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Original Article

Development of Mobile-based Health Monitoring and Disease Prediction System for Antenatal Care

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Abstract - This study presents the development and evaluation of mobile-based antenatal care support systems for rural pregnant women to enhance quick registrations, medical diagnosis, and consultation with healthcare professionals. The system was analysed and designed using an object-oriented methodology that ensures that different functionalities and requirements are adequately met. This helps to reduce complexity, identify appropriate design elements, and streamline software design. In addition, the user interface implementation was carried out using Java and Eclipse to enable seamless interaction among pregnant women and healthcare practitioners. The results of the evaluations of the system indicated that the system provides a platform for efficient registration, transmission of vital patient information, and quick decision-making by doctors and nurses. Furthermore, the system demonstrated its ability to remind pregnant women of antenatal days, educate them on healthy living during pregnancy, and monitor the vital signs of pregnant women. This facilitates healthcare staff to provide timely personalized medical services for pregnant women, improve the quality of pregnancy management, and improve delivery outcomes.

Keywords - Antenatal Care Systems, Mobile Application, Pregnancy Management, Software Development, Database Design.

1. Introduction

Recent studies have shown that people in rural areas are faced with many health challenges. Some of these health challenges include malaria, stroke, heart attack, cancer, hypertension, dementia among elderly populations, diabetes retinopathy, gestational diabetes, Parkinson's disease, etc. These health challenges have been intensified by irregular medical check-ups, lack of appropriate medical health facilities, and insufficient health information or health tips, low level of physical activities, physical abuse, etc. [1]. To reduce health challenges faced by rural dwellers, mobile-based public health information and disease prediction system applications have become important [2]. The use of mobile technology-based health applications offers excellent value for health awareness, health applications, and services, low maintenance cost, preventive care, self-monitoring, information on personal hygiene, real-time, and remote [3],[4],[5].

Despite the advantages of mobile-based systems, very few studies have attempted to develop a comprehensive and efficient mobile-based application or framework for health monitoring and disease prediction systems for antenatal care and disease prediction, especially in Nigeria. Most of the studies only develop mobile applications for antenatal care registration and management or software that enables pregnant women to get basic information [6],[7]. In addition, the problem of a lack of appropriate health information among pregnant women is more prevalent among people in rural communities, where hospitals and clinics, in most cases, have no personnel to provide such information for quick disease diagnosis and management. Moreover, the studies found in the literature were developed for the diagnosis of diseases and lack suitable features for comprehensive public health information and disease prediction. In addition, mobile-based health applications for disease prediction were mainly targeted for disease diagnosis and management of diseases in the public, excluding vulnerable individuals such as pregnant women. Largely, major issues faced by the generality of people, especially pregnant women, are how to effectively access health information or tips, especially in the event of antenatal and post-natal care, and predict the outbreak of common diseases associated with pregnancy, such as pre-term, gestational diabetes, and preeclampsia. In addition, the current system in most Nigerian antenatal clinics deploys the use of a paper-based management system to manage pregnant women's records.

These records are manually created, backed up, and generate reports by healthcare practitioners in the clinics [8]. On arrival, each pregnant woman is required to pay for booklets to record their biodata, which is then recorded in the main hospital booklet. The booklet is also used to record the obstetric history, examination progress, and any complications encountered during antenatal. The major issues with such an approach are the time-consuming nature, the costly nature, and the records are prone to errors [9]. Pregnant women's records are prone to misplacement, duplication, and human error. It also lacks security as there are no built-in versions, and it is difficult for clients to locate new changes or determine who makes changes to the patient records [6]. Recent studies have shown the importance of mobile-based applications for the management of maternal health and infant well-being. This study aims to improve the

recent implementation of mobile-based applications for pregnancy complication management [10]. Maternal health-based mobile applications help to reduce maternal and infant deaths in rural areas by enabling efficient communication between rural healthcare providers and pregnant women.

In addition, mobile applications enable pregnant women to register for antenatal care through their mobile phone, and the systems connect them with healthcare professionals and other health services to avoid delays [11]. Moreover, the system will enable pregnant women to perform a variety of tasks, minimize complications such as booking an appointment, receiving an appointment date, and receiving notifications on follow-up visitation dates. With the appropriate registration, the proposed system enables pregnant women to track health indicators such as weight, blood pressure, heart rate, blood sugar, and other healthcare parameters for both mother and fetus to minimize the maternal mortality rate among Nigerian women [12]. The development of mobile health monitoring systems, especially for pregnant women, has revolutionized the maternal and fetal health outcomes, enabling access for women to manage their pregnancies and for healthcare providers to provide timely interventions. The timely interventions provide access to care, maternal education and empowerment, personalized health monitoring and risk assessment, promote fetal health, improve access to healthcare providers, and address healthcare inequalities, especially in rural areas [13].

In this paper, a mobile-based health monitoring system (MHMS) is implemented for antenatal care support for pregnant women. The mobile application includes quick registration of pregnant women in rural hospitals/clinics, collection of vital signs, access to medical history, identification of pregnancy-related illness and symptoms, and recording of physical examination by healthcare practitioners. Furthermore, the mobile application provides an avenue for the education of pregnant women on healthy living during pregnancy and a dashboard for analysis of health details. The remaining sections of the paper are as follows: Section 2 presents the methodology, Section 3 discusses the results of the implementation, and Section 4 outlines the evaluations of the system. section 5 concludes the paper.

