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Liver Disease Detection System Using Random Forest Algorithm

Dr.Naveed Ahmad
Assistant Professor, Faculty of Engineering & Computing, National University of Modern Languages, Islamabad, Pakistan
Email : nahmed@numl.edu.pk

Fida Muhammad Khan
Director NAB, Islamabad, Pakistan
Email : fidausmani@gmail.com

Muhammad Bilal Arshad
Student Faculty of Engineering & Computing, National University of Modern Languages, Islamabad, Pakistan

Hassan Mohi Ud Din
Student Faculty of Engineering & Computing, National University of Modern Languages, Islamabad, Pakistan

Ahmer Aziz
Student Faculty of Engineering & Computing, National University of Modern Languages, Islamabad, Pakistan

ABSTRACT

Liver diseases are a major global health concern, often progressing silently until advanced stages that require critical intervention. However, traditional diagnostic procedures can be costly, invasive, and time-consuming, limiting early detection and effective management. The Liver Disease Prediction System addresses this challenge by offering an AI-powered mobile application that predicts the risk of liver disease based on clinical data. Utilizing the Random Forest algorithm, the system analyzes user-inputted medical data to deliver fast and accurate predictions. It further enhances patient care through automated report generation, personalized health recommendations, and integrated telemedicine consultations. The application is developed using modern technologies such as Flutter, Firebase, and Python, ensuring secure data handling and cross-platform accessibility. Comprehensive testing, including black-box and white-box methods, confirms system reliability and usability. Feedback from medical professionals was incorporated to refine functionality and user experience. The system enables early liver disease screening, improves patient-provider interaction, and promotes proactive liver health management.

Keywords: Liver DiseaseDetection, Medical Imaging, Random Forest Agorithm(RF), LFT Scan Analysis, Automated Diagnosis, Patient Health Monitoring, AI-based Medical Diagnosis, KM based processing

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1. Introduction

Liver diseases are a leading cause of global mortality, contributing to over 2 million deaths annually and affecting millions more through chronic conditions such as hepatitis, cirrhosis, and fatty liver disease. Early detection remains critical, yet conventional diagnostic methods—often involving invasive procedures and costly tests—are time-intensive and not readily accessible to all populations. These limitations delay timely interventions and place significant strain on healthcare resources[11].

To address this challenge, our project presents a smart mobile application designed to transform the early detection and management of liver diseases. [1].This solution extends beyond basic prediction by incorporating a full suite of healthcare features tailored to both patients and clinicians. The application utilizes machine learning—specifically the Random Forest algorithm—to analyze user-provided medical data and deliver accurate, real-time liver disease predictions[12].

Alongside predictive capabilities, the system includes automated report generation for clear diagnostic summaries, a telemedicine module for direct doctor-patient interaction, and a user-friendly interface for entering and managing health data. This integrated platform empowers patients to take proactive steps toward liver health while enabling healthcare providers to offer more timely and informed care. The aim is to streamline diagnosis, enhance accessibility, and promote early intervention—ultimately improving patient outcomes and advancing digital innovation in healthcare.

1.1. Problem Statement

The global burden of liver diseases represents a critical healthcare challenge, with millions affected by conditions such as hepatitis, cirrhosis, and fatty liver. Early diagnosis is essential but often hindered by reliance on traditional diagnostic methods that are invasive, time-consuming, and dependent on specialized medical personnel. [2].These limitations can lead to delays in diagnosis, inconsistent accuracy, and reduced access—particularly in underserved or remote areas.

Moreover, patient management following diagnosis remains fragmented. Existing systems often lack integrated tools for monitoring liver health over time, reducing patient engagement and continuity of care. In addition, communication between patients and healthcare professionals is frequently limited to in-person consultations, which can delay timely medical advice and treatment adjustments[13].

Our project aims to overcome these barriers by introducing a mobile-based solution that harnesses the power of machine learning for accurate and rapid liver disease prediction. [3].The application combines predictive analytics with features such as automated report generation, personalized health insights, secure telemedicine consultations, and user-friendly interfaces for symptom tracking and data input. [4,5].This approach ensures a comprehensive, accessible, and proactive system for both patients and healthcare providers, ultimately enhancing early detection and improving long-term liver health outcomes.

