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Med Box: Smart Medication Reminding & Monitoring

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Abstract

Effective medication management plays a vital role in a patient's recovery, and timely adherence to prescribed medication is key to achieving positive health outcomes. In our fast-paced society, many individuals face challenges in maintaining their medication schedules, which can significantly impact their recovery process. This concern is particularly pronounced among older adults and those managing chronic conditions. Inadequate medication adherence not only threatens health but can also lead to severe complications. Medication management applications have surfaced, although there has been limited advancement in this area in Pakistan, with few hospitals adopting comprehensive medication management systems. There is also a notable gap in home-based solutions that can effectively track medication intake and maintain detailed medication histories. This study aims to evaluate a newly developed medication management system that enhances patient adherence while minimizing medication errors and providing a reliable record of medication history. The proposed prototype includes both a hardware component and a mobile application called "Med App," designed to support patients in managing their medications and documenting their medication journeys. The integrated hardware features five automated containers for medication storage, all operated seamlessly through the Med App. It leverages advanced sensors and image processing technologies to ensure precise medication dispensing and tracking within each container. All collected data is securely stored on the Firebase platform, integrating information from both the app and the hardware.

Keywords: Medication Management, Smart Medication Dispenser, Patient Monitoring, Mobile Healthcare Solutions.

1. Introduction

As the saying goes, "Health is wealth." To maintain good health, it is essential to have a balanced diet and regular exercise. Unfortunately, when people become ill, they require proper medication and attentive care. Effective medication management is crucial for a patient's recovery. Administering the right medication at the right time and in the correct dosage can be challenging, and there is always the potential for human error [1]. To address these issues, a system that can automate this process with minimal human interaction is necessary.

As the baby boomer generation ages, the number of people needing medication is expected to double by 2036, when one in four individuals will be 65 or older [2]. This trend is evident in many industrialized nations, where health and social policy initiatives aim to minimize preventable diseases that contribute to healthcare usage and loss of independence [3]. In recent years, healthcare systems have confidently embraced apps and digital tools to enhance drug management. While these advanced technologies introduce new challenges for prescribers, nurses, pharmacists, and patients, their benefits far outweigh the hurdles. It is crucial for healthcare systems and personnel to ensure accurate prescriptions, guarantee that patients adhere to their medication regimens and encourage them to report any side effects promptly [4].

Many devices in hospitals assist with medication management; however, they are often expensive and complex to operate [5]. Home-based patients frequently encounter challenges during their recovery, which can pose significant risks. Therefore, there is a need for an affordable and user-friendly device that ensures accurate medication delivery and reliability.

The goal of this study is to develop a smart medication management device that notifies patients when it is time to take their medication, dispenses the correct dosage, and keeps a record of the patient's medication schedule. Additionally, the device should be secure from the access of the children. This project utilizes a Raspberry Pi as the central unit to control various components and features while also facilitating data transmission to and from a mobile application. Image processing technology is employed to monitor the inventory of medication and send reminders when supplies reach a certain level.

A. Related Work

The literature review examines the existing work highlighting key contributions, findings, and methodologies. It addresses the limitations and challenges of previous studies, indicating areas that need further exploration. By identifying specific research gaps, this review underlines the motivation for the current study and emphasizes its potential impact in the field.

A study in [6] explored the usability and functionality of smart oral multi-dose dispensing systems, which feature automated dispensing and real-time monitoring to enhance medication adherence. These systems enable automatic data transfer for actionable insights for both patients and clinicians. The review notes variations among systems and patient groups while emphasizing the role of Bluetooth, NFC, and RFID technologies in improving medication routines through reminders and adherence tracking.

The work in [7] presented a prototype smart pillbox for medication sorting and reminders aimed at elderly users and healthcare providers. It includes sound and light notifications and an Android app for tracking dosages, reducing caregiver workload and ensuring timely medication intake. Its compact design and flexibility make it practical for both individual and institutional use, showcasing how smart technologies enhance medication adherence.