2. Methodology

This section discusses the software methodology deployed for the implementation of the mobile-based antenatal care support systems. The system was designed and developed using object-oriented analysis and design methodology. The methodology standardizes the mobile application model and produces high-quality software that justifies the expectations of users and provides the needed support. object-oriented analysis applies object-modelling approaches to analyse the functional requirements of a system. It focuses on what the system does. Object-Oriented Analysis (OOA) looks at the problem domain to produce a conceptual model of the information that exists in the area being studied. The outcome of the OOA is a description of what the system functionality is required to do, in the form of a conceptual model. The different UML tools were utilised to model the proposed system. These include a set of use cases, an activity diagram, a sequence diagram, an entity relationship diagram (ERD), and a class diagram [14].

The methodology facilitates users to express their views on using the system from which the researcher derived the requirements of the system. It uses a formal and methodical approach to analyze and design mobile application systems. It creates a conceptual model of the object to develop and supports scalable and reliable, and robust software. The mobile applications involve the registration, quick check, collection of pregnant women's health and previous medical history, identification of frequent pregnant symptoms, remotely collect and access laboratory test information, capture information of healthcare practitioners, and provide healthy tips to pregnant women. To prove the graphical visualization of the system, we utilized Unified Modeling Language (UML). UML models the system using tools such as case diagram, class diagram, activity diagram, and sequence diagram, as explained in the next subsections.

2.1. Existing System for Antenatal Care

Recent studies have shown that people in rural areas are faced with many health challenges. Some of these health challenges include malaria, stroke, heart attack, cancer, hypertension, dementia among elderly populations, diabetes retinopathy, Parkinson's disease, etc., which have been intensified by irregular medical check-ups, lack of appropriate medical health facilities, and insufficient health information or health tips, low level of physical activities, physical abuse, etc. [1]. To resolve the problem, researchers have started to develop various mobile applications that offer excellent value for health awareness with low maintenance. These mobile applications enable pregnant women to register for antenatal care, consult with doctors, update their medical history, and undergo medical tests that are transmitted to healthcare professionals for care and feedback [10]. Figure 1 shows the diagram of existing mobile applications for the antenatal care system.

2.2. Proposed Antenatal Care Support System

The diagram of the proposed mobile application for the antenatal care support system is shown in Figure 2. The diagram is made up of system administrator, user profile registration, quick check, medical history, symptoms and follow-ups, physical examination, medical laboratory test, medical officers' registration, health information, and pregnancy delivery complications. The antenatal care system is also composed of data analysis and a disease prediction system. The module provides a brief analysis of the details in the hospitals. The module will enable hospital administrators to analyze data collected for decision-making. The data analysis and disease prediction system consists of data collection, data transmission and integration, data pre-processing and cleaning, and feature extraction. Other components include disease prediction modeling and performance evaluation. The data generated from pregnant women using the mobile application is sent to the hospital via the mobile application interface, where they are accessed

through the database. Then, healthcare practitioners study the data for decision-making. The architecture is the proposed system is shown in Figure 2.

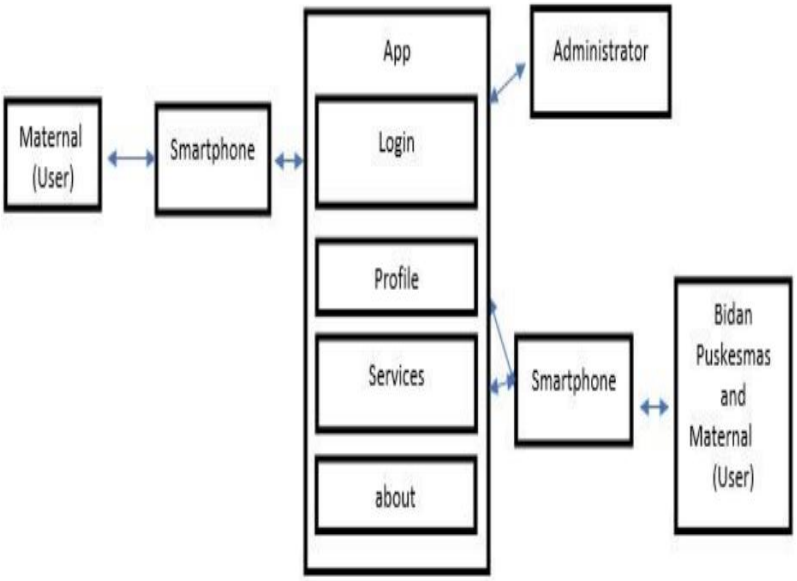

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Figure 1. Architecture of the Existing System [10]

