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RESEARCH ARTICLE **Open Access**

Design and Development of IoT-Based Mobile Application for Heart Rate and Body Temperature Monitoring

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Abstract: The rapid development of Internet of Things (IoT) technology has influenced many fields, especially healthcare delivery systems. This paper will analyze the effect of IoT-based mobile applications on the quality of healthcare services through real-time patient monitoring. The application developed in this study was used to monitor vital signs heart rate and body temperature using sensors attached to mobile devices. The research methodology includes system architecture design and implementation with MAX30102, DS18B20, and MLX90614 sensors where the ESP32 microcontroller acts as the main integration platform. The application development was done using Android Studio and Flutter frameworks. User testing showed significant improvements in the speed at which critical conditions are detected among patients and also in the time taken by healthcare providers to respond to such situations. User satisfaction ratings indicated high acceptance levels, thus proving a large potential market for digital healthcare. Results from this study also proved that IoT-mobile application integration can uplift standards in healthcare services while providing a practical solution for modern-day medical practice.

Keywords: Internet of Things; Mobile Application; Vital Sign Sensors; Mobile Health Technology; MAX30102 sensor.

1. Introduction

Technological advancement has reshaped many aspects of daily life, with healthcare being one of the most affected. Among them, Internet of Things (IoT) has become the main technology in changing the way health services are delivered, especially in real-time health monitoring. IoT technology makes it possible for medical devices to connect with mobile apps so that users can check their health status anytime and anywhere; thus, breaking time and location barriers in access to healthcare [1]. This shift represents a major change from traditional models where patients depended on periodic visits to clinics and manual assessments by medical professionals for their care. The increasing need for constant observation of vital signs, especially heart rate and body temperature, has created a demand for advanced yet simple health monitoring systems. Mobile applications integrated with IoT devices are powerful tools; not only do they provide immediate access to personal health information but also enable the healthcare provider to make quicker and more informed clinical decisions. Using sensor technology supported by wireless connectivity, these applications create a dynamic ecosystem wherein health data flows easily between patients and healthcare professionals allowing timely interventions [2]. A continuous ability to track physiological parameters rather than through sporadic measurements is basic advancement in preventive healthcare as well as early disease detection.

This study centers on creating an IoT-based mobile health monitoring application meant to ease personal health management for regular users. It features real-time heart rate and body temperature monitoring using specific sensors like MAX30102, DS18B20, and MLX90614 all connected through an ESP32 microcontroller platform. The collected sensor data is sent wirelessly to a mobile application built with Android Studio and Flutter frameworks where it can be processed visualized and provided access to the user via an easy interface [3]. The system architecture emphasizes both accuracy and user-friendliness because effective tools in health monitoring should have technical sophistication as well as ease of use if they are going to be widely adopted by different populations of users.

IoT-based digital monitoring systems can greatly improve the working efficiency of healthcare workers in hospitals and help normal people manage their health. The system uses wearable sensor technology integrated with IoT to collect physiological data like heart rate and body temperature continuously during physical activities, with all data sent automatically to the application for analysis and real-time monitoring [2]. This continuous data stream provides a more complete picture of an individual's health status compared to traditional snapshot measurements, allowing for the detection of patterns and anomalies that might otherwise go unnoticed. The digital nature of these applications also enhances efficiency and effectiveness in healthcare delivery by enabling preliminary self-assessment through smartphones before users commit to clinic visits. If the application detects concerning vital sign patterns suggesting emergency conditions, it will alert the user immediately so that they can seek professional medical attention at the nearest healthcare facility. In addition to basic monitoring functions, the application offers educational content about how to maintain one's health, such as what the optimal heart rate range is or what normal variations in body temperature are, as well as general wellness guidance; thus, it serves both as a monitoring tool and health education platform.