The study in [8] addresses medication non-adherence, especially among individuals with dementia. It proposes an Android app integrated with an IoT device that reminds patients about their medications and tracks adherence. The IoT device uses an infrared sensor to check if medications have been taken, while the app maintains medication schedules and sends real-time alerts. This solution aims to improve medication management, enhance patient safety, and reduce incorrect dosages. Future enhancements may include additional health features and voice alert notifications.

The system in [9] includes hardware and software designed to help elderly patients take their medications. It features an alarm that sounds until the patient removes their medication and health monitoring sensors that check vital signs like pulse and oxygen levels. In emergencies, it alerts caregivers and physicians. This reminder system aims to reduce dependence on younger generations and promote self-sufficiency in health management. With over 90% of individuals aged 65 and older relying on medication, the system addresses adherence challenges while ensuring timely intervention when needed.

The IoT-based smart medication adherence system addressed the challenge of ensuring that elderly individuals living independently stick to their medication routines [10]. By using IoT platforms and sensors like magnetic switches and Force Sensitive Resistors (FSRs), it monitors pill box usage and medication consumption. Caregivers receive alerts via platforms such as IFTTT, allowing them to track adherence remotely. The system features Wi-Fi connectivity through NodeMCU for real-time data transfer, reducing caregiver stress and enhancing the independence of elderly patients.

A smart medicine pill box reminder has been introduced, featuring weight sensors and app notifications [11]. It tracks medication levels, alerts patients with sound and light, and updates caregivers via the Blynk app, ensuring timely doses and effective remote monitoring.

B. Motivation

Effective medication management is crucial for ensuring patient recovery and overall health, especially for those receiving home care. However, many individuals face significant challenges in sticking to their prescribed medication schedules, which can lead to serious health risks, and in some cases, tragic consequences due to either insufficient or excessive dosages. It is essential to ensure that patients take the right medication at the right time, in the correct dosage, while maintaining accurate records to prevent complications and improve health outcomes.

The motivation for this study stems from the urgent need to address these challenges. Patients with Alzheimer’s disease often struggle with memory loss, making it difficult to adhere to their medication regimens and increasing the risk of severe health issues. Similarly, elderly individuals experiencing cognitive decline may find it challenging to manage multiple prescriptions. Young children, who rely on caregivers, may miss doses due to oversight, while busy adults frequently forget to take their medications. These factors underscore the pressing need for an effective home-based medication management solution that can support both patients and caregivers in ensuring proper adherence to prescribed treatments.

C. Contributions of the article

The key contributions of the article are as follows:

- The system provides timely alerts to patients, ensuring they take the correct medication at the right time.
- The application tailor's medication schedules based on individual patient needs, reducing the risk of incorrect dosages and medication errors.
- The system securely stores and maintains detailed medication histories, enabling easy access for both patients and healthcare providers.
- By integrating essential features for health tracking, the system promotes better medication compliance, supporting overall patient well-being.

D. Organization of the article

The rest of the article is organized in a following way: Section 2 presents the proposed system model and design, detailing how the Med Box is structured to achieve its objectives. Section 3 focuses on the validation and testing of the proposed system, providing results that confirm its effectiveness. Finally, Section 4 concludes the study, summarizing key findings and contributions.