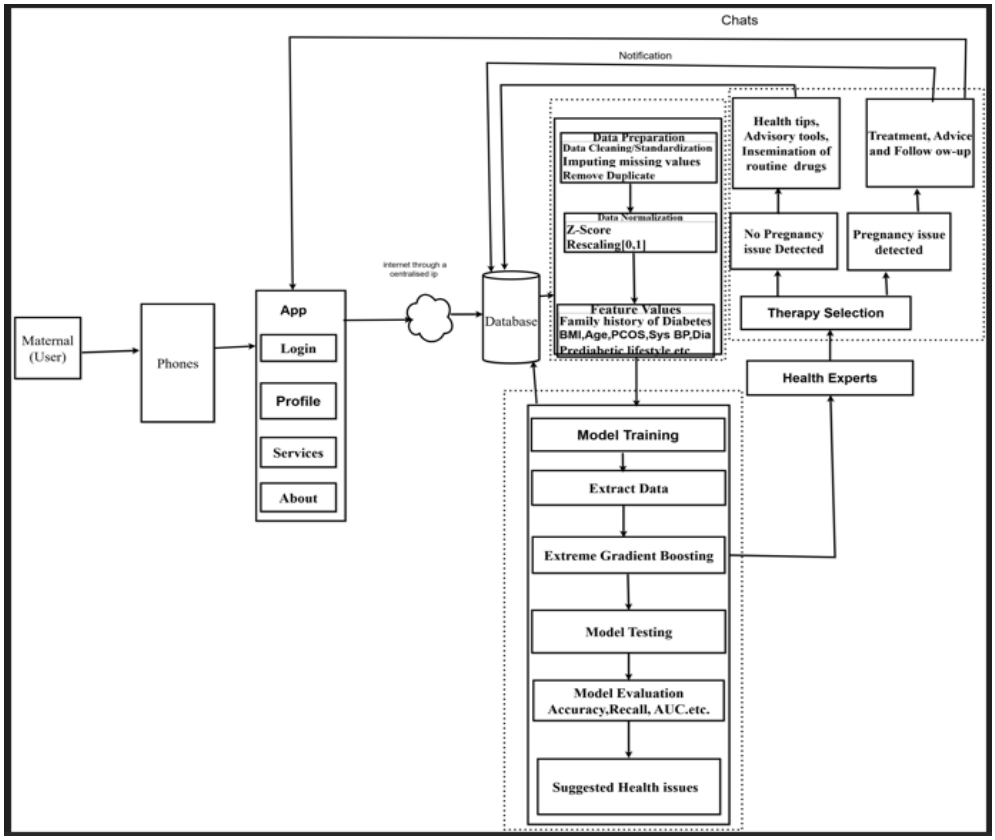

Figure 2. Architecture of the Mobile-Based Antenatal Care System

2.3. System Modeling

The mobile application for the antenatal care support system was modelled using various tools such as use cases, activities, classes, and sequence diagrams, as explained in the subsections.

2.3.1. User Case Diagram

A use case diagram is an important system design tool used to explain in detail the key elements of the system. It depicts the proposed system's expected functional requirements. The use case defines the process diagram that defines the roles of each user/actor of the system. With the use case diagram, we specify the sequence of interactions that an actor makes with the system for some specific purpose. Moreover, it connects the system users using association relationships. The different actors of the system include the hospital administrator, pregnant women, and doctors and nurses. Figure 3 depicts the use case diagram of the hospital administrator.

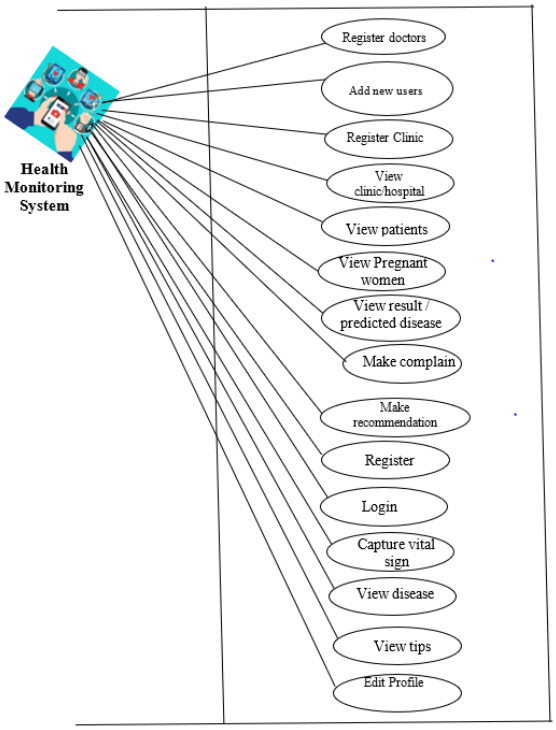

Figure 3. Use Case Diagram of the Hospital Administrator Module.

- *Hospital administrator*: He/she creates and manages various activities such as doctors, predicting diseases, adding modules and submodules, and tips. It grants access to the required number of users.
- *Pregnant women*: register their details using mobile phones, view their medical history, and tests carried out in the hospital or medical posts by doctors
- *Doctors and Nurses*: These are the staff of the hospital who manage the pregnant women. They view medical history, manage pregnant women, make recommendations, advise pregnant women on dos and don'ts during pregnancy, specify the mode of delivery, and analyze medical data.

2.3.2. Activity Diagram

The activity diagram represents the workflow of the mobile-based antenatal care support system and various actions performed in the system. These activities are conducted in parallel or preferred paths through the flow. In the proposed system, the activity diagram specifies all the steps that the users would take to use the mobile-based health monitoring and prediction system for antenatal. The activity diagram is represented in Figure 4, and the steps involved are outlined below.

