Revolutionizing Healthcare Monitoring for Elderly Patients: A Comprehensive IoT-Driven Mobile Application for Caregivers, Incorporating Bed Exit, Room Exit, Fall Detection, and Voice Alerts

WeCare: Innovations from the WatchDog Gamma Team

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ABSTRACT

In the collaborative development of an innovative healthcare system, this research paper delves into the role and contributions of the front-end developer, focusing on the creation of a mobile application using Flutter, a versatile cross-platform framework. This mobile application, designed to assist caregivers, enables the management of patient assignments within rooms. The core functionality includes real-time monitoring of patient status, particularly their presence in the assigned room and bed occupancy.

Caregivers are provided with the capability to seamlessly add and assign patients to specific rooms. Subsequently, the application employs Firebase Cloud Messaging (FCM) to relay notifications to caregivers. These notifications are of paramount importance, alerting caregivers when patients depart from their designated room, leave their bed, or encounter falls. What sets this application apart is its comprehensive approach to notification management. Notifications are not only displayed in real-time but also logged for future reference. To further enhance user accessibility and experience, the application incorporates text-to-speech functionality. Thus, notifications are not solely confined to visual cues; they are also audibly communicated to caregivers. This multi-modal approach ensures that caregivers are promptly informed of critical patient events, regardless of their immediate attention to the mobile device.

In summary, this research paper underscores the pivotal contribution of the front-end developer in the development of a healthcare-focused mobile application. By harnessing the capabilities of Flutter, caregivers are empowered with a tool that streamlines patient assignment and provides real-time, audible notifications, ultimately enhancing the efficiency and effectiveness of caregiving in healthcare settings. The paper highlights the significance of user-centered design and cross-platform development in addressing the evolving needs of healthcare professionals.

1. Introduction

a) Motivation:

The field of healthcare is undergoing a profound transformation, driven by technological advancements aimed at improving patient care and enhancing the capabilities of healthcare professionals. In this context, our research endeavors to address a critical challenge faced by caregivers – the need for real-time monitoring and notification systems to ensure the well-being and safety of patients, particularly those under their care.

b) Background:

Existing research has explored various facets of healthcare technology, with an increasing focus on remote patient monitoring and notification systems. These systems are designed to assist caregivers in tracking patient movements, especially in settings where patient mobility is a concern. Previous work has emphasized the use of sensor technologies, data analytics, and mobile applications to facilitate patient monitoring. While these approaches have shown promise, they often lack a comprehensive solution that seamlessly integrates real-time notifications with user-friendly interfaces.

c) Research Question/Problem Statement:

Our research centers around a pivotal question: How can we develop an intuitive and efficient system to assist caregivers in monitoring and responding to patient movements within healthcare facilities? The specific problem we aim to address is the lack of a cohesive and user-centric solution that provides caregivers with real-time notifications regarding patient presence, bed occupancy, falls, and room departures. This problem is

particularly pertinent in environments where timely responses are critical to patient safety and care.

In this paper, we present our contribution to the development of a healthcare system that revolves around a mobile application tailored for caregivers. This application leverages Flutter, a versatile cross-platform framework, to offer caregivers an intuitive tool for patient assignment and real-time notification management. The research outlines the importance of user-centered design and cross-platform development in crafting an efficient and effective solution for healthcare professionals. Through a detailed examination of our work, including methodology, results, and implications, we seek to shed light on how this innovation can reshape the landscape of patient care and caregiver support.

With this research, we embark on a journey to bridge the gap between existing healthcare technologies and the evolving needs of caregivers, ultimately contributing to enhanced patient well-being and caregiver effectiveness in healthcare settings.