2. System Model

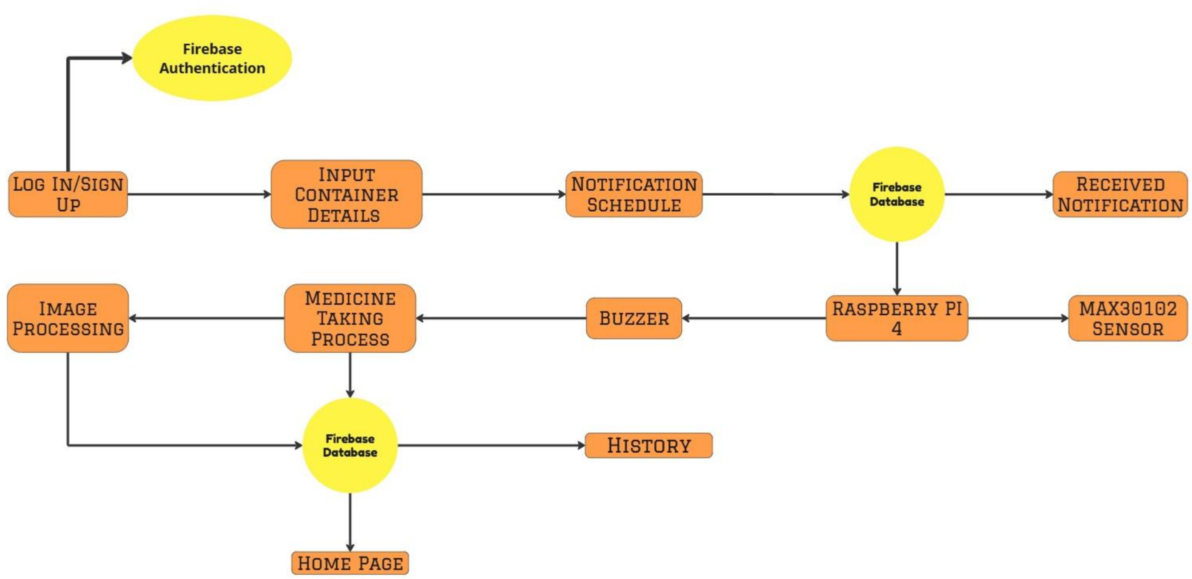

Figure 1. Process Flow

The Smart Medication Reminder & Monitoring System is designed to assist users with medication management and reduce medication errors. This system is controlled by a Raspberry Pi 4 and incorporates several components and sensors, including a servo motor, stepper motor, OLED display, IR module, LEDs, MAX30102 sensor, and Raspberry Pi camera. Figure 1 provides the process flow of the proposed system mode. The entire process is divided into three sub-processes.

- **Process 1: Initial Setups and Notification Scheduling**

The user will download the Med app and then the user will have to create an account on the Med App or if they are already using it they will just Log in to the app. There information will be saved on the Firebase. Firstly, they have to go to the Container's page and they have to select the containers they will use for their medications also adding their details in the app and placing the medicines in the circular box in the selected container. Because there are multiple containers, the system can support multiple users. The user sets notifications as advised by their doctor. They can set notifications multiple times a day, and can be scheduled for multiple days. When a notification is set, the data will be sent to the Firebase database under the patient's name, with a status of "Not Taken."

- **Process 2: Medication Reminder and Dispensing**

At the scheduled time, the user receives a notification on their mobile phone, and the hardware also begins buzzing to notify the user. To ensure security and prevent children from accessing medication, the medication dispensing process will not begin until the user initiates it through the app. When the user clicks on the notification, the status changes to "Taken". The user is then directed to a page where the medication process begins. They press the "Start" button. The first container selected during notification setup is presented in front of the user using stepper motor. The servo motor opens the container's gate, allowing the user to take their medicine and then place it back in the container after taking it. The OLED screen displays the user's name, the medicine name, and the quantity during the process. The user presses "Next" to proceed to the next medication, and this process continues until all scheduled medications have been taken. This marks the end of the second process.

- **Process 3: Medication Inventory and Monitoring**

The Raspberry Pi camera takes a picture and uses image processing to determine the quantity of medicine remaining in each container. This data is send to Firebase database and it updates the data in the app. This ensures accurate medication tracking and alerts the user when the medicine in a container reaches a certain threshold. The patient or caretaker can check the patient's medical history in the app, which displays real-time data and past records. Users can also check their heart rate and oxygen levels using the MAX30102 sensor through the app.

A. Design and Implementation

i. System Design

The IoT-based Med Box is designed to automate medication management, ensure accuracy, and maintain a medical history. It utilizes various hardware components, software, and a cloud server to facilitate users. Figure 2 illustrates the list of hardware components and the communication flow among them.