- Pregnant women initiate registration through the mobile app.
- The system can display the list of registered users.
- The system admin verifies the registered pregnant woman by comparing the record with the one in the application form. A record can be incomplete if invalid records are detected, a report can be generated, the user is notified, and the record can be updated.
- The system identifies symptoms and follow-ups on physiological signals to accurately detect complications.
- Verify if a woman who visits the health facility is pregnant.
- Collect and store all the data collected from the pregnant women's medical history, physiological signal, biodata, laboratory test results, and physical examination into the database for easy retrieval.
- Provide healthy tips to pregnant women on eating habits, exercises, and avoiding harmful practices.

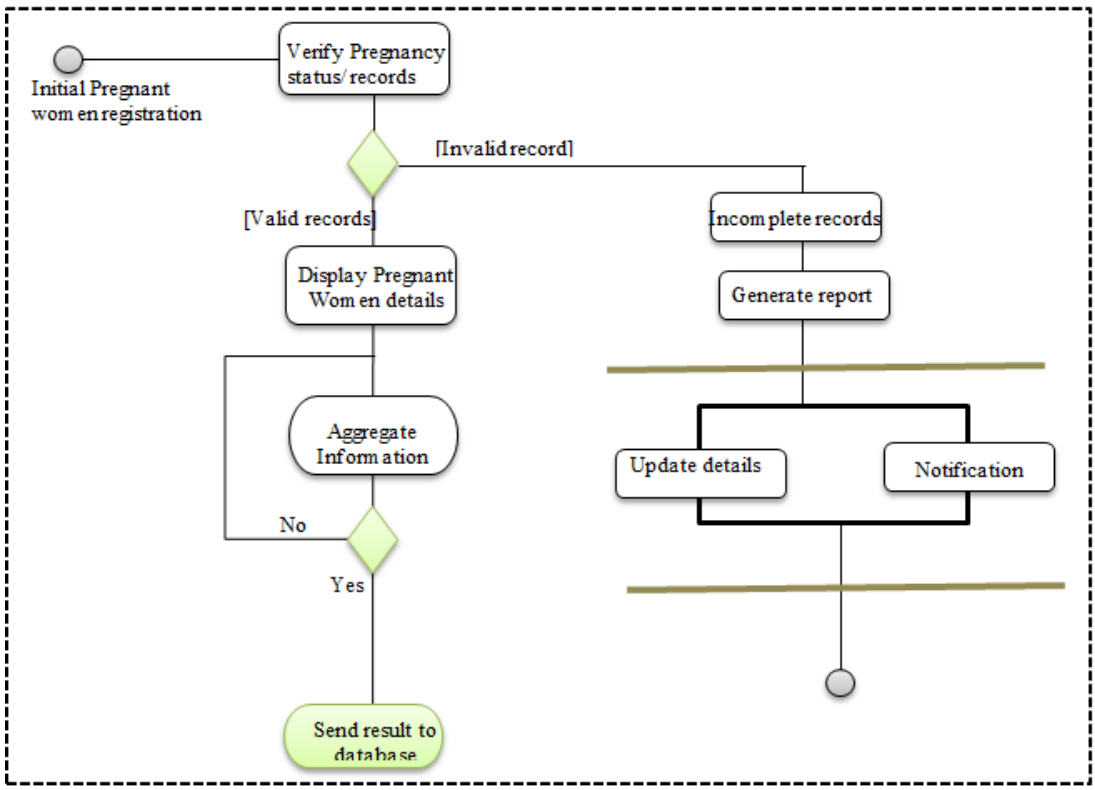

Figure 4. Activity Diagram of the Mobile-Based Antenatal Care Support System

2.3.3. Class Model Diagram

The Unified Modeling Language (UML) depicts the system's structural flow, considering various operations in the proposed mobile-based health monitoring and disease prediction system for antenatal care. The class model is shown in Figure 5, and contains various classes which include the pregnant women registration, login, and logout, quick check, medical history and demographic information, symptoms and Follow-up, Physical examination, doctors and nurse registration, clinic profiles, pregnant women medical records, clinical dashboard, and prediction details. The pregnant woman's record has multiple details associated with doctors, nurses, and the health facilities. The pregnant women go to the hospital, registers, meets with the doctors, conducts laboratory tests, and capture vital signs. The steps involve are outlined below while Figure 4 shows the class model diagram.

- Registration of health administrators, pregnant women, doctors, nurses, and other health practitioners' details;
- Verification of details and confirmation of pregnancy status;
- Consultation by doctors
- Checking and monitoring of vital signs;
- Conducting necessary medical laboratory tests;
- Physical examination of the expectant mothers;

2.3.4. Sequence Diagram

The sequence diagram depicts and visualizes the interaction between different objects in sequence. It shows how objects in the modeling communicate with each other. The diagram illustrates message flow and sequential object operation, making it an important tool for software design. In the implementation of the proposed mobile-based health monitoring and disease prediction system for antenatal care, the sequence diagram illustrates how the pregnant women, healthcare workers, and hospital administrators interact and message within the system. The objects in the sequence diagram include pregnant women, medical history, medical laboratory test, physical examination, vital signs, and access to pregnant women's records. The communication flow of the module sequence is shown in Figure 6. The communication flows include pregnant women registering for antenatal care and confirming if the women are pregnant or not. After the recommendation, the pregnant women take the recommended test and biodata information, which are recorded for medical decision-making by healthcare professionals.