2. Related work

The development and application of Internet of Things (IoT) technology in healthcare have gained significant attention in recent years. A notable contribution to this field is the work by [Authors] on a mobile IoT cloud-based health monitoring dashboard application designed for the elderly [1]. As the global population continues to age, the demand for better healthcare monitoring and services for the elderly has grown. This system employs two vital sensing modules: PI, which measures body temperature, heart rate, and oxygen saturation (SpO2), and P3, an accelerometer sensor capable of detecting falls. These sensors wirelessly transmit data to a Raspberry Pi gateway and subsequently store it in the cloud-based database InfluxDB. A mobile application developed using the Flutter framework allows users to access a dashboard displaying monitored data. It also provides real-time fall detection alerts through the OneSignal platform. The study emphasizes the rising popularity of mobile applications and cloud computing, particularly in regions like Malaysia, where mobile app adoption is on the rise. Their choice of Flutter for app development and Firebase for backend services is justified due to their effectiveness and seamless integration with other tools [1].

Another relevant contribution in the domain of IoT-based systems is the development of an IoT-based smart home security system [2]. The aim of this prototype is to enhance user convenience, comfort, and security while reducing energy consumption. The system integrates various sensors, including motion detectors, light intensity sensors, and temperature and humidity monitors. These sensors are controlled by Arduino UNO, with the Raspberry Pi serving as the central command center, connecting the system to the internet. Notably, this system leverages the Flutter mobile application platform as an open-source solution for efficient control and monitoring. The motion sensor implementation in this study holds particular relevance for our project, as it can provide insights into replicating a similar feature.

Furthermore, research on smart healthcare monitoring systems utilizing IoT technology has demonstrated its potential to revolutionize healthcare services [3]. In this context, a study presents a comprehensive IoT-based healthcare monitoring system that continuously tracks and transmits critical health parameters for patients requiring continuous monitoring [3]. The system employs a Raspberry Pi 4B as the microcontroller, along with a range of sensors such as DS18B20 for body temperature and MAX30100 for heart rate and SPO2 monitoring. The research integrates real-time data transmission to cloud storage and a cross-platform mobile application, facilitating remote monitoring by doctors and patients. Notably, the system includes an alert mechanism that promptly notifies doctors, paramedics, and patients' relatives in case of abnormal parameter values. This research collectively highlights the potential of IoT in remote healthcare monitoring and timely medical interventions. While each research project addresses distinct aspects of IoT applications in healthcare, they collectively provide valuable insights into the development and integration of similar technologies in our project.

3. Methodology

The development process for this WeCare application can be divided into several distinct phases, each contributing to the creation of a highly functional and user-centric tool. The methodology adopted reflects a blend of design thinking, technological integration, and a continuous feedback loop, ensuring the application not only meets but exceeds the requirements of its intended users.

a) Initial Conceptualization and Wireframe Design

The journey began with a thorough conceptualization phase, where the primary aim was to outline the basic structure and functionality of the application. This phase involved creating detailed wireframes for key screens such as the home page, login and signup pages, and the edit pages for caregiver and patient profiles. The wireframes were meticulously designed to ensure a logical flow and an intuitive user interface, setting a solid foundation for the application’s development. This stage was crucial in visualizing the end product and served as a roadmap for the development team.

b) Authentication and User Management

With the wireframes in place, the focus shifted to developing core functionalities. The implementation of Firebase Authentication marked a significant step in this phase, providing a secure and efficient way to handle user login and registration. This feature not only ensured the security of user data but also streamlined the

process of user management, a critical aspect for any application dealing with sensitive personal information.

Figure 1: frontend validations for login and signup

As shown in Figure 1, alert boxes and frontend validations have been added to the login and signup which further improves the accuracy and efficiency of the application flow for the user.

c) Enhancing Patient Profiles and Data Capture

The patient addition feature underwent a significant evolution during the development process. Initially, patient profiles were created using static images. However, to enhance the accuracy and effectiveness of the machine learning model, a video capture feature was later integrated. (See Figure 2.) This feature allowed for the collection of more dynamic and comprehensive data, significantly improving the application's ability to accurately recognize and monitor patients. The automatic assignment of patients to caregivers' profiles further simplified the management process, making it easier for caregivers to track and access patient information.

