in 1964, LCD (Liquid Crystal Display) is a technology that uses liquid crystals and light polarizers to form images, common in electronics such as cell phones and TVs (HIGA; MARQUES, 2023).

Alphanumeric LCD displays are found in various devices, have practical interfaces and although they are a technology that is more than twenty years old, they remain popular and economical (PUHLMANN, 2015).

The interface for connecting a microcontroller is standardized, varying between 14 and 16 pins depending on the presence of the backlight, which has a typical current of 60 mA and a maximum of 75 mA, with direct voltages of 3.5V and 3.6V, respectively (PUHLMANN, 2015).The LCD display will be essential for the creation of the project, because through it the user will be able to see the time, the name of the box and the compartment in which the motor is being activated interactively on the front. The following figure shows the structure of an LCD board:

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

Figure 4 – Display LCD



Source: ArduCore (2024).

3.1.3 Jumpers

Jumpers are electrical wires that make connections between components. They come in different colors, thicknesses and sizes and are mainly used in Protoboards and Arduinos (MONK, 2014).

In this application we will use female-to-female jumpers, which are used to connect male pins and female-to-male jumpers, as we will be using the ESP-32 and the Protoboard, so this is the ideal type of jumper for the project. Below is a demonstration image of some types of jumpers:

Figure 5 – Jumpers

Source: Casa da Robótica (2024).

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

3.1.4 Passive Buzzer

Buzzers are electromechanical devices that transform electrical energy into audible sound and are widely used in various applications to emit alerts or melodies due to their low cost and ease of connection and operation (Alvarez, 2023).

The passive buzzer reproduces the sound according to the shape of the electrical signal that triggers it, allowing it to imitate specific sounds, unlike the active buzzer which only emits a whistle with its own timbre. (GUIMARÃES, 2017).

The passive buzzer will be used to sound when the patient needs to take the medication prescribed by the doctor.

Figura 6 – Passive Buzzer

Source: Eletrônica Cuiabá, 2024.

3.1.5 Stepper Motor + Control Module (ULN2003Driver)

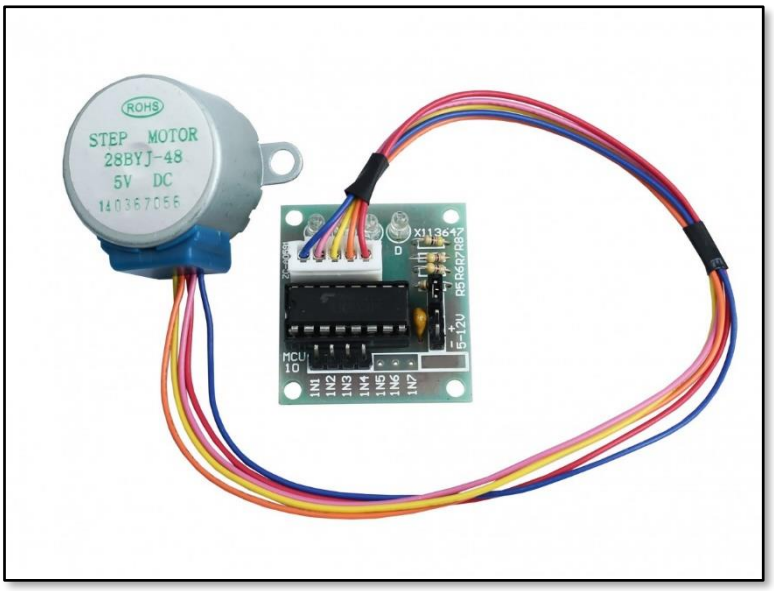
The Stepper Motor + Control Module (ULN2003Driver), according to Viana (2022), is a direct current electric motor in which its shaft rotates in precise steps, moving by a fixed amount of degrees, being precise in angle, speed, position and synchronism.

The motor is unipolar and has 4 windings which are called phases, so they are connected together (ELETROGATE, 2018). This motor is generally used in conjunction with the ULN2003 Driver, which allows the stepper motor to be easily controlled with a microcontroller (VIANA, 2022).

The component will be responsible for managing the drop of the medication directly into the PillTrack box cup, because when it rotates, its movement must be precise, thus allowing the compartment where the medication is stored to rotate 180º, releasing the pill drop, one at a time. When the pill “dump” is complete, the system will automatically return to its original position.

The figure below shows an image of the Stepper Motor + Control Module (ULN2003Driver):

Figure 7 – Stepper Motor + Control Module (ULN2003Driver):



Source: Usinainfo (2024).