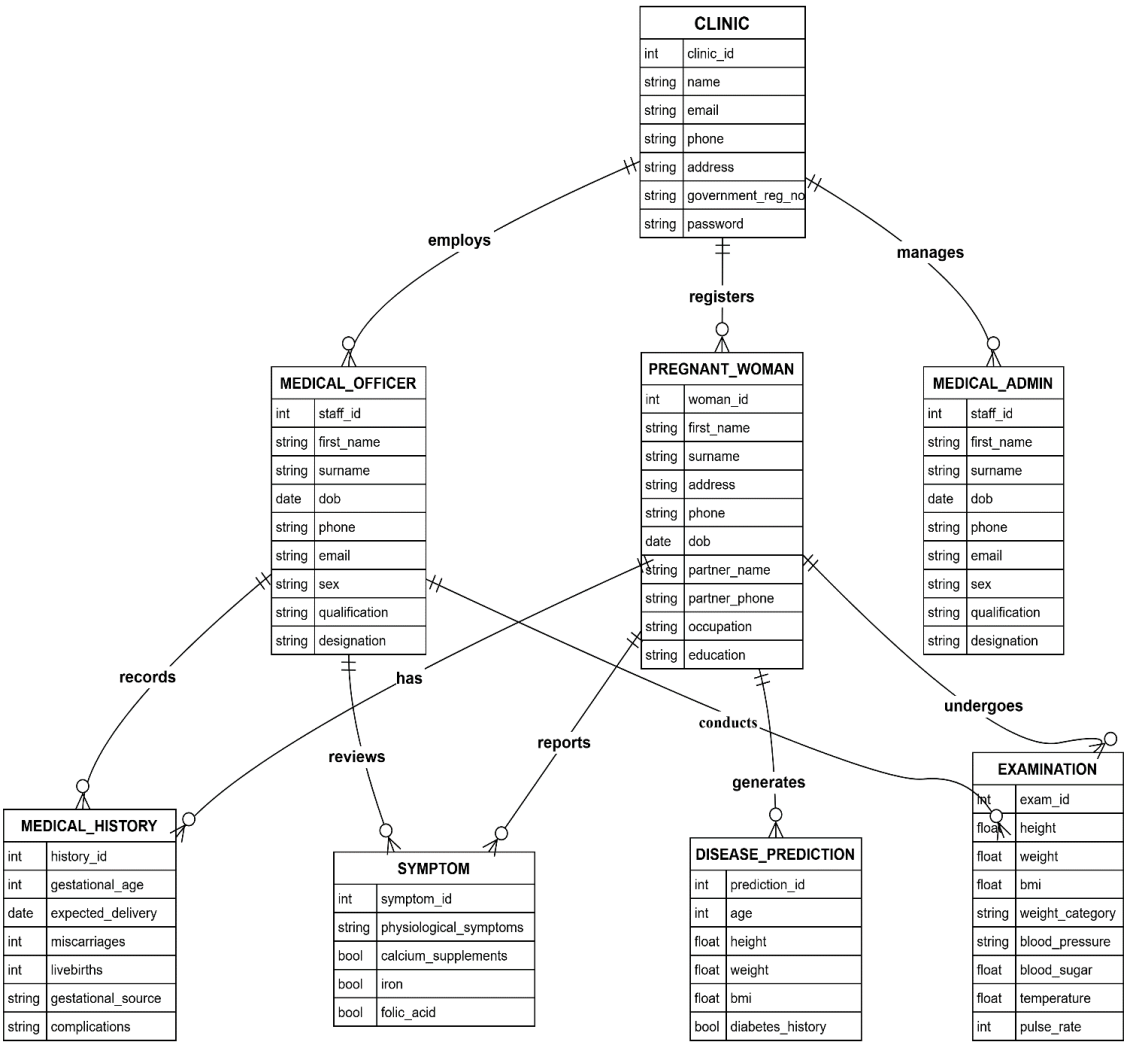

Figure 5. Class Model Diagram Of The System.

2.3.5 Database Implementation

The system was designed using MongoDB and the MySQL database system. The system contains multiple tables with different specifications as outlined below. The tables include login, pregnant women, clinical registration, medical history, pregnant women's symptoms, physical examination, and medical officers.

- Log in Table: Contains login details of registered users
- Pregnant Women table: This database table contains patients' details
- Clinic Registration table: This database table contains the details of the clinic where the pregnant woman registered.
- Medical History table: This database contains previous and current medical history.
- Pregnant women Symptom table: This database table comprises of different medication intake and side effects.
- Physical Examination: This database table comprises different medication intake and side effects.
- Medical officers table: This database table contains the doctor's details.

