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Design a Mobile Application for the Maintenance of Hemodialysis Machines using Flutter Framework

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ABSTRACT

The hemodialysis machine is an artificial kidney facilitating the hemodialysis process and is considered a crucial life-sustaining device. Any delays resulting from malfunctions or improper maintenance of these machines can significantly impact the duration of dialysis for patients.

In Khartoum state, numerous highly skilled biomedical engineers are employed at dialysis centers, each with varying experience levels. However, the current training workshops provided to them are inadequate in ensuring proper maintenance of the machines. Many engineers struggle to address daily malfunctions and face challenges when referring to service manuals.

The recent proliferation of mobile applications has proven beneficial in several fields, particularly healthcare. This project will utilize a specific framework to develop a mobile application tailored to maintain hemodialysis machines. The app is designed to assist biomedical engineers in their daily tasks, particularly those in junior positions. By leveraging Flutter frameworks and the Dart language, a hybrid language capable of unifying code across Android, desktop, and iOS platforms, the "HDservice App" was created. This application offers detailed information on four common models of machine malfunctions in Sudan, along with corresponding solutions. Biomedical engineers have successfully integrated the app into their mobile devices, utilizing it for maintenance tasks. Subsequently, they conducted an evaluation comparing the app's effectiveness to that of traditional service manuals, yielding the desired outcome.

Keywords – *Hemodialysis machine, Maintenance, Mobile application, Flutter framework.*

INTRODUCTION

There are approximately 100 service engineers in Khartoum state, overseeing 1591 machines as reported in the latest inventory from the National Center of Kidney Diseases and Surgery in February 2023. This significant number of engineers managing a large quantity of machines, each with varying levels of experience ranging from 1 to 17 years, results in challenges related to supervision and training, particularly for junior engineers.

In the current landscape, mobile devices, such as smartphones and tablets, are prevalent among healthcare professionals, especially in light of the COVID-19 pandemic. Given the common occurrence of malfunctions in hemodialysis machines, there is an opportunity to consolidate maintenance procedures into a software package, such as a mobile app, to enhance the training program for engineers.

Hemodialysis Machine:

A dialysis machine works to filter a patient's blood. This process includes the removal of impurities and excess water.[1]

Hemodialysis machines have three basic functions:

1. Circulation of blood from the patient's access through the dialyzer and back to the access using a blood pump and a disposable tubing set.[2]
2. Preparation of dialysate from purified water and one or more concentrates and circulation of that dialysate through the dialyzer using a system that also controls the rate of fluid removal.[2]
3. Monitoring for any loss of integrity in either the blood or dialysate circuit or any excursion of an operating parameter outside a predefined range.[2]

Fault in Hemodialysis Machines:

Mechanical and electrical faults first cause faults in hemodialysis machines due to these five elements: pumps, power, transducers and sensors, pressure, and conductivity.[3]

And secondly, errors can arise from human error, such as misuse during operation or improper patient connection by nurses. These issues could be mitigated by ensuring that procedures are not initiated without full knowledge, particularly since they directly impact patient care. Biomedical engineers should also support nurses by offering comprehensive machine usage and maintenance training.

Furthermore, machine-related faults can also occur, underscoring the critical role of biomedical engineers in preventing risks associated with faulty or unchecked equipment. They must fulfill their responsibilities diligently and ensure that these machines remain operational for as long as possible during their duty cycles. As previously mentioned, their involvement in dialysis procedures and hemodialysis centers is crucial, with specific roles including:

1. Gain a comprehensive understanding of the operational mechanisms of hemodialysis equipment.[4]
2. Engage in the dialysis apparatus's operation, upkeep, repair, and sterilization.[5]
3. Take charge of ensuring the integrity of dialysis solutions, which involves overseeing electrolyte levels, osmotic pressure and conducting assessments for microbial/endotoxin presence.[5]
4. Participate in collaborative endeavors to enhance dialysis machinery and pioneer new treatment modalities with a proactive approach to disseminating findings through publications and conference presentations.[5]

Maintenance

Maintenance encompasses the activities undertaken to sustain equipment in its functional state, whether by averting its deterioration into a nonfunctional state or by restoring it to operation post-failure. This gives rise to a variety of maintenance practices that can be strategically planned to fulfill the maintenance goal, including preventive, predictive, or corrective measures.[6]

In hemodialysis facilities, to prolong the lifespan and efficiency of the machines, a focus on preventive maintenance is essential to reduce the frequency of corrective maintenance interventions.