1.2. Objective

Our main objective is to develop a Smart Liver Disease Prediction system with integrated healthcare features. Our primary focus is creating a mobile application that allows the user to input their clinical data to determine the likelihood of liver disease, also generating a report providing details about the risk level and contributing health indicators. [6,9].Our system also features a communication module enabling direct interaction between the user and the liver specialist. The system also includes a unified alert and symptom tracking module for assisting the user in managing their health effectively.

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The development extends to a mobile application created for liver specialists, with an efficient and fast prediction and report generation module. The system also includes a patient history module, enabling doctors to easily track and access the patients' previous medical history. Our system's primary objective is to efficiently and accurately predict liver disease risk, enabling early diagnosis and assisting patients, without requiring multiple visits to the hospital.

1.3. Developed System

The system combines **machine learning** with **telemedicine** in a mobile health platform. Key components:

1.3.1User Interface (UI)

Cross-platform mobile app with intuitive data entry (sliders, dropdowns) for **demographic and lab values** (e.g., bilirubin, enzymes).

1.3.2.Authentication Module

Secure login for **patients and clinicians** to ensure data privacy.

1.3.3.Prediction Engine (Random Forest Model)

Analyzes inputs and outputs a **liver disease risk score**.
Chosen for **robustness and interpretability** on clinical data.

1.3.4.Report Generation Module

Creates a **PDF report** with risk likelihood, contributing factors, and health recommendations.

1.3.5.Telemedicine Module

Enables **virtual consultations** with hepatologists.

1.3.6. Data Flow Diagram

User Input → Prediction Engine → Report → Telemedicine.)

2. Related Work

This chapter examines existing studies and tools for liver disease prediction, focusing on their methodologies, limitations, and how our system addresses unmet needs in clinical practice. While machine learning has been widely applied to liver disease diagnosis, most solutions lack **end-to-end integration** of predictive analytics with patient management tools.

2.1. Existing studies.

2.2.1 ML-Based Liver Disease Detection

Several studies have applied machine learning algorithms like Random Forest, SVM, and Logistic Regression to predict liver diseases using clinical data such as enzyme levels and bilirubin. Among these, Random Forest has shown high accuracy and reliability.

2.3. Comparison between the Existing Studies and the Developed System

The comparison table in Table 2.2 highlights the Liver Disease Prediction System's strengths, including accurate predictions, real-time recommendations, a user-friendly mobile application, and telemedicine integration, distinguishing it from existing systems focused on cardiovascular or diabetes management. It emphasizes the proposed system's unique focus on liver diseases and its ability to generate comprehensive reports for proactive healthcare management. [18,10].

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Table 2.1 Comparative Analysis

Sr.	Criteria	Cardiovascular Disease Systems	Diabetes Management Apps	Proposed System
1	Accurate Disease Prediction	✓ YES	✓ YES	✓ YES
2	Mobile Application Integration	✓ YES	✓ YES	✓ YES
3	User-Friendly Interface	✗ NO	✓ YES	✓ YES
4	Real-Time Recommendations	✗ NO	✓ YES	✓ YES
5	Focus on Liver Diseases	✗ NO	✗ NO	✓ YES
6	Telemedicine Consultation	✗ NO	✗ NO	✓ YES
7	Comprehensive Report Generation	✗ NO	✗ NO	✓ YES
8	Continuous Algorithm Updates	✗ NO	✓ YES	✓ YES

3. Methodology

3.1. Incremental Development Approach

The methodology chosen for this system is the “Incremental Model” as it is best suited for effectively developing such a system with various feature sets. Figure 3.1 illustrates the Incremental Process Model.

We have used an incremental model for this system for the following reasons:

● Allows to accommodate changes with ease, making the system flexible and capable of evolving.

● Allows parallel deployment and testing of different increments, leading to efficient and fast development.

● Includes early and continuous user feedback which ensures that the system is according to the user’s requirements, leading to the identification and resolution of issues and enhancing the functionality of the system.

● Provides a well-organized framework for project management, making it easier to plan, monitor and control development.