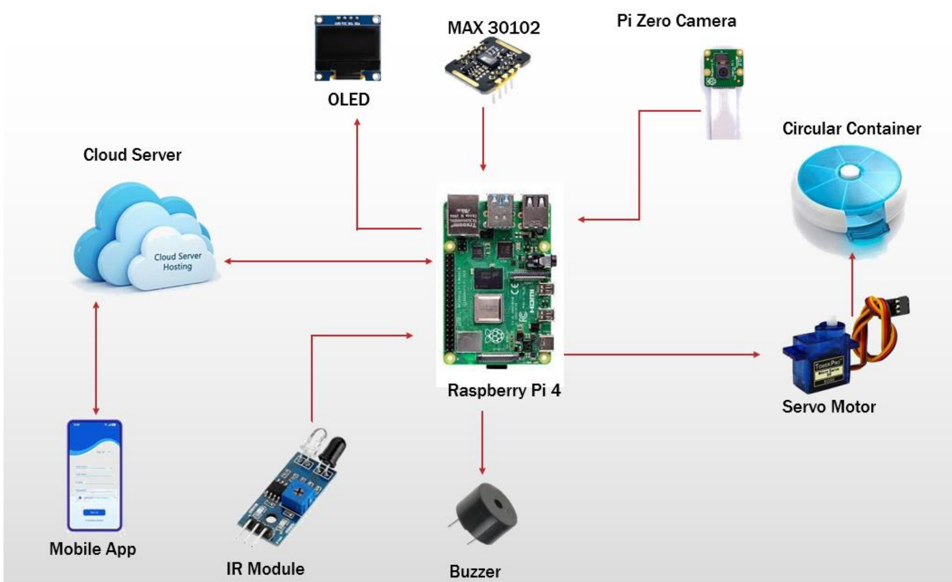

Figure 2. Proposed Model for the Med Box

ii. Hardware Components:

Raspberry Pi 4 B Model: The central control unit, managing various components and sensors, communicating with Firebase and the Med App to send/receive data and instructions. It is programmed using Python and performs image processing to determine medicine quantity.

Raspberry Pi Camera: Captures images of medicine packets, sending them to the Raspberry Pi for image processing.

Stepper Motor (28BYJ-48) with ULN2003 Driver: Rotates the Med Box clockwise and counter-clockwise, positioning the required container in front of the user.

Servo Motor (SG90): Opens and closes the container gate for medication dispensing. Also used for security to prevent children from accessing medications.

IR Module: Determines the initial position of the Med Box upon startup.

OLED Screen (SSD1306 I2C): Displays medication-related information to the patient.

MAX30102 Sensor: Measures the patient's heart rate and oxygen levels.

Hardware Structure: A circular structure consisting of five containers made of lightweight, strong plastic, enabling easy rotation by the stepper motor.

iii. Software:

Python: Used to program the Raspberry Pi, reading sensor data and controlling various components. The program also handles communication with Firebase for data and instruction exchange.

Google Colab & YOLOv8n: A custom dataset of medicine packets, consisting of five different types of medications, was created with 400 images captured using a Raspberry Pi Camera. This approach ensures consistency between the dataset and real-world deployment, preventing discrepancies caused by variations in camera hardware. The model was trained using Google Colab, utilizing the Ultralytics YOLOv8n framework and validated with standard metrics. Several Python libraries were employed during the training process, along with the Google T4 engine, which significantly enhanced training speed and efficiency.

We also considered alternative models, such as other YOLO versions and frameworks like TensorFlow and TensorFlow Lite, which are commonly used for image processing tasks. However, we ultimately selected YOLOv8n due to its high accuracy, efficiency, and seamless compatibility with the Raspberry Pi environment, making it the most suitable option for our application. We have updated the manuscript to include these details.

Med App: A user-friendly app developed for medication management, featuring notification setup, real-time data display, and history tracking.