Although disinfection procedures and decalcification are routinely conducted on weekends, the execution of corrective maintenance is lacking due to inadequate training programs, as highlighted in the identified issue.

Computerized Maintenance Management System (CMMS):

A CMMS is a sophisticated software solution that houses a comprehensive computer database containing vital information about an organization's maintenance operations. Within healthcare technology management, the CMMS serves as a tool for streamlining the documentation of all tasks associated with medical equipment, encompassing equipment scheduling, inventory supervision, corrective and preventative maintenance protocols, spare parts regulation, service agreements, and medical equipment notifications.[7]

Flutter Frameworks:

Reasons for Choosing Flutter Framework: Flutter is a cutting-edge application development framework developed by Google for building cross-platform mobile applications that can run on both iOS and Android operating systems. As detailed on the official website (https://flutter.io/), it was selected for its primary objective of simplifying, accelerating, and enhancing the development process.[8]

For end-users, programmers, and designers utilizing Flutter. Moreover, Flutter is a versatile programming language that enables the creation of a single codebase for Android, desktop, and iOS platforms. The preferred approach in this context involves leveraging the innovative Flutter framework with the Dart programming language.

THEORETICAL BACKGROUND

Mobile Applications in Healthcare:

Healthcare applications encompass various mobile apps designed to assist in various health-related tasks. These apps can range from lifestyle mHealth solutions such as fitness and meditation applications to more advanced products that heavily rely on technological advancements, like those created to aid medical professionals in diagnosing and addressing complex medical issues.[9]

In a recent publication, a comprehensive framework for a smart mobile Internet-of-Things (IoT) healthcare system was proposed to monitor patients' health risks using a smartphone and 5G technology.[10] Web and mobile applications were developed to cater to the needs of patients, doctors, laboratory analysis, and hospital services. This study used these applications to collect physiological data such as body temperature, pulse rate, and oxygen saturation levels. The physiological data were then processed using 5G technology, body sensors connected to Arduino boards, and Raspberry Pi boards.[10]

This innovative system provides real-time advice and alerts to doctors and medical assistants regarding changes in patients' vital signs and significant environmental changes. This enables medical professionals to take preventive measures swiftly, potentially saving lives in critical care and emergencies.[10]

Furthermore, mobile applications are sometimes utilized in telemedicine technologies, such as the mHealth applications operating in India as detailed in a recent study. These applications offer features like online doctor consultations or offline doctor appointment bookings, serving as an effective medium for doctor-patient communication and leading to notable enhancements in patients' health outcomes. The study involved a cross-sectional, observational, and web-based research approach.[11]

METHODOLOGY

Designing Questionnaires, Data Sorting, and Analysis

After data collection, the common issues and malfunctions identified from questionnaires and experiences with various machine types were analyzed. Subsequently, the data was categorized into four groups based on machine types, each encompassing all relevant data and malfunctions. These categories were then reviewed with the company's expert engineers to identify suitable solutions from manuals. The identified issues were then condensed and organized into four groups based on the occurrence timeline, from machine startup to disinfection before the next patient. This systematic arrangement facilitated sorting errors and the implementation of appropriate solutions, preparing them for inclusion in the codes.

Selecting the Appropriate Code Editor

Initially, the coding environment on the computer must be set up. The Android Studio and the Flutter framework were utilized as the code editor. Subsequently, the Flutter was integrated into the Android Studio, and the preferred Android version was selected; in this case, Android version 4.0.0 was chosen to ensure compatibility with devices possessing minimal specifications, thereby enabling widespread usage of the application. Constructing the Architecture of the Flutter Framework.

Constructing the Framework Architecture for Flutter

To construct a robust architecture, it is essential to incorporate a plugin for the Dart compiler, a separate plugin for code analysis, and yet another plugin for managing the Flutter developer workflow, encompassing tasks such as building, running, and debugging. These plugins can be seamlessly integrated within Android Studio for optimal efficiency.

Creating App Widgets

The user interface (UI) and widgets utilized in the design process were carefully crafted with a harmonious color scheme and intuitive interactive features to align with the primary project objectives. The diagram in Figure (1) below showcases the app's key buttons and navigation element illustrating how users will engage with the application.