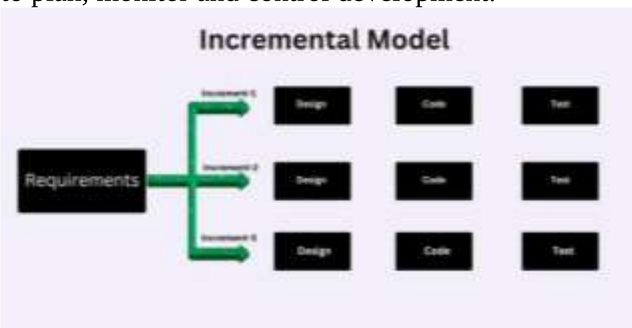

Figure 3.1 Incremental Model

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3.2 Application Development

The Liver Disease Prediction System is a **cross-platform solution** comprising a mobile application for patients and a web interface for clinicians. Built with modern technologies, it ensures **scalability**, **real-time processing**, and **secure data handling**, mirroring the seamless interaction framework of systems.

3.2.1 Front end Development

- Mobile app (Android/iOS)
- Designed using **Flutter** or **Figma (for UI mockups)**

3.2.2 Back End Development

- The backend uses Python (Flask/FastAPI) to process patient input and generate liver disease predictions using a trained ML model. It provides RESTful APIs for prediction, doctor listings, and securely manages patient data.
- Firebase provides backend services, including:
  - Firebase Authentication for secure login and user management.
  - Firebase Firestore for real-time database management and patient records.
  - Firebase Cloud Storage for storing and processing LFT images.

3.2.3 Database Management System

Firebase Firestore is used as the database to store user records, medical history, and chat interactions.

3.3. AI Model for Liver Disease Detection

The AI model for the Liver Disease Prediction System is a supervised machine learning model (e.g., Logistic Regression, Random Forest, or Neural Network) trained on patient medical data to predict the risk of liver disease. It analyzes features like age, bilirubin levels, liver enzymes, and protein levels to output a risk classification (e.g., high or low).[1,11]

3.3.1 Image Preprocessing

Before feeding patient data into the AI model, the following preprocessing steps were applied:

- **Missing Value Handling:** Patient records with incomplete data were either removed or missing values were imputed to ensure model accuracy.
- **Data Normalization:** Input features such as bilirubin, enzyme levels, and proteins were normalized to bring all values to a similar scale for better model performance.
- **Feature Selection:** Relevant medical indicators strongly correlated with liver disease were selected to enhance prediction accuracy and reduce noise.

3.3.2 Random Forest model Architecture

The Random Forest model was trained using a structured dataset containing patient medical records. It consists of an ensemble of decision trees that work together to classify the risk of liver disease[1,7].

- **Feature Analysis:** The model considers key medical features such as age, bilirubin levels, liver enzymes, and protein ratios to make predictions.
- **Prediction Process:** Each decision tree provides a classification, and the final result is based on a majority vote across all trees.

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- **Model Evaluation:** Performance was validated using metrics like accuracy, precision, recall, and F1-score to ensure reliability and generalization[12,3].

4. System Design & Implementation

The **Liver Disease Prediction System** is designed as a mobile-based AI-powered healthcare platform that enables early prediction of liver diseases, supports patient management, and facilitates real-time communication with doctors. The system follows a modular and scalable architecture to ensure smooth functionality, maintainability, and future enhancements.

4.1 Liver Disease Prediction Module

This core module is responsible for analyzing patient data using a trained machine learning model (Random Forest) to predict the risk of liver disease[11,4].

- **Medical Data Analysis:** Analyzes key indicators such as age, bilirubin levels, liver enzymes, and protein levels to predict the likelihood of liver disease.
- **Risk Assessment:** Provides output as "Low Risk" or "High Risk" with a confidence score, supporting early diagnosis and intervention.

4.2 Automated Report Generation Module

The report generation module translates the findings from the prediction module into a comprehensive report that provides detailed insight into the liver disease stages.The following are the key features of this module:

- User-friendly Interface: Present format in an easily understandable format to enhance user engagement.
- Comprehensive Report: Generates a formal, detailed and user-friendly diagnostic report on the liver disease based on the analysis.
-

4.3 Communication Module

The Communication Module provides a secure and efficient channel for direct interaction between patients and healthcare professionals, enabling seamless consultations and medical guidance. By facilitating real-time communication, this module reduces the need for frequent hospital visits, allowing patients to receive timely support from specialists. [17,5]. It ensures confidential and reliable exchanges of medical information, improving patient care and treatment outcomes. Key features of this module include:

- **Conversation Request**: Enable patients to select doctor and send a conversation request and wait for the doctor to accept the conversation invitation for healthcare services.
- **Document Sharing:** Enables the patient to securely share their diagnostic reports, fostering collaborative and informed medical discussion.