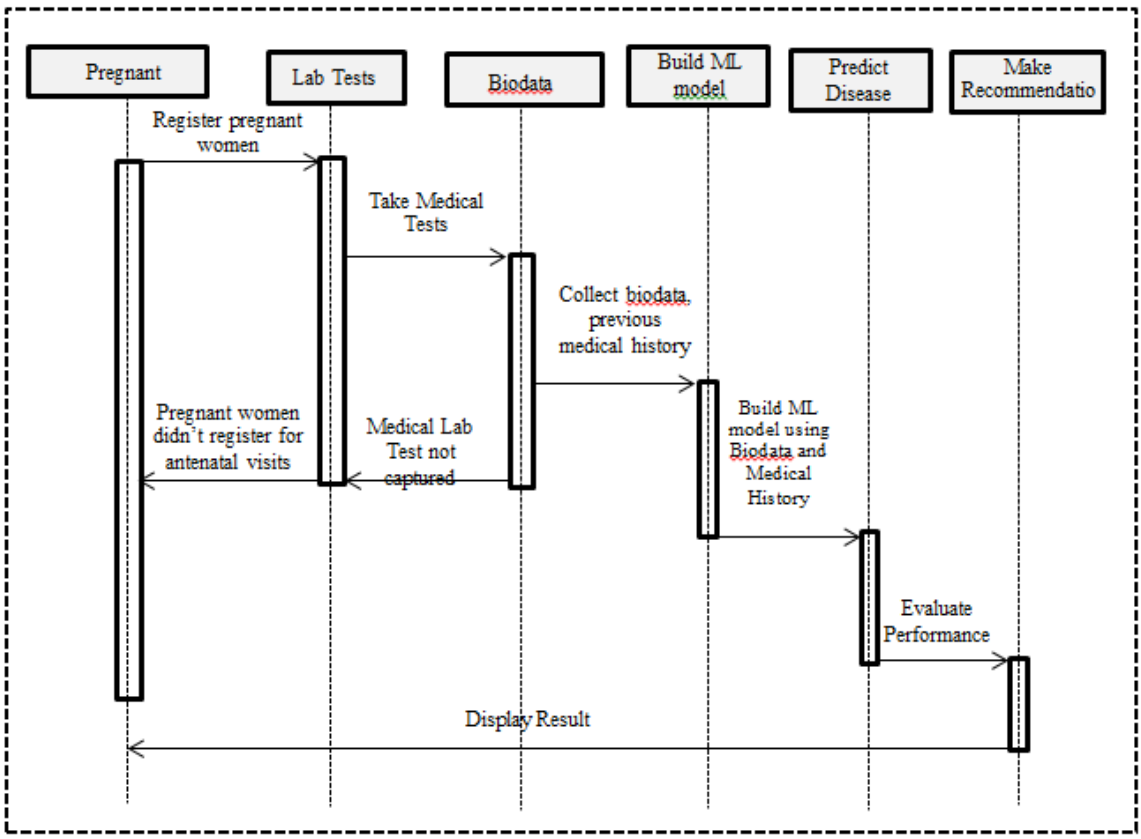

Figure 6. Sequence Diagram For Pregnant Women's Health Monitoring And Disease Prediction

3. Results and Discussion

This section describes the sample outputs design generated by the mobile-based health monitoring and disease prediction system for antenatal care. These include the clinic dashboard, Pregnant women's medical records, clinical profiles, onboard screen, daily tips, and full tips. The outputs are illustrated in Figures 7 to 10.

- **Clinic Dashboard**: The clinic dashboard provides a brief analysis of the hospital activities to enable administration to take appropriate decisions. The clinic dashboard is shown in Figure 7.

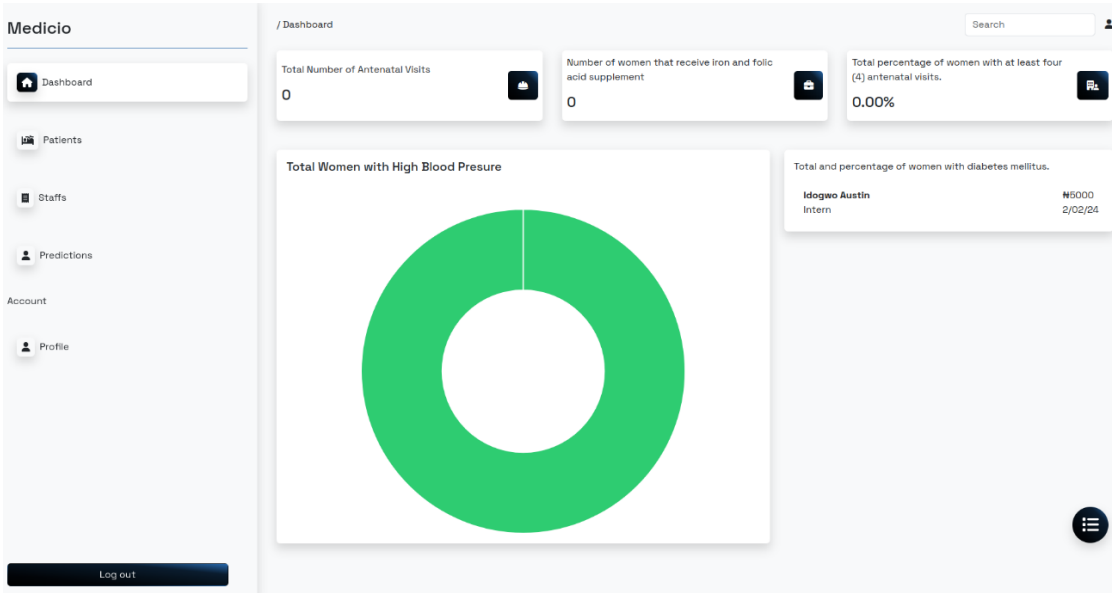

Figure 7. Clinic Dashboard

- **Registered Pregnant women**: this shows the samples of the report generated after registrations of pregnant women. The report is shown in Figure 8.

