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KidneyDoc: A Patient management platform for the nephrology department of CNHU

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Dedication

This bachelor's thesis is dedicated to my dear father, Tieko **KONE**, and my beloved mother, Laura Yêyinou Estelle **LOKO**. Their unwavering support and encouragement have guided me throughout my academic journey. Their love, sacrifices, and belief in my abilities have been instrumental in my successes, and I am deeply grateful for their steadfast faith in me.

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Résumé

La complexité croissante de la gestion des patients en néphrologie nécessite des solutions innovantes pour optimiser l'efficacité administrative et le suivi des évolutions médicales, y compris la prédiction des stades de la maladie rénale. Pour répondre à ces enjeux, le projet KidneyDoc vise à développer une application web complète qui numérise et optimise la gestion des informations des patients au sein du service de néphrologie du CNHU. En intégrant des pratiques avancées de gestion des données, KidneyDoc offre aux professionnels de santé un accès rapide aux informations médicales et leur permet de suivre efficacement l'évolution des patients. De plus, l'application inclut une fonctionnalité innovante qui prédit les stades de la maladie rénale, facilitant ainsi une prise de décision proactive et éclairée dans le parcours de soins. L'application offre une connexion sécurisée, des profils patients complets et des outils de visualisation des données qui facilitent l'analyse des indicateurs de santé. Grâce à cette initiative, nous visons à fournir une aide précieuse aux médecins dans leur prise de décision et à améliorer la gestion des ressources au sein du service.

KidneyDoc est développé avec Next Js, offrant une interface utilisateur réactive. L'architecture du système repose sur Docker pour la conteneurisation, et une intégration au cloud est prévue pour garantir une scalabilité optimale à l'avenir. Des tests rigoureux ont été réalisés tout au long du développement, confirmant que toutes les fonctionnalités répondent aux exigences de performance et de sécurité. Les résultats des tests ont été concluants, validant ainsi la robustesse et l'efficacité de KidneyDoc.

Mots clés : Gestion des patients, Néphrologie, Application web, Gestion des données, Next Js, Suivi des évolutions, Aide à la décision médicale, Prédiction des stades de la maladie.

Abstract

The increasing complexity of nephrology patient management requires innovative solutions to optimize administrative efficiency and the monitoring of medical evolutions, including the prediction of kidney disease stages. To address these challenges, the KidneyDoc project aims to develop a comprehensive web application that digitizes and optimizes patient information management within the CNHU Nephrology Department. By integrating advanced data management practices, KidneyDoc provides healthcare professionals with rapid access to medical information and allows them to efficiently monitor patient progress. In addition, the application includes an innovative feature that predicts kidney disease stages, facilitating proactive and informed decision-making in the care pathway. The application offers a secure connection, comprehensive patient profiles, and data visualization tools that facilitate the analysis of health indicators. Through this initiative, we aim to provide valuable support to physicians in their decision-making and improve resource management within the department.

KidneyDoc is developed with Next Js, offering a responsive user interface. The system architecture is based on Docker for containerization, and cloud integration is planned to ensure optimal scalability in the future. Rigorous testing has been carried out throughout the development, confirming that all features meet performance and security requirements. The test results have been conclusive, thus validating the robustness and efficiency of KidneyDoc.

Keywords: Patient management, Nephrology, Web application, Data management, Next Js, Progress tracking, Medical decision support.

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Acronyms and abbreviations

AI :	Artificial Intelligence
CKD :	Chronic Kidney Disease
CNHU-HKM :	Centre National Hospitalier et Universitaire Hubert Koutoukou Maga
CSS :	Cascading Style Sheets
EHRs :	Electronic Health Records
HIPAA :	Health Insurance Portability and Accountability Act
HTML :	Hypertext Markup Language
IFRI :	Institut de Formation et de Recherche en Informatique
JSON :	JavaScript Object Notation
KIDNEYDOC :	Kidney Doc
UAC :	Université d'Abomey-Calavi
UML :	Unified Modeling Language
VS Code :	Visual Studio Code

Glossary

API :

It is an Application Programming Interface. It is a standardized set of classes, methods, functions, and constants that serve as the facade through which software offers services to other software.