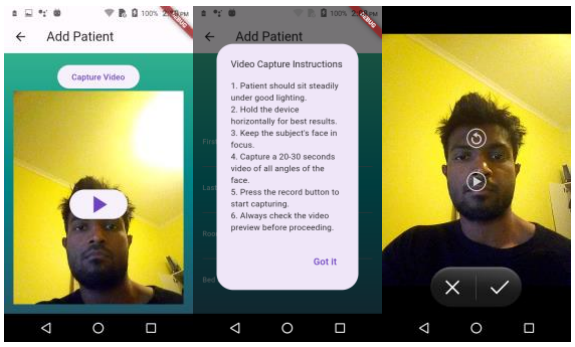

Figure 2: Video capturing feature on the application

d) Notification System: A Pillar of the Application

The notification system was designed to be a cornerstone of the application, providing timely and relevant alerts to caregivers. The integration with Firebase Cloud Messaging was a key aspect of this system, ensuring the delivery of notifications in real-time. The system was intelligently designed to trigger alerts only under specific conditions, such as when a patient deviated from preset constraints, thereby avoiding unnecessary notifications. The addition of a text-to-speech feature was a thoughtful inclusion, catering to situations where caregivers might not be able to immediately read the notifications.

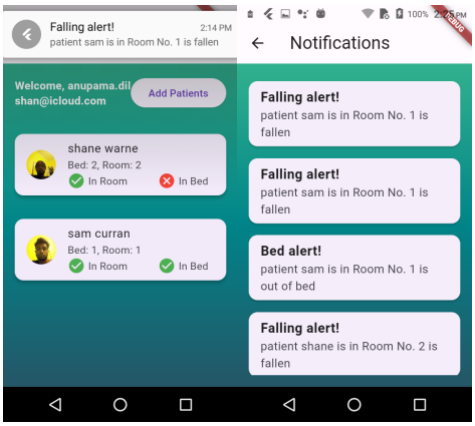

Figure 3: displaying notifications on the app

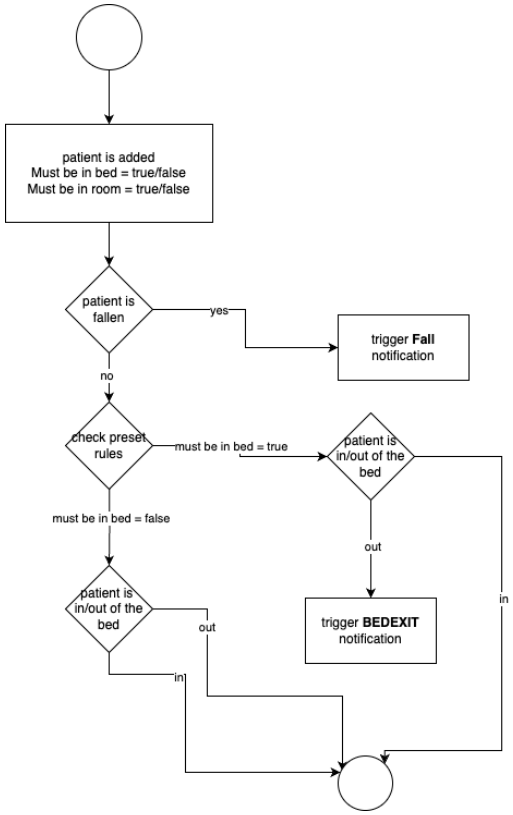

Figure 4: How the fall detection and bed exit works

Figure 4 in the diagram represents the logic flow for fall detection and bed exit monitoring in the caregiving application. The process begins when a patient profile is added to the system, with two key parameters being set: "Must be in bed" and "Must be in room," which can be either true or false.

For fall detection:

The system continuously monitors the patient to detect if a fall has occurred.

If the patient has fallen and the "Must be in bed" condition is set to true or false, a "Fall notification" is triggered. This indicates that regardless of the patient's set location constraints, a fall will always result in an immediate notification.

For bed exit monitoring:

The system checks preset rules based on the patient's profile settings.