Test Execution

The Dart language continuously self-evaluates the code to detect any errors before running the application. The final evaluation of the entire code and its structure is done through a specific function in the Android file named "test." This function verifies the integrity of the code even in the absence of errors.

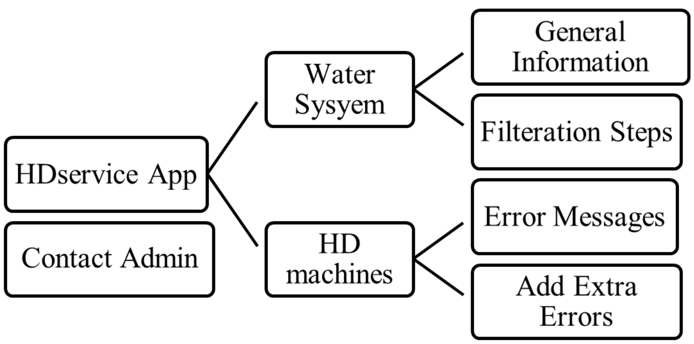

FIGURE 1. UI of the app.

Application Execution

Prior to launching the application, a virtual device emulator must be created on the laptop to preview the simulated app. Once everything appears satisfactory, the application is named "HDservice."

Creation of Application Icon

When developing any application, it is essential to have a unique logo that symbolizes the app's purpose. Once the logo is chosen, the image should be saved in PNG format using the website www.icongenerator.com.

APK Release

The final stage involves converting the application into APK format to make it accessible to a wider audience. The command "--release "generates two files that engineers can easily install on Android mobile devices to achieve the intended goal.

RESULTS AND DISCUSSION

The Data Obtained from the Questionnaire

The survey was completed by a cohort of 100 biomedical engineers, from which various data points were collected. These included the duration of training, ranging from one to six months, as well as the number of years of experience in the field of dialysis, as illustrated in Figure 2 below.

Moreover, the engineers encountered challenges in handling and interpreting service manuals due to several factors. To begin with, 71.1% expressed that insufficient training and workshops were provided. Additionally, 17.8% reported a lack of company engineers available for guidance and training, while 11.1% found the service manuals unclear and written in complex language.

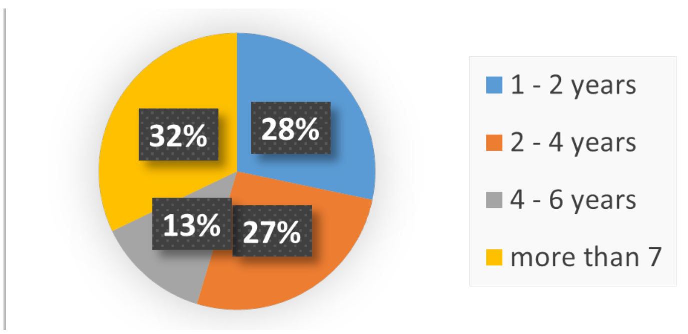

FIGURE 2. The years of experiences.

The second reason is related to the nature of the job itself. A total of 88.9% of respondents indicated no written guidelines for daily, weekly, and monthly maintenance, while 11.1% stated that such guidelines exist in their hospitals. In the event of new malfunctions, technicians typically follow a series of steps to address them, such as consulting service manuals, reaching out to colleagues, or contacting the company's engineers. The comparison between the current procedures performed and the ideal procedures as perceived by the technicians is illustrated in Figure 3 below.

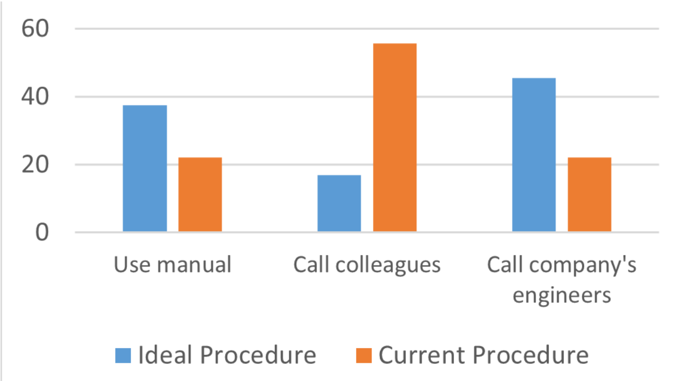

FIGURE 3. Comparison between procedures of fixing errors.