Cloud :

The cloud refers to an infrastructure in which computing power and storage are managed by remote servers to which users connect via a secure Internet connection. Cloud services enable on-demand access to a variety of computing resources and services.

framework :

In computer programming, a framework, also called software infrastructure, is a coherent set of software components used to create the foundations and outline of the software.

Git :

Git is a decentralized version control software used for tracking changes in source code during software development. It allows developers to work collaboratively and maintain a history of their work.

JavaScript :

JavaScript is a scripting language primarily used in interactive web pages and is considered one of the core technologies of the World Wide Web. Along with HTML and CSS technologies, JavaScript enables the creation of dynamic and interactive web content.

KidneyDoc :

KidneyDoc is a web application for patient management that aims to digitize and optimize the management of medical information within the nephrology department. It enables healthcare professionals to manage medical records securely and efficiently while facilitating access to data and analyzing health indicators of patients.

Machine Learning :

Machine Learning (ML) is a subset of artificial intelligence (AI) that enables systems to automatically learn and improve from experience without being explicitly programmed. It uses statistical techniques to allow machines to find patterns and make decisions based on data.

General Introduction

1. Context and justification

In the healthcare sector, the management of patient data is crucial for effective treatment and care. Traditionally, healthcare professionals have relied on manual processes to sort and organize patient records, which can be both tedious and time-consuming. This manual sorting often leads to errors, delays in patient treatment, and a significant waste of valuable time for healthcare providers. Furthermore, the lack of a centralized digital database complicates quick access to patient information, making it difficult to perform statistical analyses, identify trends, or monitor the progression of patients' health conditions.

The introduction of the KidneyDoc web application aims to transform patient information management within the nephrology department at CNHU-HKM. By digitizing and optimizing medical records, this application not only streamlines data retrieval but also includes advanced features for predicting the stages of kidney disease. This capability allows healthcare professionals to proactively manage patient care, enhancing the quality of treatment and decision-making processes.

The application will feature robust functionalities, including secure login for healthcare providers, comprehensive patient records, and the ability to create new consultations. It will facilitate the recording of analysis results, the addition of observations, and provide a search function to quickly locate patient files. By incorporating advanced data visualization tools, the application will support healthcare professionals in analyzing patient data, identifying trends, and predicting disease progression, thereby significantly improving the overall quality of care provided to patients.

2. Problematic

Traditional patient management systems face significant challenges, including reliance on manual processes, inefficiency in accessing patient data, and difficulty in analyzing health trends. In the context of the Department of Nephrology at CNHU-HKM, these issues are particularly critical, as accurate and timely patient monitoring is essential to ensure quality care. The development of the KidneyDoc project introduces a comprehensive web application that not only digitizes and optimizes patient information management within the Nephrology Department but also enhances the ability to predict the progression of kidney disease stages. This feature empowers healthcare professionals to make informed decisions, improving patient outcomes. The application will facilitate efficient

data management, enable rapid access to medical records, and support the analysis of patient health trends, ultimately enhancing the overall delivery of healthcare services.

3. Objectives

The general objective of KidneyDoc is to enhance patient management within the nephrology department of CNHU by making it more efficient, accessible, and user-friendly, addressing the typical limitations of traditional systems.

More specifically, we aim to:

- Develop a comprehensive web application that digitizes and optimizes the management of patient information for the nephrology department.
- Implement secure login and data management features to ensure the confidentiality and integrity of patient records.
- Facilitate quick access to patient data, enabling healthcare professionals to retrieve information efficiently.
- Integrate data visualization tools to assist in analyzing patient health trends, identifying risk factors, and predicting the progression of kidney disease stages.
- Provide an intuitive user interface that allows healthcare providers to easily interact with the application and manage patient records.
- Enhance overall patient care by streamlining processes, improving data accessibility, and supporting informed decision-making.

4. Structure of the Document

The document is divided into three chapters, namely:

- **Literature Review**. We will start by defining the key concepts related to patient management and then present existing technologies in the fields of digital health and data management, as well as current solutions in the domain of nephrology.
- **Design and Technical Choices**. In this chapter, we will present in detail the materials and methods used, as well as the technical choices made for the development of the KidneyDoc application.
- **Results and Discussion**. This is the third and final chapter of the thesis. We will present our proposed solution and the results obtained. These results will be followed by potential future directions to enhance the efficiency of the application.