Flutter: Used to develop the Med App using the Dart language. The app, designed in Android Studio, leverages Flutter's multi-functional nature (combining C, C++, and JavaScript) for UI/UX design. It is also programmed to communicate with Firebase.

Firebase: Firebase provides secure data storage, transmission, and retrieval capabilities for the Med Box and Med App. To ensure data security and privacy, Firebase allows only authorized users with valid login credentials to access their respective data. Each user has a unique account, and their medication records are securely stored in Firebase Firestore, ensuring data isolation and preventing unauthorized access. These security measures collectively ensure that patient information remains private, protected, and accessible only to the intended users. The final product, illustrated in Figure 1, comprises various hardware components and features dedicated sections within the box for storing different medicines.

Figure 3. Med BOX

3. Validation and Testing

The implementation involves integrating hardware, software, and the cloud server to create a fully functional Med Box. The following outlines the process:

A. Storing Medicine:

To begin, the user downloads the app and completes the sign-up or login process. Once logged in, the Med Box is powered on, and it automatically rotates to identify its initial position using the IR sensor. The user then navigates to the containers page in the app and selects the desired containers for medication storage. Next, the necessary details, including the medicine name, initial quantity, and user information, are entered into the system. Once the data is recorded, the selected container moves to the front, allowing the user to place the medicine inside the designated section. This ensures that the medication is properly stored and tracked within the system. Figure 4 illustrates the GUI of the login window, where the user can sign in.

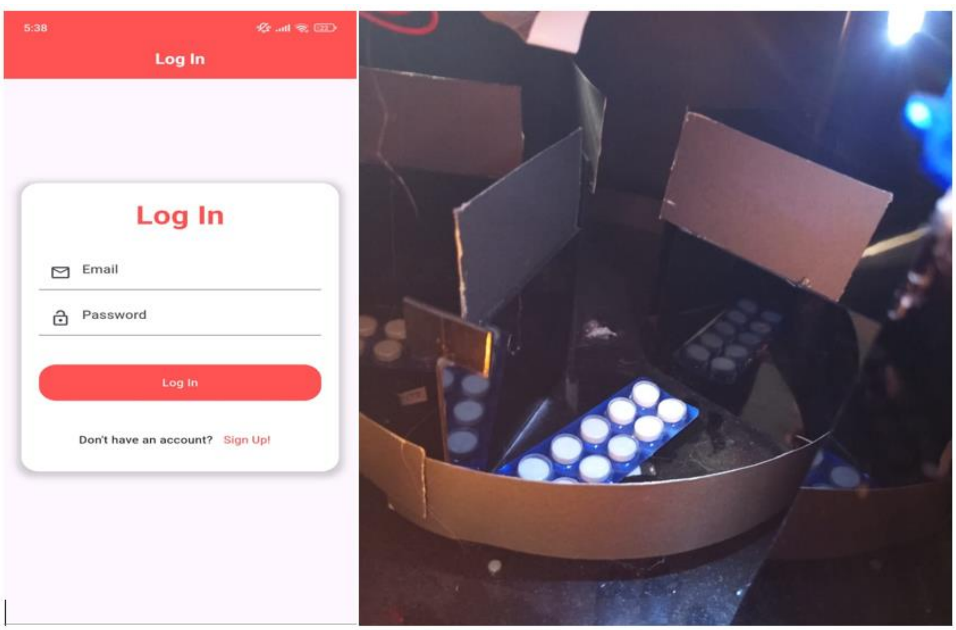

Figure 1. Login Page & Stored Medicine

B. Scheduling Notifications:

To set up notifications, the user navigates to the notification page within the app and schedules reminders for medication intake. They specify the frequency per day, the total number of days, the username, and select the appropriate containers and medication quantities for each notification. Once configured, all the entered data is securely stored in Firebase Firestore, ensuring that the notification is scheduled and delivered at the specified times. Figure 5 displays the notification menu, where the user receives reminders for medication.