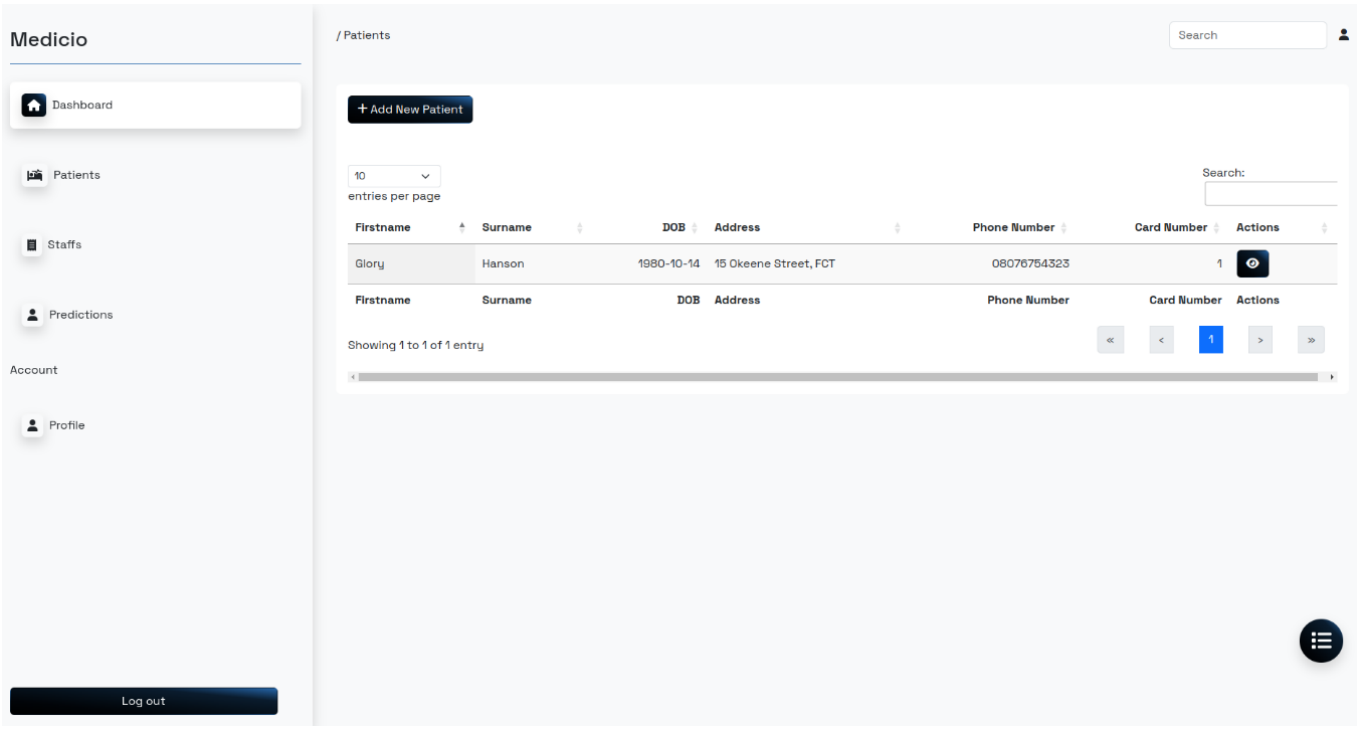

Figure 8. Registered Pregnant Women's Details

- **Clinic/Hospital Profile**: This provides the profile details of the registered clinic in the system. The profile is as shown in Figure 9.

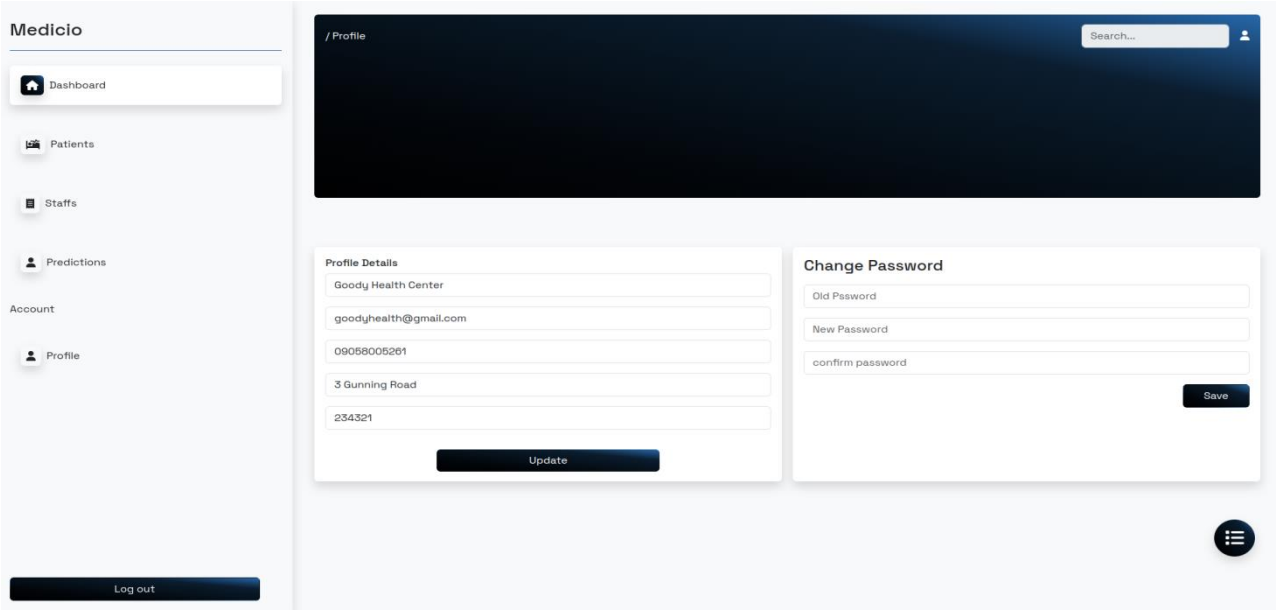

Figure 9. Clinic/hospital profile

- **Daily Tips**: The output provides daily tips on exercise, hospital visitation, and medical care for pregnant women. The output is depicted in Figure 10.