Chapter 1

Literature review

Introduction

This chapter aims to define certain concepts and notions necessary for a proper understanding of our work. On the other hand, we will address existing solutions and provide our critical opinion on them. Our goal is to highlight the importance of effective data management in nephrology and to present KidneyDoc as an innovative solution.

1.1 Clarification of Key Concepts

In this section, we will explore the fundamentals of medical data management, digital health, and artificial intelligence applied to nephrology. These concepts are essential for understanding KidneyDoc, an innovative patient record management platform designed to improve the efficiency of care in nephrology.

1.1.1 Medical Data Management

Medical data management involves the collection, storage, and analysis of patient information to improve the quality of care.

Good data management allows healthcare professionals to quickly access relevant information, ensure effective patient follow-up, and make informed decisions. Electronic Medical Record (EMR) systems play a key role in this management by centralizing medical information and facilitating its sharing among different professionals.

1.1.2 Digital Health

Digital health encompasses the use of information and communication technologies to improve healthcare. This includes tools such as health applications, wearable devices, and medical data management systems.

These technologies enable patients to monitor their health, access medical information, and communicate with healthcare professionals, thereby improving patient engagement and the quality of care.

1.1.3 Artificial Intelligence

Artificial intelligence (AI) in healthcare allows for the analysis of large amounts of data to identify trends and patterns. It can help predict disease progression, optimize treatments, and improve patient outcomes.

For example, Machine Learning algorithms can analyze patient data to identify risk factors and recommend personalized interventions. AI can also automate repetitive tasks, allowing healthcare professionals to focus on more complex care.

1.1.4 KidneyDoc Platform

KidneyDoc is a web application designed to optimize patient information management in nephrology, streamlining patient care and improving access to medical data. The platform focuses on efficient record-keeping, consultation management, and tracking patient health progress. Key features include:

- Comprehensive patient record management, including medical history and ongoing treatments.
- Appointment scheduling and real-time tracking of consultations.
- Tools for secure data storage and easy retrieval of patient information.
- Simplified access to medical data for quick decision-making by healthcare professionals.

By integrating these concepts, KidneyDoc positions itself as an innovative solution to address the current challenges of data management in nephrology.

1.2 Existing Solutions

In this section, we will examine existing solutions in the field of patient record management, highlighting their advantages and limitations. We will also pay particular attention to initiatives in Africa, where the digitization of health data is rapidly expanding.

1.2.1 Epic Systems

Epic Systems is one of the leading providers of Electronic Medical Record (EMR) systems in the United States. It offers an integrated platform that allows hospitals and clinics to manage patient records, billing, and healthcare.

- **Advantages:**
  - Intuitive and customizable user interface.
  - Seamless integration with other healthcare systems.
  - Advanced analytics tools to improve quality of care and patient follow-up.
- **Limitations:**
  - High implementation and maintenance costs.
  - Complexity of training for medical staff.

1.2.2 Cerner Corporation

Cerner is another major player in the EMR field, offering solutions that help healthcare facilities optimize their clinical and administrative operations.

- **Advantages:**
  - Integrated telemedicine tools, facilitating remote consultations.
  - Data analytics for patient follow-up and care improvement.
  - Customizable solutions according to the needs of the facilities.
- **Limitations:**
  - May require frequent updates, leading to additional costs.
  - Some users report compatibility issues with other systems.

1.2.3 Solutions in Africa

Africa is experiencing rapid growth in the adoption of digital solutions for health record management. Here are some notable initiatives:

1.2.3.1 Kea Medical

Kea Medical is a mobile health initiative based in Benin that focuses on collecting health data and providing medical services remotely. These solutions are particularly effective in rural areas where access to care is limited.

- **Advantages:**
  - Increased accessibility to healthcare.
  - Real-time monitoring of patients' health conditions.
  - Reduced transportation costs for patients.
- **Limitations:**
  - Dependence on internet connectivity and mobile technology.
  - Risks of data privacy.