If the "Must be in bed" rule is true, the system then monitors the patient specifically for their presence in bed. When a patient is detected to be moving in or out of the bed, the system decides the next step based on their movement:

- If the patient is moving out of the bed, the system triggers a "BEDEXIT notification," alerting the caregiver that the patient who is supposed to stay in bed has left it.
- If the patient is moving into the bed, there is no notification triggered, as the patient is complying with the preset condition.

However, if the "Must be in bed" condition is false, indicating that the patient is not required to stay in bed, the system still monitors for in and out bed movements but does not trigger a notification. This would be relevant in less critical scenarios where the patient has more freedom of movement and is not at immediate risk if they leave the bed.

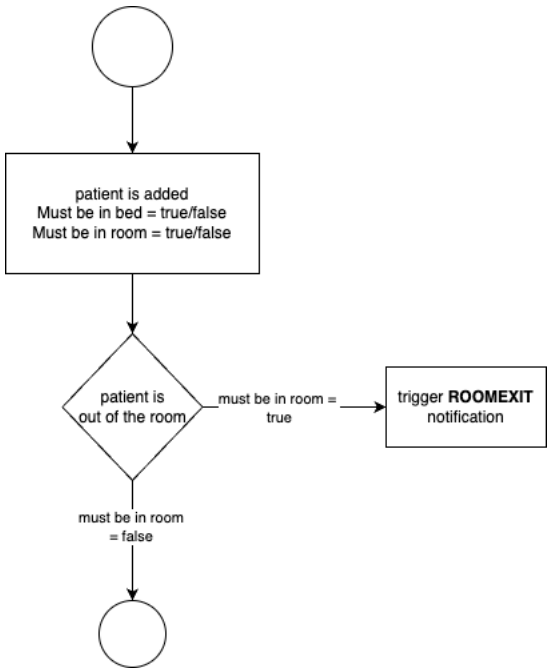

Figure 5: How the room exit works

Figure 5 in the provided diagram illustrates the logic flow for room exit monitoring in the caregiving application. This functionality is crucial for ensuring the safety of patients, especially those who may require constant supervision due to the risk of wandering or getting into potentially dangerous situations.

The flow begins with the addition of a patient to the system. Upon creation of the patient profile, two conditions are set: "Must be in bed" and "Must be in room," each with the possibility of being true or false. These settings are likely tailored to individual patient needs and risk assessments.

The system checks if the patient has left the room.

If the "Must be in room" condition is set to true and the patient is detected as being out of the room, the system triggers a "ROOMEXIT notification." This alert is critical as it indicates that a patient who should not leave the room has done so, prompting immediate action from the caregiver.

If the "Must be in room" condition is set to false, the system does not trigger a notification when the patient leaves the room. This setting might apply to patients who are not considered at risk when moving about more freely.

In essence, Figure 2 depicts a targeted alert system that notifies caregivers when patients with specific spatial restrictions move out of their designated safe area. This feature is particularly important for patients with conditions that may lead them to unknowingly put themselves in harm's way if they leave a certain space without supervision. The system thereby assists in the

proactive management of patient safety within a caregiving environment.

e) User Experience and Interface Refinements

Parallel to these functional developments, significant efforts were directed towards refining the user interface and experience. This involved creating an aesthetically pleasing design that was also highly intuitive and easy to navigate. The application featured smooth transitions between screens and included interactive elements such as loaders and alert boxes, which not only added to the visual appeal but also enhanced the overall usability. (see Figure 6.)

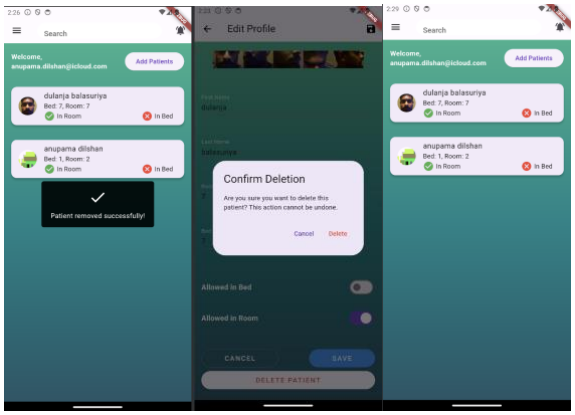

Figure 6: visual appearance

f) Demonstration, Feedback, and Future Enhancements

The final phase of the project involved presenting the completed application at a demonstration event. This provided an invaluable opportunity to gather feedback from potential users and stakeholders. The positive reception of the application's frontend functionality was encouraging, highlighting the success of the development process. However, constructive feedback, such as the suggestion to add a feature for deleting notification log entries, was also received. This feedback is crucial for the ongoing development and enhancement of the application, ensuring that it continues to meet the evolving needs of its users.