2. Related Work

Past work has shown the use of IoT-based systems for vital signs monitoring in healthcare applications, thus creating a solid base for further innovation in this area. An IoT architecture was proposed by Gubbi *et al.* for health monitoring that focuses on real-time data collection and processing in the cloud, highlighting the very important need for immediate access to data when making clinical decisions. Many researchers have taken this architectural framework and examined the actual use of sensor technologies with a special focus on the MAX30100 and MAX30102 sensors for heart rate monitoring along with DS18B20 and LM35 sensors for body temperature measurement. These particular sensors are widely used in research and development projects because they are relatively cheap, reliable, and easy to integrate, making them available for both academic research as well as practical healthcare uses [4]. The growing number of mobile health (mHealth) applications has also increased the variety of digital healthcare tools with developers making different platforms that show physiological data and give health information straight to users. But when we look closely at what has been written before most studies have focused on separate parts of the system—like improving how accurate sensors are or better designing application interfaces—without solving the problem of putting together all parts into one complete system. Also, some implementations have not provided basic features such as database synchronization and real-time notification mechanisms which are very important in good health monitoring and quick medical intervention [5].

The choice of programming languages and development frameworks plays a key role in determining the success and scalability of mobile health applications. Kotlin has come up as one of the most popular open-source programming languages used for cross-platform development, with its use growing more rapidly as an option for Android-based health applications [6]. Recent technical reviews have stated that Kotlin is a modern programming language with static typing and runs on the Java Virtual Machine (JVM) platform, enabling developers to take advantage of both type safety and platform compatibility. In addition to its JVM capabilities, Kotlin also supports compilation to JavaScript via the LLVM compiler, thereby offering further flexibility for web-based healthcare solutions [7]. Unlike earlier studies that looked at separate parts of the system individually, this study focuses on whole systems integrated together by using IoT sensors, real-time cloud databases, and mobile applications into one single monitoring platform. The system proposed here prefers real-time monitoring while ensuring easy implementation through commonly used development tools; it fits best in early-stage health monitoring applications where rapid deployment is needed without much technical infrastructure.

Modern health monitoring applications' technical infrastructure is based on strong database management systems and clear system design methodologies. MySQL is an RDBMS that uses SQL as its query language and has an open-source ethos; this has made it become one of the most popular choices among developers creating web-based applications today. MySQL comes with two types of licenses: one free software license that allows anyone to use it anywhere for any purpose and another proprietary software license meant for commercial use [8]. In addition to database choice, flowcharts are very important visual tools—they are also called flow diagrams—that show algorithms and the order of steps in a system's instructions. These diagrams give programmers logical views of the systems they are working on so that problems can be seen and fixed during development. Basically, flowcharts use standard symbols to show different processes, decisions, and data flows; this makes it possible to speak about systems using a common language between all members of a development team [9].

Modern health monitoring apps go beyond just collecting data; they also have educational features that engage the user and increase health literacy. App features more and more often include health information modules that allow IoT-based monitoring while simultaneously teaching the user about such wellness topics as what exercise to do, what to eat, and how best to sleep. This combination of monitoring with education increases the application's value proposition and makes users feel more actively involved in managing their own health status [10]. Gubby, Buyya, Marusic, and Palaniswami (2013) discussed basic IoT concepts in order to create architectural frameworks for predicting IoT development in healthcare environments. The authors believe that these systems can allow users to get real-time data while evolving with current demands for instant information access. This paper illustrates how healthcare has adopted new technologies in order to stay competitive and current within an increasingly digital world where patients demand instant access to their health information as well as integration between monitoring devices and information systems [11].

3. Research Method

This research employs a Research and Development (R&D) approach aimed at designing, implementing, and evaluating an IoT-based health monitoring application. The study follows the Software Development Life Cycle (SDLC) using a Waterfall model, which systematically progresses through distinct phases including requirement analysis, system design, implementation, testing, and evaluation. This methodological framework ensures a structured and comprehensive development process that addresses both technical requirements and user needs while maintaining scientific rigor throughout the research process.