1.2.3.2 OpenMRS

OpenMRS is an open-source platform designed to manage electronic medical records, particularly used in developing countries. It allows healthcare facilities to customize their systems according to their specific needs.

- **Advantages:**
  - Reduced costs due to its open-source nature.
  - Flexibility and customization to meet local requirements.
  - Large community of developers and healthcare professionals.

- **Limitations:**
  - Requires technical expertise for implementation and maintenance.
  - Lack of technical support in certain regions.

1.2.3.3 AfyaPro

AfyaPro is a medical record management solution developed for the African market. It targets small and medium clinics, offering features tailored to local needs.

- **Advantages:**
  - User-friendly and easy-to-use interface.
  - Appointment and prescription management features.
  - Integration with local payment systems.
- **Limitations:**
  - Fewer advanced features compared to larger platforms like Epic or Cerner.
  - Dependence on sometimes limited technological infrastructure.

1.2.3.4 Kenya Health Information System (KHIS)

The KHIS is a system established by the Kenyan government to collect and manage health data at the national level. This system aims to improve decision-making in public health.

- **Advantages:**
  - Centralization of health data at the national level.
  - Improvement of transparency and accountability in healthcare management.
  - Facilitates monitoring of epidemics and public health trends.
- **Limitations:**
  - Challenges related to integration with other health systems.
  - Issues with training staff for effective system use.

1.2.4 Comparison of Existing Solutions

The following table compares the main existing solutions for managing electronic medical records (EMR) and their advantages and limitations:

Solution	Advantages	Limitations
Epic Systems	- Intuitive and customizable interface. - Advanced analytics tools. - Seamless integration with other systems.	- High implementation and maintenance costs. - Complexity of staff training.
Cerner Corporation	- Integrated telemedicine tools. - Customizable solutions. - Advanced data analytics.	- Requires frequent updates. - Compatibility issues reported.
Kea Medical (Benin)	- Real-time monitoring of health conditions. - Increased access to healthcare in rural areas.	- Dependent on internet connectivity. - Risks of data privacy.
OpenMRS	- Open-source and customizable. - Large community support.	- Requires technical expertise for implementation. - Lack of support in some regions.
AfyaPro	- Simple interface for small clinics. - Appointment and prescription management.	- Limited features compared to larger platforms. - Dependent on technological infrastructure.
Kenya Health Information System (KHIS)	- Centralized national health data. - Improvement of transparency and accountability.	- Integration challenges with other systems. - Training required for staff.

Table 1.1: Comparison of Existing EMR Solutions

Overall, the comparison in table 1.1 highlights some notable advantages such as the customizable interfaces and advanced data analytics found in solutions like Epic Systems and Cerner Corporation, which enhance the overall user experience and decision-making process. Furthermore, solutions like Kea Medical and OpenMRS stand out for their focus on accessibility and open-source flexibility, providing tailored solutions to specific regional needs.

However, common limitations observed in table 1.1 include high implementation costs, technical expertise requirements, and integration challenges. These issues underscore the need for cost-effective, user-friendly solutions that can be adapted to smaller healthcare facilities or specific departments, such as nephrology.

Chapter 2

Design and technical choices

Introduction

The goal of this research project is to develop a web application, called KidneyDoc, that optimizes the management of patient records in the nephrology department at CNHU. This application aims to digitize and centralize patient data, making it accessible in a secure and efficient manner. In addition, the application integrates predictive analytics tools, powered by artificial intelligence (AI), to assist in clinical decision-making.

The main functionalities of KidneyDoc include the ability to consult and manage patient files, create new consultations, record medical test results, and generate statistical reports. By automating these processes, KidneyDoc reduces manual errors and improves overall patient care. The AI component will also enable the prediction of patient kidney disease progression based on medical data.

This chapter presents the steps we have taken to design and implement the KidneyDoc solution, including the development of its various features and the integration of cutting-edge technologies such as AI and data analysis tools.