4.4 Unified Alert Module

The alert system is designed to support patients in managing their liver health by providing timely and relevant notifications. It helps keep patients informed about important health advice, lifestyle recommendations, and upcoming medical engagements.

- **Medication Alerts:** Patients receive personalized alerts about their medication schedules to help them stay on track with their treatment.
- **Lifestyle & Diet Notifications:** Provides guidance on diet (e.g., foods to avoid) and hydration, encouraging healthy habits that support liver health.
- **Appointment Notifications:** Reminds patients about upcoming doctor visits and necessary preparations to ensure they don't miss important consultations.

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4.5 Symptom Tracking Module

The Symptom Tracking Module empowers patients to actively participate in managing their liver health by recording and monitoring symptoms over time. This continuous tracking helps healthcare professionals better understand the patient's condition, track disease progression, and tailor treatment plans more effectively. It also improves communication between patients and specialists, enabling timely interventions and improved care outcomes.

Key components of the Symptom Tracking Module include:

- **Symptom Logging:** Allows patients to regularly log liver-related symptoms such as fatigue, jaundice, abdominal pain, nausea, and other relevant indicators. Patients can record severity, frequency, and any new symptoms experienced.
- **Symptom History Review:** Provides patients with an easy-to-access overview of their symptom history, helping them identify patterns or changes over time and better understand their health status.
- **Exportable Symptom Report:** Enables patients to generate comprehensive reports of their symptom logs that can be shared with healthcare specialists for more informed consultations and personalized treatment decisions.

4.6 Patient History Module (Doctor Side)

Designed exclusively for healthcare professionals, the Patient History Module offers a comprehensive and organized view of a patient's medical history related to liver health. This module enables doctors to make well-informed treatment decisions by providing access to past diagnostic reports, symptom logs, and previous treatment records. It allows physicians to track the progression of liver disease over time, compare historical and current data, and evaluate the effectiveness of earlier interventions[15,6].

By ensuring quick and seamless access to critical patient information, this module reduces redundant testing and improves the continuity of care. Doctors can identify patterns in liver disease progression, assess risks, and tailor future treatment plans based on comprehensive historical insights. Reviewing prescribed medications, prior consultations, and follow-up notes further supports personalized and efficient patient management.

Patient Dashboard

Simultaneously, the app offers patients an easy-to-use interface to input symptoms, view their diagnostic reports, receive personalized health alerts, and communicate with their healthcare providers. This empowers patients to actively engage[16,9] in their own care and facilitates timely medical intervention.

Key features of this module include:

- **Treatment Record:** Maintains detailed records of previous treatments, including medications, therapies, or procedures related to liver disease management.
- **Diagnostic Test Results:** Stores and provides access to diagnostic data such as blood test results, liver function tests, imaging reports, and system-generated prediction reports, offering a full overview of the patient's liver health history.

5. System Architecture & Diagrams

The Liver Disease Prediction System is built on a modular, service-oriented architecture that integrates AI-driven liver disease prediction, patient symptom tracking, real-time communication, and healthcare management functionalities. The architecture is designed to ensure scalability, high efficiency, and secure handling of sensitive health data across mobile applications for patients and web platforms for healthcare professionals.[19,8]