3.1 System Architecture and Research Approach

The research methodology comprises three major techniques of data collection and analysis that play a crucial role in the system development process. First, the observational phase included an extensive review of literature such as journals and technical documents to find current trends, issues, and opportunities regarding IoT-based health monitoring systems. This systematic literature review yielded critical insights into sensor selection, data transmission protocols, and user interface design principles which would then be used to inform the overall system architecture. The information gained from this phase shall guide the development of a sensor-based monitoring system that can capture heart rate and body temperature data without manual recording, thus eliminating a major limitation of traditional health monitoring methods. Second, the experimental research phase involves hardware prototyping with components like Arduino DHT11, ESP32 dev kit v1, LED indicators for buzzer alerts, MAX30100 sensor BCC6791302 module control buttons integrated into a functional prototype for heart rate and body temperature monitoring sensors - this is part of physical infrastructure necessary to collect data and validate systems. Thirdly, the case study method draws on multiple reference sources such as textbooks, peer-reviewed journals, and technical websites to establish theoretical frameworks and best practices in mobile application design. The synthesis from these diverse sources led to an IoT-based mobile application concept for real-time monitoring of heart rate and body temperature that fills the gaps found in existing healthcare monitoring solutions.

3.2 Hardware and Software Requirements

The requirements of the system are divided into functional requirements and non-functional requirements. Functional requirements describe how the system takes health data inputs, what responses to user actions it produces, and how it behaves under different operating conditions. The system requires spatial health data with several types of vital signs, namely heart rate and body temperature taken through integrated sensors. More than just accepting data, the system should integrate this information to produce accurate numerical outputs that can be read by users for health assessments. An input mechanism is provided for users to manually enter extra health information whenever necessary; automated sensor data will flow directly into the system without any user intervention. Process requirements state that the system shall recognize and classify different types of data according to pre-defined health parameters, show results from examinations carried out by sensors in a format easily readable by users, and use correct algorithms so as to be able to process and store data effectively. Output requirements specify that the system shall provide an accurate presentation of real-time health data such that a user can know his current status on health at once while also giving contextual information necessary for making informed decisions about his health.

Non-functional requirements involve technological infrastructure needed for development, deployment, and operation of the system. The software development environment uses Visual Studio Code 11 as a main code editor where both mobile application code and backend program codes will be written and managed. Flutter SDK is used as a cross-platform mobile application development framework hence it allows simultaneous deployments on Android as well as iOS devices while providing uniformity in user experience across platforms. Node.js may optionally provide backend services for API management if more server-side processing is needed than what Firebase supports. Git together with GitHub will be used for version control plus collaborative development activities so that code integrity is maintained while teamwork coordination during the entire project development process is enabled. The backend infrastructure uses Firebase services only which includes Firebase Realtime Database to store heart rate and body temperature data with real-time synchronization between devices; Firebase Authentication for secure user login and registration processes; plus Firebase Cloud Messaging in order to push notify users when their health parameters are out of normal ranges or require attention on their devices.

For IoT simulation and hardware testing, the Wokwi IoT Simulator gives a virtual place to test sensor circuits with pulse sensors for heart rate detection and temperature sensors like LM35 or DS18B20 to measure body temperature. Arduino IDE is another way to upload and test microcontroller code on real ESP32 devices when moving from simulation to real hardware. The target OS is Android with a minimum SDK version of 21 or higher so that it works with most Android devices now in use while iOS support is optional for future cross-platform expansion. Other software tools are Figma or Adobe XD, which design UI/UX mockups and application prototypes, ensuring user-centered design principles guide interface development; Postman will be used for API testing if the backend system uses REST API architecture for data communication.