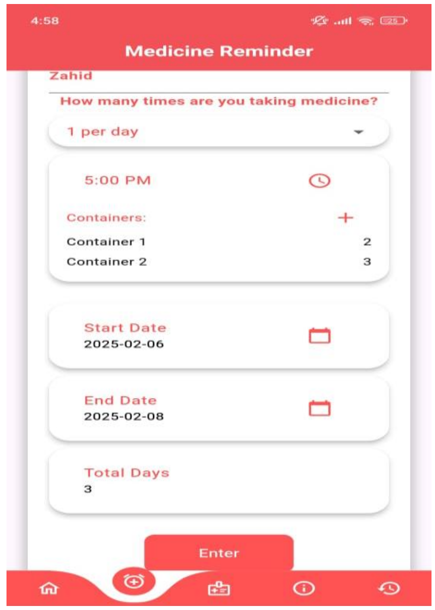

Figure 2. Scheduling Notification

C. Medication Taking Process:

At the scheduled time, the user receives a notification and a buzzer alert as a reminder to take their medication. Upon clicking the notification, the status updates to "Taken" (green) in the history log. The user then navigates to the medication-taking process page and selects "Start" to begin. The system automatically positions the first scheduled medicine container in front of the user, while the OLED display shows the username, medicine name, quantity, and container number. After taking the medicine, the user returns the packet to the container and taps the "Next" button to proceed to the next scheduled medication. This process continues until all scheduled medications have been taken. The entire medication-taking process is illustrated in Figure 6.

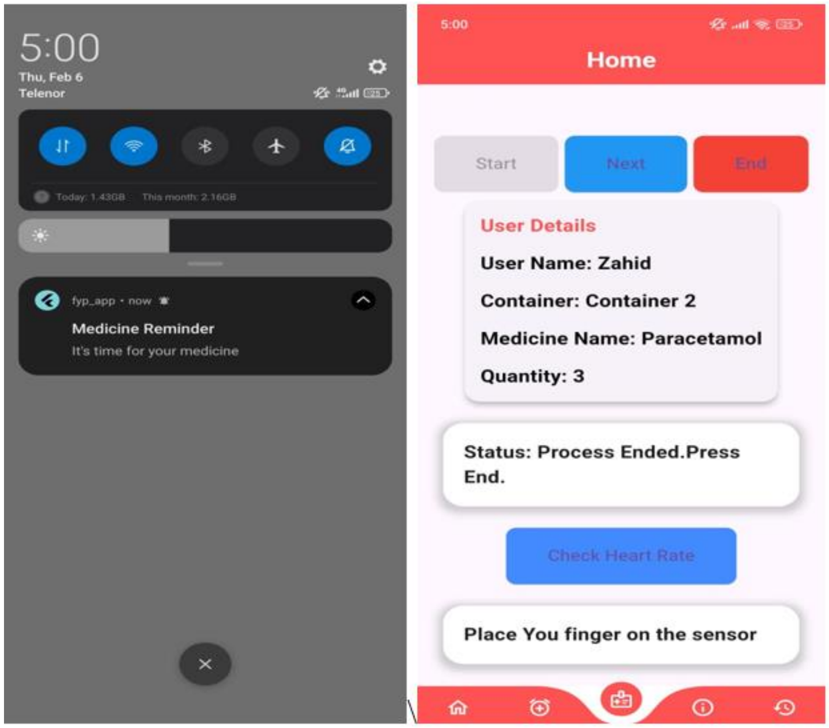

Figure 3. Receiving Notification & Medicine Taking Process

D. Image Processing:

After the medication-taking process, the image processing system is activated. The Raspberry Pi camera captures images of each container to analyze the remaining quantity of medicine. The captured images undergo processing to accurately detect and count the medicine packets inside each container. The model was evaluated both during training and in real-time, using 74 test images, and achieved 100% accuracy. This high accuracy is primarily due to the fact that the system operates with a single class, where the medicine packet is always placed in a designated container. The model efficiently detects and counts the pills, updating the respective container's data accordingly. The processed information is then displayed on the OLED screen, and the mobile app is updated with details such as the container number, medicine name, and updated quantity. Additionally, the Firebase database is updated in real time to ensure seamless data synchronization across the system. Figure 7 presents the confusion matrix, demonstrating 100% accuracy in medication detection. Additionally, the detected medicines are visually represented in this figure.