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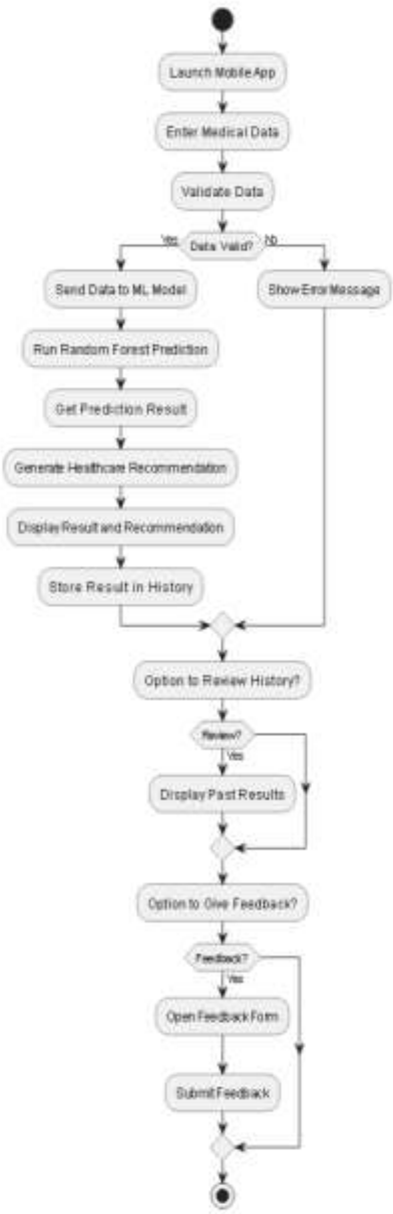
5.1 Flowcharts

Patients register and log in to the mobile app to input symptoms and medical data. The AI model analyzes this data to predict liver disease risk and generates a clear diagnostic report. Patients receive health notifications and can request consultations with doctors. Doctors access patient histories, reports, and treatment records via the web app to provide care and update plans.[20,3] Continuous symptom tracking and alerts support ongoing monitoring, while secure communication between patients and doctors ensures timely medical guidance.

Figure 5.1 Flow Chart



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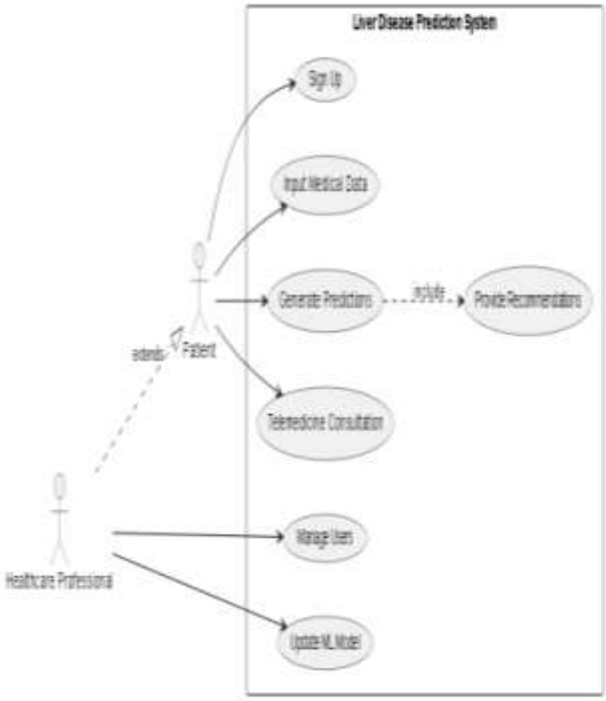
5.2 Use Case Modeling

The figures 5.3 illustrates the use case modeling of the system.

Figure 5.3 Use Case Diagram



5.3 System Class Diagram

The class diagram shows the system's main classes, their attributes, methods, and relationships. Figure 5.4 highlights:

- **User:** Patients and Doctors
- **MedicalData:** Symptoms and test results
- **AI Model:** Liver disease prediction
- **Report:** Diagnosis and recommendation
- **Chat:** Doctor-patient communication
- **Notifications:** Health alerts and reminders

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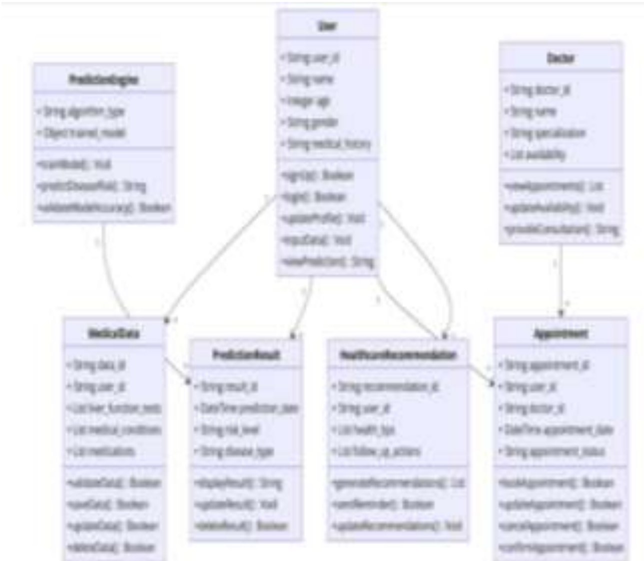