2.1 Development environment

2.1.1 Tools and Technologies

In our KidneyDoc project, we will use FastAPI[1] for its strong capabilities in building high-performance APIs and integrating machine learning models. We'll also use JavaScript[2] for building the interactive user interfaces of the application. For smooth user experiences and top-notch performance, we rely on Next.js for server-side rendering and MongoDB for efficient database management. Additionally, Docker will be used to containerize the application for easy deployment across various environments, and Visual Studio Code[3] will be our preferred Integrated Development Environment (IDE)

[1] FastAPI is a modern, fast (high-performance), web framework for building APIs with Python 3.7+ based on standard Python type hints. It is designed to be easy to use and produce code that's efficient and scalable.

[2] JavaScript is a scripting language primarily used in interactive web pages and is an essential part of web applications.

[3] Visual Studio Code is a lightweight, yet powerful source code editor that supports many programming languages and comes with built-in Git support. It is highly customizable with extensions, making it ideal for software development.

for development.

2.1.1.1 FastAPI

FastAPI[3] is a modern, fast (high-performance), web framework for building APIs with Python based on standard Python type hints. In KidneyDoc, FastAPI was chosen to handle the integration of machine learning models, allowing seamless interaction between the application and our predictive models.

2.1.1.2 NextJS

Next.js[1] is a React framework for building full-stack web applications. Its server-side rendering feature makes it particularly suitable for our KidneyDoc application, where fast data retrieval and rendering of patient records are crucial.

2.1.1.3 MongoDB

MongoDB[4] is a source-available, cross-platform, document-oriented database program. It is a NoSQL database chosen for KidneyDoc to store patient records securely and efficiently. Its document-based model allows for the flexible handling of complex medical data. MongoDB is highly scalable and supports a variety of queries, making it ideal for managing large volumes of patient data.

2.1.1.4 Docker

Docker[7] is a tool for packaging an application and its dependencies in an isolated container, which can be run on any server. It allows us to package the application and its dependencies into lightweight containers that can run consistently across different environments. This ensures that our application will function the same in development, testing, and production environments. Docker is particularly useful for the deployment of our web application on cloud platforms.

2.1.1.5 Visual Studio Code

Visual Studio Code[8] is a code editor redefined and optimized for building and debugging modern web and cloud applications. It offers a wide range of extensions that support various programming languages and tools, including FastAPI, JavaScript, and Docker. VS Code's integrated Git support makes it an ideal choice for managing version control and collaborating on the KidneyDoc project. Its debugging tools and IntelliSense feature, which provides intelligent code completions, make development faster and more efficient.

2.1.2 Justification

We selected FastAPI for its ease of use and performance in handling machine learning model integrations, ensuring scalability and low-latency responses. Next.js was chosen as the full-stack framework due to its user-friendliness and production-readiness. MongoDB was chosen for its flexibility in handling diverse patient data formats. Docker was selected for its portability and ease of deployment, ensuring consistency across environments. Visual Studio Code was selected as the development environment for its robust feature set, customizability, and its excellent support for multiple languages and tools. Machine learning techniques, integrated via FastAPI, provide the flexibility and power

needed for complex predictive analytics. Each tool was chosen to best fit the needs of the KidneyDoc application, ensuring scalability, performance, and ease of use for healthcare professionals.

2.2 Development methodology

The development of the **KidneyDoc** application was structured into several distinct phases to ensure a smooth and efficient implementation process. Each phase contributed to the robust architecture and functionality of the final product.

- Definition of Requirements The initial phase involved gathering and documenting the functional and non-functional requirements for KidneyDoc. Stakeholders from the nephrology department provided insights into the essential features needed for patient record management and clinical decision-making. This document served as the foundation for the entire development process.
- Identification of Features (User Stories) The requirements were broken down into user stories, which represent small, manageable tasks that deliver value to the healthcare professionals using KidneyDoc. Each user story focused on a specific feature, such as consultation management, predictive analysis, or report generation, making the development process more manageable.
- UML Modeling Unified Modeling Language (UML) was used to visualize the system's architecture and design. Diagrams such as class diagrams, sequence diagrams, and use case diagrams were created to map out the relationships between different components of the application, including the database, user interfaces, and AI-driven analytics.
- Technology Stack Selection The technology stack was selected based on project requirements and the need for scalability, security, and compatibility with existing systems at the CNHU. **Next.js** was chosen for the frontend due to its performance and ease of use, while **MongoDB** was selected for the backend because of its scalability and ability to handle large amounts of medical data efficiently. Additionally, **FastAPI** was used to manage backend services and integrate predictive analytics powered by **AI**.
- Application Development This phase involved implementing the core features of KidneyDoc. The development team focused on creating a responsive, user-friendly interface for managing patient records. Backend services were developed to securely store and process patient data, while AI models were integrated to provide real-time predictive insights into kidney disease progression.
- Validation of Developed Features Throughout the development process, features were validated against the requirements to ensure alignment with user needs. Healthcare professionals from the nephrology department were involved in reviewing and testing the features to guarantee that the system met clinical requirements and provided valuable functionality.
- Unit and Application Testing Each feature was subjected to rigorous unit testing to ensure proper functionality. Additionally, the entire system was tested with real data provided by the department to ensure that KidneyDoc performs well under real-world conditions.