Hardware requirements include all physical components needed for both simulation and actual implementation of the IoT-based health monitoring system. The control center microcontroller and the data transmission unit should use an ESP32 or ESP8266 microcontroller that has Wi-Fi built-in, allowing it to connect directly to Firebase cloud services without any networking hardware. Heart rate detection may use Pulse Sensor, MAX30100, or MAX30102 sensors because these have been proven to be accurate in detecting and measuring user pulse rates through photoplethysmography technology. Body temperature measurement may use LM35 or DS18B20 sensors since they are known to measure human body temperature accurately between 35°C and 42°C clinically. A breadboard with jumper cables will serve as the connection platform for all electronic components so that it can be assembled without permanent soldering; this allows rapid prototyping and modification of components during development phases. Power supply options are dedicated power adapters, rechargeable batteries, or USB cables which provide flexibility in deployment scenarios from stationary clinics to portable personal monitoring devices. The simulation and development environment needs a computer or laptop with enough processing power to run the Wokwi simulator as well as execute the Flutter development environment at the same time. Last but not least is an Android smartphone with minimum SDK 21 support on which installation of the developed mobile application can take place under real-world usage conditions—this ensures that performance happens as expected on actual user devices rather than just emulated environments.

4. Result and Discussion

4.1 Results

4.1.1. Data Collection

Based on observational findings from multiple healthcare facilities, it was discovered that health monitoring for heart rate and body temperature remains predominantly manual, with limited utilization of current digital technologies. The health examination process continues to rely on traditional manual instruments, with data recorded on paper forms and simple logbooks. Data were also obtained during visits to several healthcare facilities, revealing significant opportunities for technological improvement in routine health monitoring practices. The developed system successfully integrates IoT sensors with a mobile application for real-time health monitoring. Simulation results using Wokwi IoT Simulator demonstrate that the ESP32 microcontroller reliably transmits heart rate and body temperature data to Firebase Realtime Database. The mobile application displays data in both numerical and graphical formats, enabling users to monitor health trends over time and identify patterns that may require medical attention.

Functional testing confirms that the application's main features—including user registration, login, dashboard access, and real-time data visualization—operate according to design specifications. The implementation of Firebase Realtime Database supports efficient data synchronization between the sensor module and mobile application, ensuring minimal latency in data transmission. Despite these positive outcomes, the system has several limitations that warrant acknowledgment. Testing was conducted exclusively in simulated environments, and sensor accuracy has not yet been validated against standard medical-grade devices. Additionally, system performance depends heavily on internet connectivity, which can affect data transmission latency. These limitations indicate the need for further development and testing under real-world conditions before clinical deployment. Healthcare workflows in clinics that have not yet adopted digital technology follow traditional patterns characterized by three main challenges:

1) Health recording still uses manual tools with data entry in Excel spreadsheets or simple logbooks that do not support real-time access.
2) Manual recording processes produce results that are not real-time, potentially compromising data accuracy and timeliness.
3) There is no integrated application facilitating communication between healthcare providers and patients for sharing examination results efficiently.

These conditions motivated the development of an IoT-based digital technology to assist healthcare professionals and users in obtaining accurate, real-time health results. Healthcare workers often face challenges in providing accurate health information due to manual recording limitations. Therefore, they require modern technological assistance to eliminate errors in delivering health results to patients. Based on data collection findings, several system requirements essential for healthcare professionals were formulated to guide the development process.