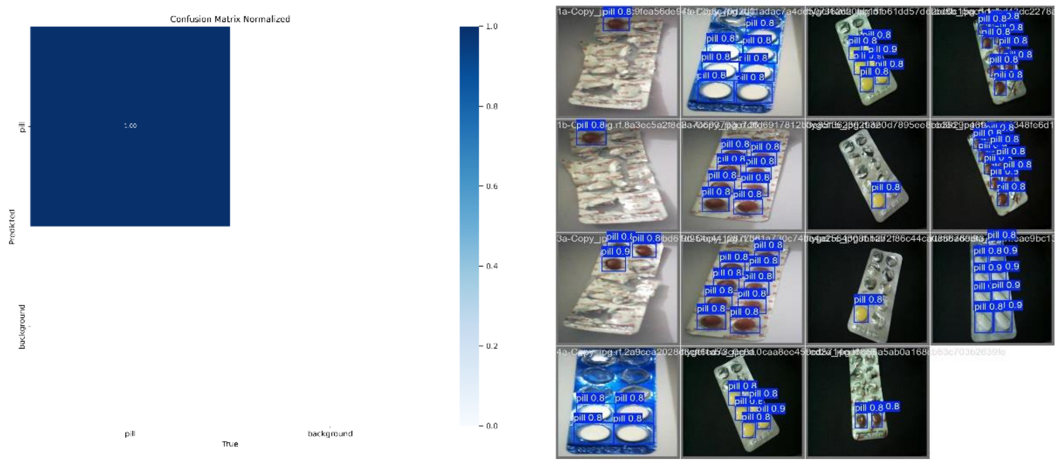

Figure 4. Raspberry Pi Cam & Led

E. Vital Monitoring Process

- We clicked on "Vital Check" to measure oxygen levels and heart rate.
- The readings were displayed on the OLED screen and the app.

Table 1 presents the various steps of the proposed problem and their results and discussion on these results.

Table 1: Experimental Results

Sr.	Problems	Result	Discussions
1	**Error due to Traditional Methods**	Automate the Medicine taking process to eliminate error.	The whole process is been automated, so that manual error does not occur.
2	**No Timely Notification**	Develop app so that the user can be timely notified.	User can use the app to schedule notification to take medicine on time, so they do not have to manually track it.
3	**Lack of Real-Time Monitoring**	Real-time data is displayed on the mobile app via Firebase integration.	Instant updates enabled users to make informed decisions about energy usage.
4	**Patient History**	Developed history page for user to see their history.	History page is added, so the caretaker can check the history.

5	**Vital Checks**	Add a sensor to measure the vitals of patient.	Real-time oxygen and heart rate measure at one click.
6	**Complexity in User Interaction**	Intuitive mobile app interface for easy interaction and control.	Simplified control through user-friendly design, making it accessible to non-technical users.
7	**Limited Scalability of Existing Systems**	Easily scalable with additional sensors and devices.	Future-proof design allows expansion for more devices and advanced functionalities.
8	**Limited Accessibility in Remote Areas**	Wi-Fi enabled access allowing remote control from anywhere.	Empowered users with control over utilities regardless of physical location.

4. Conclusion:

Medication management is an important thing when recovering a patient health, taking medicine on time, the right amount, the right medicine and completing your full medication course will make you healthier and happier. It very difficult in this fast growing world to remember everything and specially your medication not only yours but also your love ones. Med Box will help you with king of problem helping you with your medication, scheduling, updating and keeping your medication history. You can also use Med Box to check your heart rate and oxygen level at home. It's a new concept in Pakistan but using this people can take care of their health and their love ones.

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