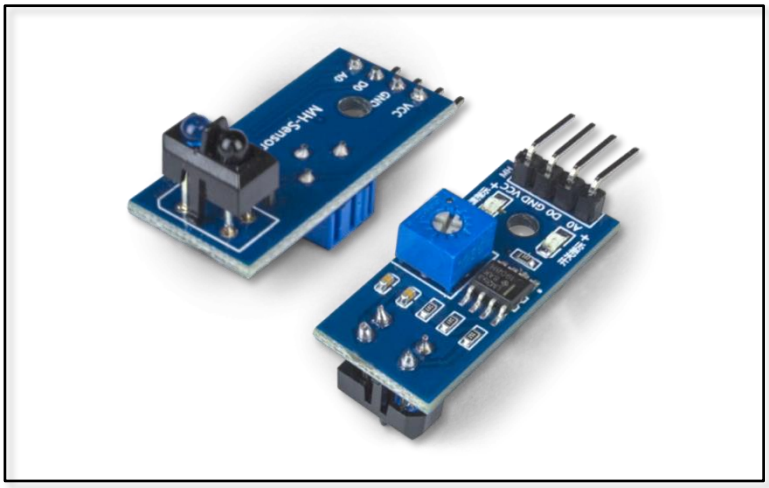
3.1.6 TCRT500 optical sensor

The TCRT5000 is a reflective optical sensor that uses infrared reflection technology to detect the presence of objects (ELETROGATE, 2017). It consists of an infrared LED and an IR phototransistor, both attached to a plastic support. When an object approaches the sensor, the infrared light is reflected to the phototransistor, activating it (ARDUINO E CIA).

This sensor will be extremely important for detecting the withdrawal of the medicine through its infrared light, because when it is removed, its reflection is interrupted, so the sensor will emit the absence of the medicine by sending a signal to the system, which will be interpreted by the application that the user has ingested the medicines, thus being able to update the report so that the patient is following the medical prescriptions correctly.

You can now see an image of the TCRT5000 Optical Sensor:

Figure 8 – TCRT5000 Optical Sensor



Source: RoboCore (2024).

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

3.1.7 IoT

The Internet of Things, known as IoT, is the network of devices and, in general, things that are connected and communicate with each other and through networks, to perform certain tasks without requiring human interaction (SANTOS, 2018). The “IoT product” goes beyond the smart product and the connected product, as they exploit the full capacity of the internet in physical products, so it is effectively a system, or rather a system of systems. (SINCLAIR, 2018).

3.1.8 UML

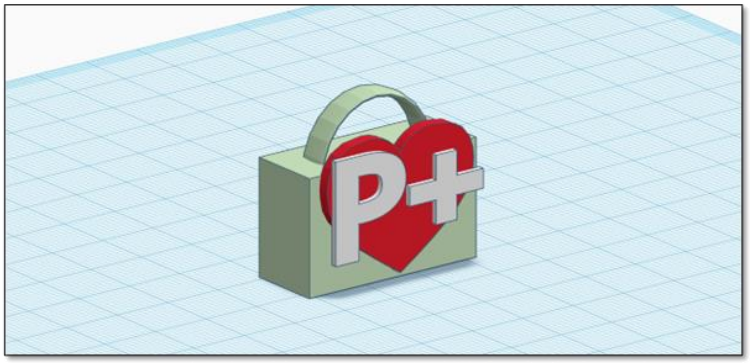
UML, or rather Unified Modeling Language, is a visual language widely used to portray object-oriented software. It is a versatile language applicable to various domains and has been adopted as an international standard in software engineering (GUEDES, 2018). It emerged from the union of several graphical object-oriented modeling languages that emerged in the 1980s and 1990s, so since its introduction in 1997, it has been a resource valued by many developers (FOWLER, 2005).

Modeling is linked to communication, and the UML provides important tools for visualizing, specifying, building and documenting artifacts of many complex software systems (BOOK, 2006). It is important to model every system before starting its implementation, because information systems tend to grow in size, complexity and scope, so they are dynamic and always evolving. (GUEDES, 2018).

3.1.9 3D modeling

3D modeling is considered a process of developing characters, objects or scenarios in three dimensions, i.e. they have depth in addition to height and width (LOPES, 2023). Below is an example of 3D modeling, and the prototype of a model created for 3D printing after being printed and painted.