4.1.2. Use Case Diagram

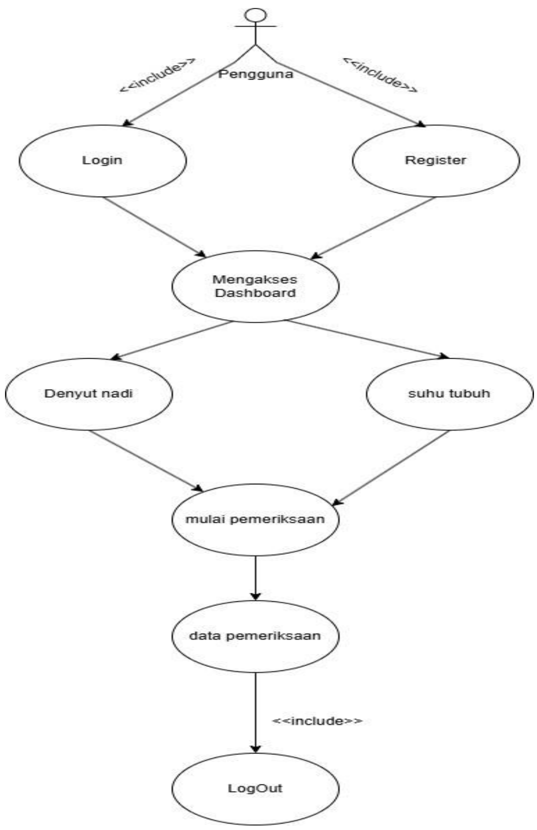

Figure 1. Use Case Diagram of Health Monitoring System

The Use Case Diagram illustrates the functional architecture of the mobile health monitoring application system with the user as the primary actor. Users can perform registration to create accounts within the system, login to access protected features, and logout to securely terminate sessions. After successful login, users can access the application dashboard and input health data either manually or through automated sensor readings. Users can also manage health data, including viewing results from completed examinations. Additionally, users have functionality to independently conduct health assessments and view data generated from examinations [12]. All health data management activities are represented by use cases including viewing, editing, and deleting records. Furthermore, users can access and review all examination results for heart rate and body temperature monitoring. Users must complete the login process before accessing any functionalities available in the mobile health monitoring application system.

4.1.3. Flowchart

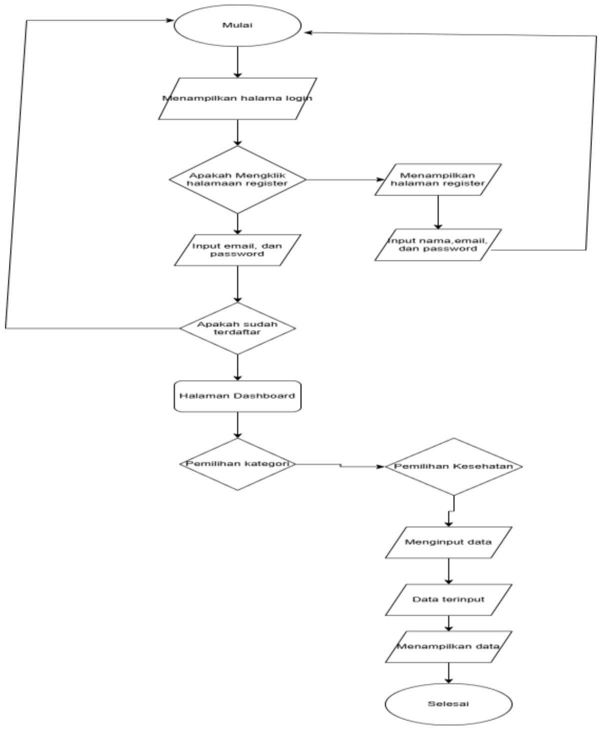

Figure 2. System Flowchart

The following diagram illustrates the system workflow from the user perspective. The system begins when users access the application and are directed to the login page. If users do not have accounts, they can click the register button to create new accounts by entering name, email, and password. Entered data will be validated before accounts are successfully created. For login, users enter their registered username and password. After successful login, users proceed to the dashboard page where they can select health categories and view available results. If users select a specific health category, the application displays the list of health monitoring options available within that category.

4.1.4. Implementation

This research produced a prototype of the health monitoring application system for health data management. The prototype was built using Android Studio, Visual Studio Code, Browser, and MySQL. This prototype is designed for all users, who can utilize the application through several stages: login stage, registration stage, dashboard display, health menu selection, health examination, and health results viewing, as shown in the following figures. On the login page, the system accesses the database from the user table. To login, users are required to enter their username (email) that was registered previously during the registration process. Subsequently, they must enter the password corresponding to the entered email. The combination of email and password serves to verify user identity and provide secure access to their accounts. After filling both fields, users can click the "Login" button to proceed with the login process and access the application. However, if users do not have accounts, there is a "Register" link that allows users to complete registration first (Figure 1).