The methodology employed in the development of this caregiving application was comprehensive, encompassing everything from initial design to user feedback integration. Each phase was executed with a focus on quality, user experience, and technological innovation, resulting in an application that is not only functional and efficient but also intuitive and user-friendly. This approach ensured the creation of a tool that genuinely addresses the needs and challenges of caregivers, ultimately enhancing the quality of care provided to patients.

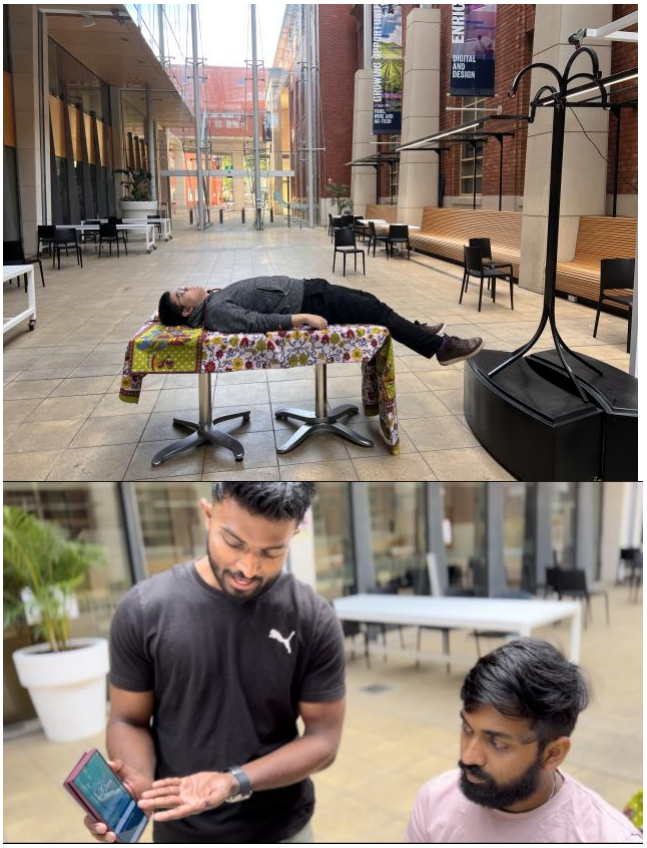

Figure 7: demo video day

4. Results and discussion

In the research conducted for the development of a WeCare application, the results and subsequent discussions reveal significant insights into the application's functionality and user interaction. The application, designed for enhanced patient monitoring and alert systems, underwent extensive testing to assess its performance.

The patient data collection and recognition capabilities of the application were a primary focus of the testing. The results showed that the application could successfully capture and process patient data, including initial photographs and 20-minute videos. Importantly, the integrated machine learning model accurately recognized patients in various settings based on this data. This effectiveness in patient recognition highlights the application's potential in providing reliable monitoring, a crucial aspect for caregiver responsiveness and patient safety.

Another key area of the application was user authentication and engagement, managed via Firebase Authentication. The system demonstrated high reliability with no reported failures, and user engagement data indicated frequent use of patient profile editing and video viewing features. The robustness of the authentication system provided a secure environment for caregivers, and the high

engagement levels suggested the application's user-friendly nature and practical utility in caregiving scenarios.

The efficacy of the notification system was also tested. Integrated with Firebase Cloud Messaging, the system functioned as intended, correctly triggering notifications under specified conditions. The text-to-speech feature, which audibly read out alerts, worked accurately. The reliability of the notification system is vital in urgent caregiving situations, and its performance, along with the benefit of audible alerts, significantly enhances a caregiver's ability to respond promptly.