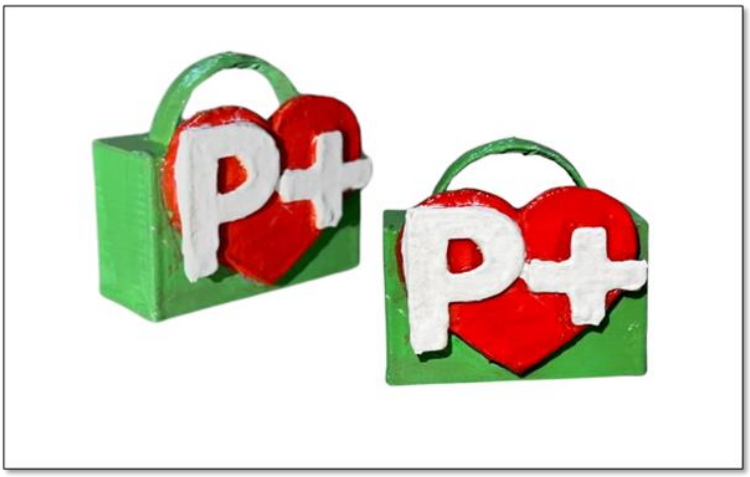
Figure 9 – Example of 3D modeling



Source: From the authors (2024).

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

Figure 10 – Example of 3D printing



Source: From the authors (2024).

3.1.10 C++

Developed by Bjarne Stroustrup at Bell Laboratories in the 1980s, C++ was created as a low-level programming language providing additional features to the C language (DEITEL; PAUL, 2015). Its versatile syntax supports object-oriented, procedural, generic and functional programming (LOCAWEB). Below is an example of simple code programmed in C++:

3.1.11 React & React Native

React is a JavaScript library that simplifies and streamlines the task of developing user interfaces (SILVA, 2021). React Native, based on React, is a JavaScript framework for creating cross-platform applications and offers an authentic user experience (ESCUDELARIO; PINHO, 2020).

Containing a declarative approach and code sharing, it speeds up development, enabling teams to create native applications efficiently (REACT NATIVE). The operation of React Native depends on Node.js, which converts JavaScript code for platforms such as Android and iOS (DEVMEDIA).

3.1.12 Node.js & NPM

Node.js, created in 2009, is a server-side JavaScript execution platform known for its asynchronous architecture and efficient I/O operations, ideal for developing APIs, real-time applications and scalable backends (PEREIRA, 2014). Node.js uses a non-blocking thread model, optimizing processing by eliminating I/O stalls, which makes it possible to create scalable and efficient applications without long waits (DUARTE, 2020).

NPM is the Node.js package manager, facilitating the management of dependencies, access to JavaScript libraries and version control, simplifying the development and sharing of projects. (GADO, 2021).

3.1.13 Firebase

According to Oracle (2023), Firebase is Google's mobile and web application development platform, which benefits from an end-to-end development environment, fast application creation and scalable infrastructure. The Firebase console offers the most sophisticated environment for managing products, apps and configurations at the Firebase project level. (FIREBASE, 2023).

7º EnGeTec | 2024
ISSN 2675-4479
Dezembro de 2024

3.1.14 Firestore

Cloud Firestore is a NoSQL database that allows data to be stored, synchronized and consulted on mobile devices and the web, as well as providing security rules for accessing the database without having to maintain the server itself (FIREBASE).

In addition, it focuses on developing the application using a managed, serverless document database, making adjustments in order to meet any demand without maintenance windows or downtime. (GOOGLE CLOUD, 2024).

4. Results and Discussions

The system was created to help with the correct management of medication, especially for those who are elderly and find it difficult to medicate themselves according to the doctor's prescription, but an imprecise period of usability and security testing is needed so that the system can offer good results for users.
Although its basic features have been well executed, there are still doubts and insecurities when implementing the device in a real environment, especially when punctuality and precision are required for patients' health.

As a result, tests become indispensable in order to point out any flaws in the system, to ensure that patients can be sure that the PillTrack system really is effective for the correct management of medicines.

5. Final considerations

The PillTrack system aims to help patients, especially those who are elderly and find it difficult to manage their medication, to medicate correctly and improve adherence to treatment. Through the app, it will be possible to improve communication between the patient and the doctor, so that the professional can be sure that the patient is following their prescription correctly, whereby the patient will have precise treatment efficacy.

In order to ensure precision in time control and pill release, we will use the ESP-32 microcontroller which will connect to the app via Bluetooth and the Stepper Motor which will be responsible for releasing the pill at the correct time. For the application, it was considered that the best choice for its development would be the *UI software* framework, React Native, which is available for both Android and IOS.

Although the system has not undergone security and reliability tests, it is true to say that PillTrack was created to propose an improvement in the healthy lifestyle of the system's users. We look forward to the project being developed and contributing to the lives of patients who need special help to take their medication correctly according to their doctor's prescription.

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The authors of the work declare that no Artificial Intelligence (AI) tool/service was used during the preparation of the manuscript, and that all text produced is the responsibility of the authors.