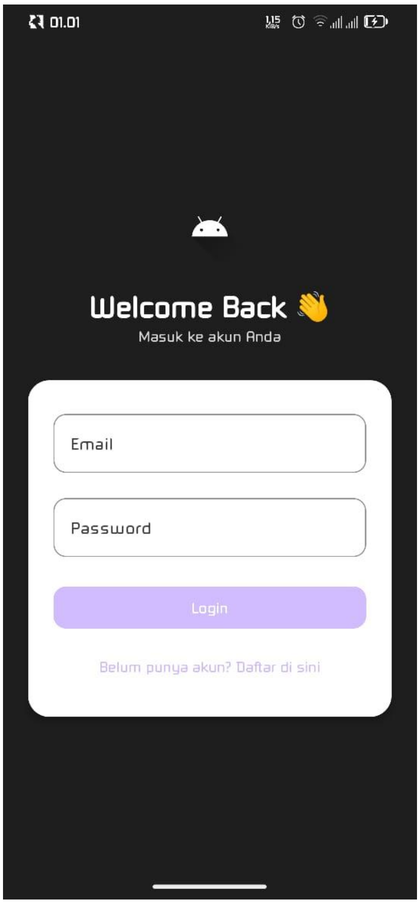

Figure 3. Login Page Interface

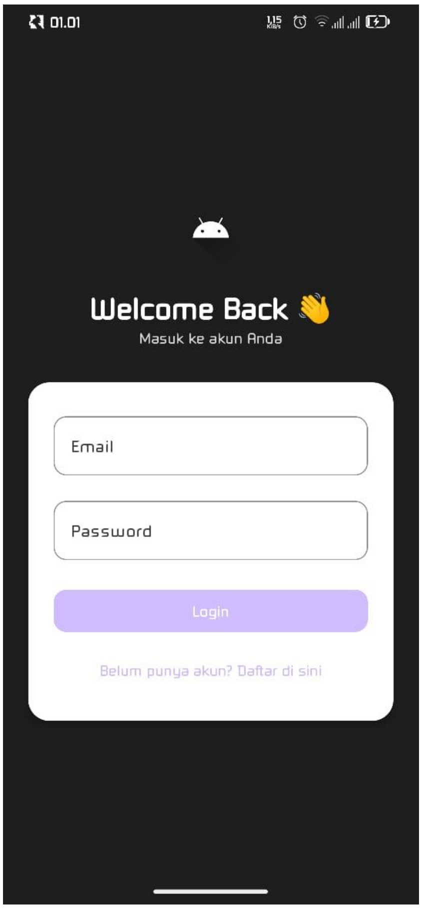

Figure 4. Registration Page Interface

On the registration page, users must create accounts before they can login by filling several available fields. First, users are asked to enter their full name. Next, users must input their email address. After entering personal data, users are required to create a password to secure their accounts. After completing all required fields, users can click the "Register" button to finalize the registration process. However, if users wish to cancel or change their decision, there is a "Login" link that allows users to return to the login page if they already have existing accounts. Data entered during the registration process is stored in the database within the user table (Figure 2).

Figure 5. Dashboard Interface

The dashboard page is designed with an attractive and intuitive interface to facilitate user navigation. The dashboard displays health buttons, examination items, examination results, and other health information. The dashboard page also features a sidebar button and search functionality to find additional information.

4.2 Discussion

The results of implementing digitalization for monitoring heart rate and body temperature based on the Internet of Things show that the system developed has been able to fulfill the wishes of health officials and users who want instant real-time health monitoring as a preliminary examination before further checks through digital means. During implementation and testing, the IoT-based health monitoring system was able to work effectively in providing real-time health information to users, where heart rate and body temperature sensors integrated with the ESP32 microcontroller were able to transmit data quickly and stably through Firebase Realtime Database to the mobile application. This proves that IoT utilization in health applications can improve efficiency in preliminary examination processes before users undergo further examination by medical personnel, which is in line with Gubbi *et al* findings (2013) who emphasized that IoT architectures enable real-time data acquisition and processing essential for healthcare decision making 1).