Figure 5.4 Class Diagram

5.2 Sequence Diagram

Sequence Diagram illustrates the order of interaction between various software objects, visually representing the sequence and the flow of control, showing how objects collaborate to achieve a specific task or functionalities. These diagrams provide a clear view of the dynamic behaviour of the system and the communication between different components. Following is the Sequence Diagrams of our system, highlighting various processes and their interactions in detail.

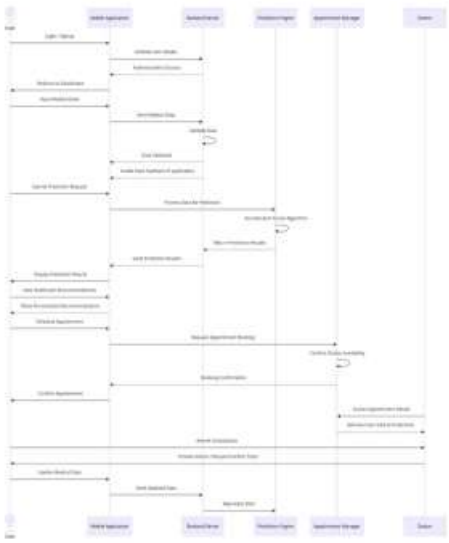

Figure 5.10 Sequence Diagram

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5.6 Component Diagram

Figure 5.11 showcases the visual representation of the system components and their relationship with each other, providing a blueprint of the system's structure.

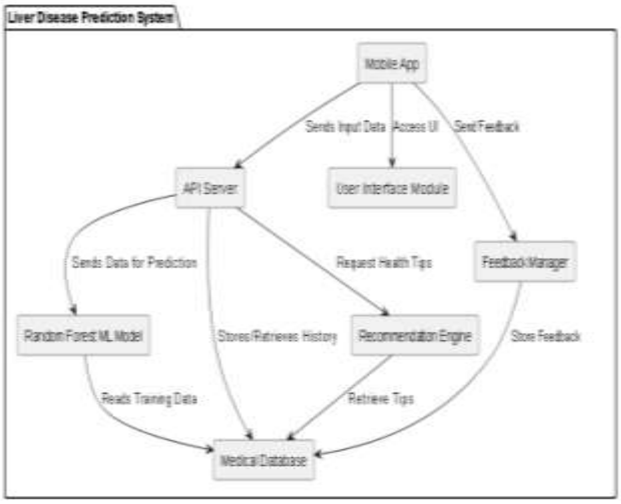

Figure 5.11 Component Diagram

5.7 Firestore Schema

Figure 5.13 represents the Fire Store schema that will be employed in our database:

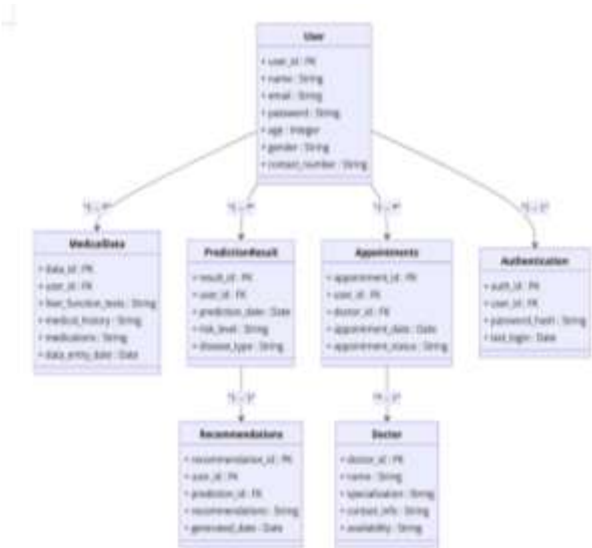

Figure 5.13 Firestore Schema

6. Results & Testing

The system underwent thorough testing to ensure accuracy, reliability, and usability. Both

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black-box and white-box testing methods were applied to validate its functional and non-functional requirements.