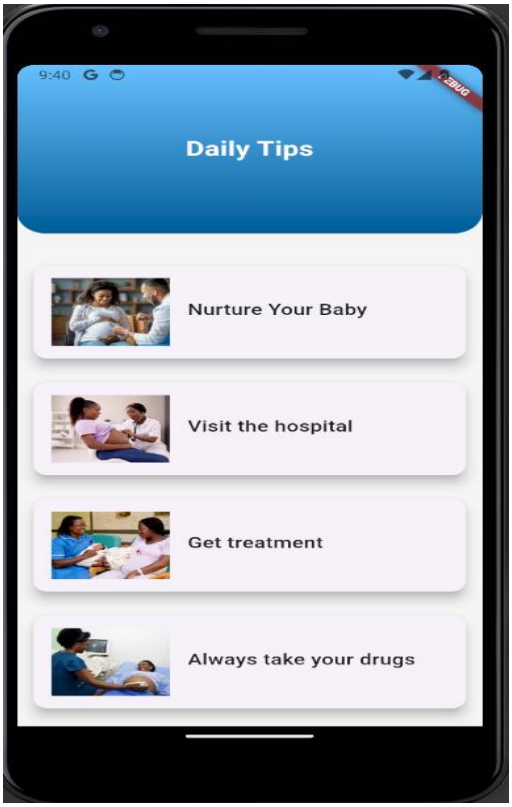

Figure 10. Tips On Pregnancy

4. Application Testing and Validation

System testing is the evaluation of the designed system to achieve the specification requirements. System testing is done with full system implementation and environment. In this system testing, tests have been done on both Windows 10 and Windows 11 operating systems, and it functions effectively. The modules of the mobile applications were tested on raw data to ensure that they perform as expected. The module, such as registration of pregnant women, can register the women's bio-data. In addition, the individual modules, such as the system home page, user login, registration of medical officers, and medical history, were integrated and tested for the overall performance of the system. Table 1 shows the different modules with expected and actual test results.

Table 1. Evaluation of the Mobile-Based Antenatal Care Support System

Module	Expected Test Result	Actual Test Result
New system	Expected to design a system that could handle pregnant women registration, handle antenatal visits, consultations, and collect medical history	A system was designed that could handle pregnant women registration, handle antenatal visits, consultations, and collect medical history
Create dashboard	Expected to create a dashboard to display the number of antenatal visits, total visits per pregnant woman, etc.	The dashboard created was able to display the number of antenatal visits, the total number of pregnant women, biodata, etc.
Predict gestational diabetes mellitus	The system is expected to predict gestational diabetes mellitus using medical history and biodata of pregnant women	The system predicted gestational diabetes mellitus and other pregnancy complications using medical history, biodata, and machine learning algorithms.

After testing to ensure every module of the system is working, the conversion approach was implemented. Various conversion approach was tested and include direct conversion, parallel conversion, and phase conversion. In the direct conversion process, the manual file system used in recording details of pregnant women at the clinics/hospital was completely replaced by the new mobile-based antenatal care support system within a day or holiday period. Also, the implementation considered the parallel and phase changeover that enables manual and developed systems to be deployed in parts or as a complete system. After the conversion and deployment of the system, the installation process required several technical steps, including server setup, extraction of necessary files, and initiating backend services using command-line tools like *npm*. After installation, users of the system, such as pregnant women and healthcare professionals, were trained on the functionalities of the developed mobile application. All stakeholders, such as doctors, hospital staff, and pregnant women, were given training sessions supported with manuals

and user guides. Security training was emphasized to prevent data breaches. For broader accessibility, online tutorials and live support were made available to assist users in navigating the application independently, fostering digital literacy and system confidence among the user community

5. Conclusion

In this paper, the description, development, and implementation of a mobile-based antenatal care support system are presented. The paper aims to design and implement a mobile application that enables pregnant women to register and receive healthcare services using their mobile phone to ensure prompt medical attention during pregnancy. The integration utilized important technologies such as mobile technologies and personalized medicine to support pregnant women and doctors to develop a real-time pregnancy complications and antenatal care support system. The mobile application was designed using object-oriented and software design methodology that uses rapid application development to develop software packages. With the software methodology, the functional requirements of the system were analysed and modelled using Unified Modeling Language. In addition, the software design approach enables users to express their views while using the software and suggest specification modifications before the final implementation of the mobile applications. After the implementation, the mobile applications enable continuous collection of user information to ensure health status checks, pregnancy complication monitoring, and registration of previous medical history. In future work, we will aim to develop an onboard implementation of a disease prediction system on mobile devices to reduce pregnancy-related complications.

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