The disparity between the optimal solution and the current practice lies in the unavailability of the company's engineers due to their obligations with the vast hemodialysis centers and other responsibilities.

In line with the issue, the training workshops for engineers have proven insufficient to adequately equip them. Over the past five years, 68.2% have only attended 1–2 workshops, 25% have attended 3–4 workshops, and 6.8% have participated in more than 5 workshops.

The feasibility of the app concept was deliberated upon before its inception, with an overwhelming 89% expressing strong approval, while the remaining individuals exhibited varying degrees of disinterest.

The engineers anticipated that the app would serve as the ultimate solution during their work, with 64% endorsing this notion, marking a pivotal moment in the project's initiation.

The successful launch of the HDservice App has come to fruition.

Subsequent data will elucidate the culmination of the preceding chapter, showcasing the app post-launch to offer the desired solutions or information. Figure 4 illustrates the app's nomenclature and logo icon, epitomizing its purpose - the name conveys the provision of hemodialysis services, while the logo underscores the importance of maintaining the hemodialysis machine.

The subsequent figures will reveal the culmination of the previous chapter, displaying the app upon launch to provide the desired solution or information. Figure 4 showcases the app's name and logo icon, symbolizing the app's purpose - the name signifies the provision of hemodialysis services, while the logo conveys the importance of maintaining the hemodialysis machine.

FIGURE 4. The app's name and logo.

The application has been meticulously programmed and will continue to be enriched with new information through collaboration between my supervisor and me. It has been intricately coded to operate seamlessly offline, thus circumventing the prevalent network issues in Sudan. This design choice aims to enhance user experience for biomedical engineers, facilitating their search for errors. However, online connectivity is required for users to communicate with us, the developers, to report errors or suggest solutions for inclusion in the subsequent version. The following diagrams depict the application's process to troubleshoot and resolve various issues.

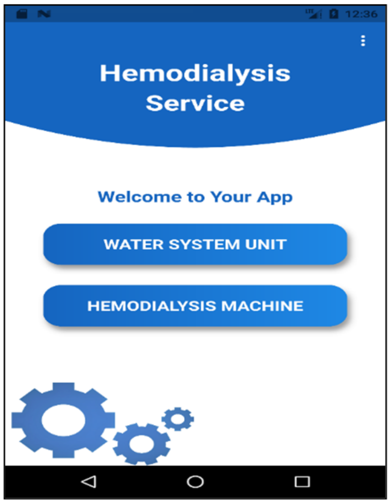

FIGURE 5. First app's screen.

The illustration depicted in Figure 5 displays the initial interface of the application, also known as the welcome screen. This screen features the app's title and a menu bar, which includes contact information as illustrated in Figure 6. The buttons in the center serve as a submenu that allows users to navigate to different screens within the app.

FIGURE 6. Contact information.

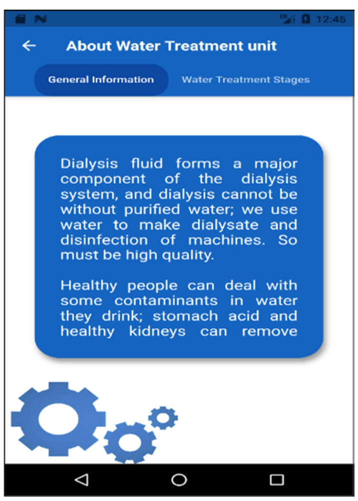

FIGURE 7. The section of water treatment unit.

The illustration above provides a comprehensive app overview and offers guidance on identifying and resolving issues. Subsequent illustrations will further elucidate this process.

For instance, if an error occurs in a BBraun machine during a self-test, the engineer must first double-click on the hemodialysis machine icon (Figure 6). Following this, the engineer should double-click the self-test button in Figure 8. Once the self-test button is double-clicked, the engineer will be directed to Figure 9 to locate the error message or code.

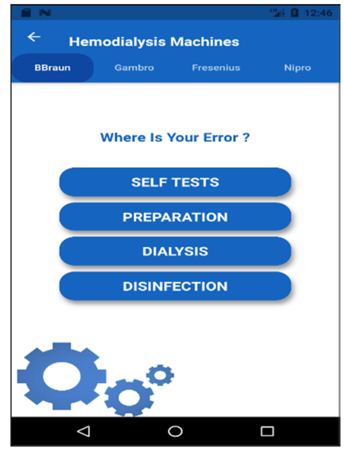

FIGURE 8. The section of HD machines.