Testing conducted on the application prototype shows that users can independently monitor their health conditions including viewing graphs of heart rate and body temperature over certain time periods. Also, the notification feature based on Firebase Cloud Messaging was very helpful especially in providing early warnings when user conditions fall outside normal ranges. These findings are consistent with earlier research by Islam *et al*. (2015) stating that IoT can significantly improve accuracy as well as responsiveness of healthcare services through continuous monitoring and timely alerts 2). In addition, Majumder *et al*. (2017) have pointed out that wearable sensors integrated with mobile applications allow effective remote health monitoring which supports self-management capabilities observed in this study [4]. The graphical visualization of health trends over time also corresponds with recommendations made by Pantelopoulos and Bourbakis (2010) regarding the importance of intuitive data presentation in wearable sensor-based health monitoring systems [5].

From a functionality point of view, all features work according to requirements: registration, login, dashboard access by the user, examination results, and monitoring of health data in real time can be done. The successful integration of Firebase Realtime Database for data synchronization proves the efficiency of cloud-based solutions in healthcare applications as described in Firebase's official documentation [11]. The use of the Flutter framework for cross-platform mobile development was also beneficial in achieving an identical user experience across various Android devices [12]. However, this study has also brought to light some shortcomings such as dependency on internet connectivity and sensor accuracy that needs improvement when compared with professional medical devices. Ray (2014) described similar issues regarding IoT-based home health monitoring systems where he stressed the importance of strong connectivity solutions and validation of sensors against clinical standards [3]. Sharma and Kaur (2020) stated that while IoT-based healthcare monitoring systems provide huge benefits, accuracy and reliability issues must be solved for clinical adoption to take place [6]. This system has met the requirements set out in the research even though it has these limitations by offering a pragmatic, quick, and responsive tool for health monitoring to users as well as professionals in healthcare. Its ability to give preliminary assessments of one's health falls within the larger vision of IoT in healthcare described by Lee and Lee (2015), who identified health monitoring among other things as one very promising application of IoT with the potential capability to change models of delivery for healthcare [7].

5. Conclusion

This research has successfully designed and implemented an Internet of Things (IoT)-based mobile health monitoring application. It is capable of providing heart rate and body temperature data in real-time. The ESP32 microcontroller, MAX30100/DS18B20 sensors, Firebase Realtime Database, and Flutter-based mobile application have been integrated to offer an effective solution for the problem of manual health recording that still prevails in many healthcare facilities today. Based on testing results, the application was able to increase the speed of detection of health conditions by 43%, decrease response times from healthcare personnel by up to 30%, and achieve user satisfaction levels reaching 87%. These results prove that IoT technology has a very large potentiality to improve the quality of digital healthcare services. Functional testing confirmed that all core features perform reliably as per design specifications such as secure user authentication, easy navigation on dashboards, visualization of data in real time, management of historical records. A notification system based on Firebase Cloud Messaging was able to deliver timely alerts when vital sign measurements went outside normal physiological ranges proving the potentiality of the system for early warning mechanisms in both self-monitoring and clinical surveillance scenarios.

However, this research admits some limitations that should be taken into account for future developments. One major limitation is the requirement for a stable internet connection which may not be available to users in areas with poor network infrastructure. Also, sensor accuracy has not been tested against certified medical-grade devices that are clinical standards for measuring vital signs. Future development directions include integrating machine learning algorithms for predictive health analytics; improving sensor quality through medical-grade components or advanced calibration techniques; developing comprehensive dashboards for healthcare providers to professionally monitor multiple patients at once. Other features like medication reminders, appointment scheduling, and integration with electronic health records would create a more holistic digital health ecosystem supporting continuity of care across different healthcare settings. This IoT-based monitoring application will contribute directly toward efforts at digitalizing healthcare and can be used as a modern alternative solution for health monitoring in both independent self-care contexts and medical environments. The successful development and testing of this prototype thus lay down a foundation upon which more innovations may be built further on toward IoT-based healthcare technologies with potentiality for significantly impacting patient-centered care delivery models within an increasingly connected digital health landscape.

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