Furthermore, the machine learning model's responsiveness in recognizing patient deviations from pre-set conditions was observed. This high accuracy is pivotal in minimizing false alarms and ensuring that caregivers are alerted to genuine instances of patient need or emergency.

The user experience with the application's interface was overwhelmingly positive. Users reported ease of use, intuitive navigation, and smooth screen transitions, indicating the application's user-friendly design and practicality in real-world caregiving situations. Table 1 summarizes the testing status of each feature of the application.

Feature	Working?	Remarks
Login and Signup authentication	yes	Secure login and signup through firebase authentication with frontend validation.
Add patient profile	yes	Allow caregivers to add patient profiles with any constraint.
Capture patient video	yes	Instructions are displayed prior and the video capture is limited to 20 seconds.
Fall detection notification	yes	Automatically notify caregivers of any falls (according to the angle/position of the camera sometimes wrong poses are detected as falls and get wrong notifications constantly)
Bed Exit notification	yes	Alert caregivers when a patient exists the bed if the 'must be in bed' constraint is set.
ML model accuracy	yes	Due to different qualities of the phone's camera and the actual detection camera some faces are not recognized well.
User interface usability	yes	Intuitive navigation, smooth transitions and easy accessibility of features.

Table 1: Summary of app functions tests

Finally, the research highlighted the importance of feedback integration for system improvement. Feedback from the demonstration day, particularly regarding the addition of a feature to delete notification log entries, was noted for future updates. This continuous integration of user feedback is essential for the application's evolution, ensuring it remains aligned with user needs and industry advancements.

In conclusion, the testing phase of the caregiving application indicates a high level of functionality and user satisfaction. Its ability to accurately collect and process patient data, coupled with a reliable notification system and a user-friendly interface, demonstrates its potential as an effective tool in the caregiving sector. However, areas for improvement were identified, underscoring the need for ongoing development. Overall, the application represents a significant advancement in using technology to support and enhance the caregiving process, paving the way for further research and development in this field.

5. Conclusion

The research and development of the caregiving application culminated in an innovative tool designed to significantly enhance the caregiving process. This conclusion section reflects on the key findings of the project, its implications, and the potential for future advancements in the field of caregiving technology.

The application successfully integrated advanced technologies, including machine learning and Firebase Cloud Messaging, to create a robust platform for patient monitoring and caregiver alerts. The testing phase demonstrated the application's capability to accurately collect and process patient data, effectively utilize video and image recognition for patient monitoring, and provide reliable, real-time notifications to caregivers. The inclusion of a user-friendly interface and intuitive navigation further contributed to its practical utility in caregiving scenarios.

One of the most noteworthy aspects of the project was the application's machine learning model. Its ability to accurately identify patient deviations from predetermined conditions exemplified the potential of AI in enhancing patient care and safety. Furthermore, the reliable and secure user authentication system, managed via Firebase Authentication, provided a foundational layer of security and trust, essential in healthcare-related applications.

User feedback, gathered during the demonstration and testing phases, played a pivotal role in identifying areas for improvement.

Suggestions such as the need for a feature to manage and delete notification log entries highlighted the importance of ongoing development and user-centric design. This feedback will be invaluable in guiding future enhancements to the application.

The project's implications extend beyond the immediate scope of the application. It demonstrates the immense potential of technology in transforming caregiving, offering tools that can make patient care more efficient, responsive, and personalized. As the field of healthcare technology continues to evolve, applications like this can serve as models for future innovations, driving forward the integration of technology in healthcare settings.

In conclusion, the caregiving application represents a significant stride in the application of technology within the healthcare sector. Its successful development and positive reception underscore the feasibility and necessity of such technological solutions in modern caregiving. Looking ahead, this project lays the groundwork for further research and development, opening avenues for more advanced, intuitive, and effective caregiving tools, ultimately contributing to the betterment of patient care and caregiver support.

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