6.1 Testing Approach

Testing is conducted to ensure whether the system's functions working correct or not. Software testing evaluates every aspect of the application including its responsiveness to user input and accuracy of system's output based on given input. [7,3].Testing focuses on analyzing how system responds to different inputs. Each functionality of the system is tested in a real-world setting. Functionalities are checked by comparing the system's output to various user inputs. So, for every aspect of the application, test cases are designed to ensure that weather system meets the specified criteria. Various testing methodologies are used such as white box, black box, unit testing integration testing, and system testing. Black box testing focuses on how system works externally without knowing its internal structure. The user or tester is unfamiliar with how the system operates from the inside. To test each portion of system working correctly, black box testing is used. Testers provide different inputs and commands to each part, module, and component of the system.

6.2 Test Bed

Test bed is a controlled environment specially designed for testing a particular software, hardware or a system's component. To test the entire application appropriate operating systems, hardware, and test bed software are essential to create the right environment. Testing involves specific activities to determine if the system works correctly according to the requirements.. Table 6.1 shows the testing conducted of the various Modules of the system.

Table 6.1 Test Cases of Various Modules

Test Case	Expected Outcome	Status
Registration Test Case	Verify that new user can register successfully by entering valid details.	Pass
Login Test Case	Allows user to login successfully using valid credentials.	Pass
Reset Password Test Case	Verify the functionality of the "forgot password" feature to ensure that user can reset their password successfully through register email.	Pass
Upload report	Verify that	Pass

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Test Case	scanner successfully processes the LFT test images	
Find a doctor Test Case	Verify that patient can search a doctor by its name, and initiate a chat with selected doctor.	Pass

6.3 Summary

Testing is a critical step to verify that all system features perform as intended. Its primary goal is to identify defects before deploying the system globally. During testing, each feature—both on the patient's mobile app and the doctor's web app—was thoroughly examined for correctness and reliability. User interactions were carefully reviewed to ensure proper system response. Overall, testing confirmed that the system functions accurately and efficiently with no major issues, making it ready for reliable deployment for both patients and doctors.

7. Conclusion and Future Work

7.1 Conclusion

The Liver Disease Prediction System enhances liver health diagnosis by analyzing patient symptoms and medical data to generate detailed AI-driven reports on disease risk and progression. Patients use a Flutter mobile app to input data, receive predictions powered by TensorFlow Lite, and communicate with doctors via real-time chat.

Firebase manages secure authentication, real-time data processing, and efficient patient management. The doctor's web portal supports patient monitoring, report review, and consultation scheduling, making the platform comprehensive and scalable.

This integrated system improves early detection accuracy, streamlines patient-doctor communication, and enhances healthcare accessibility.

7.2 Future Work

Future work and enhancement planned for the system that will be added in the system to improve its usability and expand its features. Efforts are focused on integrating new 84 functionalities and developing new modules to make system even more advance, comprehensive and user friendly as well.

i. Video and Voice Call feature

The Video and Voice Call feature will enable real-time communication between doctors and patients, facilitating better consultation and treatment discussions. This feature allows doctors to provide immediate guidance, assess the patient's condition more accurately, and recommend the best treatment options. Additionally, it enhances the overall patient experience by offering a more personalized and interactive approach to healthcare.

ii. Doctor Fees Payment Method

Integration of secure Payment gateway will streamline the process of settling doctor fees,

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allowing patients to make payment easily within the app. It will help to enhance the financial efficiency of the system and improve user satisfaction by offering seamless way to manage payments.

iii. Multi-language Support

Multi-language support will help to make system usable for global audience. This means user will be able to choose their preferred language, breaking down language barrier an making it easier for everyone. It will also help to improve user experience and engagement by ensuring that all content is accessible and clear.

iv. Enhanced Security Measures

Continuous efforts to improve security measures, including regular updates to encryption methods and security protocols, will ensure that user data remains protected from emerging threats. By focusing on technological advancements Liver Disease Detection system will remain adaptable to changing healthcare needs and competitive in the market.

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