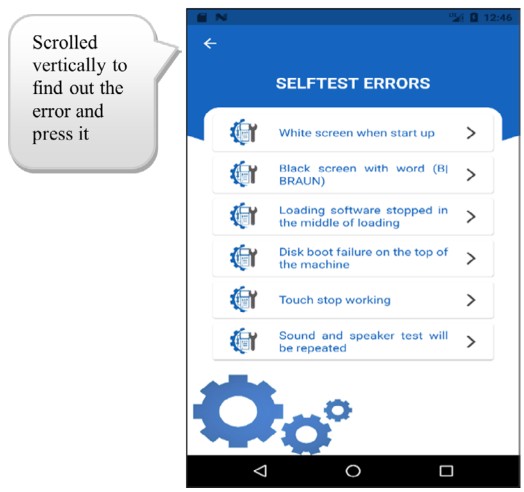

FIGURE 9. Scrolled list-view for self-test errors.

The diagram provided above displays all the errors detected during the self-test. The list-view widget was utilized to ensure that the errors can be displayed without any limitations in length, and can be expanded in the future. Each error message is represented as a widget known as a "card," which, when clicked, will navigate the user to the corresponding solution screen, as illustrated in the upcoming diagram. The solution screen depicted in Figure 10 below provides detailed explanations for why the error occurred and the potential causes behind it, this applies to all the other cards and machines as well.

FIGURE 10. The error's solution.

Assessment Feedback

Following the utilization of the application, we sought to gain a comprehensive understanding of its functionality, user satisfaction, and overall worthiness for further development. To achieve this, we conducted an online survey to assess user acceptance. The initial feedback revealed a strong acceptance rate of 89%, with the remaining responses varying between disapproval and moderate interest, as depicted in Figure 11 below. Respondents highlighted the app's user-friendly interface, which facilitated enhanced knowledge sharing and interaction between junior and senior users and provided valuable training on proper maintenance practices. This positive reception corroborated our objectives.

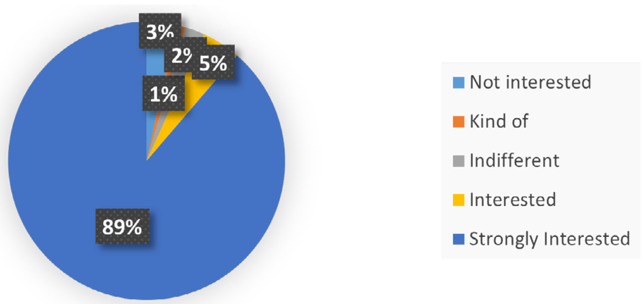

FIGURE 11. The acceptance of HDservice App.

Furthermore, the application underwent evaluation by a panel of engineers at the Military Hospital, including Eng. Salim Mohammed Musa, the chief engineer in Sudan and former technical representative of Gambro in Sudan, along with representatives from SAMASU Medical Company, the current technical agent of Gambro in Sudan.

CONCLUSIONS

The advancement of technology, particularly mobile applications in healthcare, is highlighted in this article. The mobile applications suggested here aim to offer extensive services to aid training programs and provide maintenance information for biomedical engineers regarding hemodialysis machines and water treatment systems. Using the Flutter framework to develop the app resulted in a user-friendly interface with a single code base for multiple platforms. The app's classes facilitated the easy addition of new information, serving as a foundation for knowledge sharing and experience exchange.

Employing the "HDservice app" for maintenance purposes enhances the expertise of biomedical engineers, enabling them to quickly identify the correct solutions without the need to consult colleagues. The app serves as a comprehensive guideline, akin to service manuals, thereby minimizing errors during maintenance procedures. Navigating through the app's interface to access information on different machines is swift, aiding in rapidly diagnosing malfunctions.

Furthermore, the app educates users on error solutions and fosters the sharing of experiences between seasoned engineers and novices. The authors will regularly update the app with new information based on user submissions, promoting continuous learning. The increasing integration of mobile applications in healthcare is anticipated, with this app serving as a pioneering platform for developing apps for other medical instruments.

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