- Deployment and Maintenance After successful testing, the application was deployed on the hospital's internal servers, ensuring secure access to healthcare professionals. A maintenance plan was established to address future updates, bug fixes, and performance improvements.

2.3 Our approach

Our approach focuses on the optimization of patient data management within the nephrology department. We emphasize the digitalization and centralization of medical records, as well as the integration of predictive analysis tools to improve clinical decision-making. The aim is to streamline workflows for healthcare professionals and enhance the quality of patient care.By utilizing advanced data management tools and artificial intelligence (AI), our system not only enables the efficient management of patient information but also assists in predicting kidney disease progression.Moreover, our system provides healthcare providers with a user-friendly interface developed in NextJs, ensuring that the application is responsive and easily accessible.

2.3.1 Overview

In the context of our thesis on patient data management and AI-driven healthcare applications, we focus on creating a platform that not only centralizes medical records but also uses predictive analytics to improve clinical decision-making.

Our approach is built on three fundamental axes:

- Designing a Versatile Application: We are developing a web-based application, KidneyDoc, capable of securely managing and displaying patient data in real time. This allows healthcare professionals to access critical patient information quickly and efficiently.
- Training AI Models: We are developing and training machine learning models that predict the progression of kidney diseases. These models use historical patient data to forecast potential health risks, thus aiding doctors in making informed decisions.
- Data Analysis and Visualization: We are integrating data analysis tools that enable healthcare providers to visualize patient trends and outcomes through charts and predictive analytics, helping them better monitor patient health over time.

This approach is centered around the secure collection, storage, and analysis of patient data, providing a comprehensive solution for healthcare professionals to improve the quality of care through data-driven insights.

2.3.2 Predictive model integration

In our approach, we opted to integrate an existing Machine Learning model to predict kidney disease stages using **FastAPI**. This model, trained using clinical data, provides high accuracy in analyzing patient records to forecast the progression of kidney disease. By leveraging this pre-trained model, our goal is to streamline the prediction process and assist healthcare professionals in making data-driven decisions efficiently.

- **Integration of Existing Predictive Models with FastAPI**
  We have integrated a well-established machine learning model for predicting kidney disease stages via FastAPI. This model has been trained on a diverse dataset and validated in various clinical scenarios. Using FastAPI enables quick and efficient API deployment, allowing the model to analyze patient data, such as medical history and test results, to predict future disease progression in real time.

By integrating this pre-trained model, we enhance KidneyDoc's ability to assist healthcare professionals in predicting patient outcomes, thus improving overall decision-making and patient care.

2.4 Modeling

2.4.1 UML Modeling

In our project, we utilized three distinct types of UML diagrams to illustrate our system. The first diagram focuses on the functionalities of our platform; this is known as the use case diagram. The second diagram emphasizes the system's components, referred to as the class diagram. Lastly, we have the sequence diagram, which outlines the interactions over time.

2.4.1.1 Use Case Diagram

This diagram provides a high-level overview of the functional behavior within the software system. Each use case signifies a specific interaction between a user and the system, representing a meaningful unit of work. The use case diagram for our KidneyDoc application depicts various interactions between users, such as doctors and heads of department, highlighting functionalities like managing patient records, conducting data analyses, and performing predictive assessments.

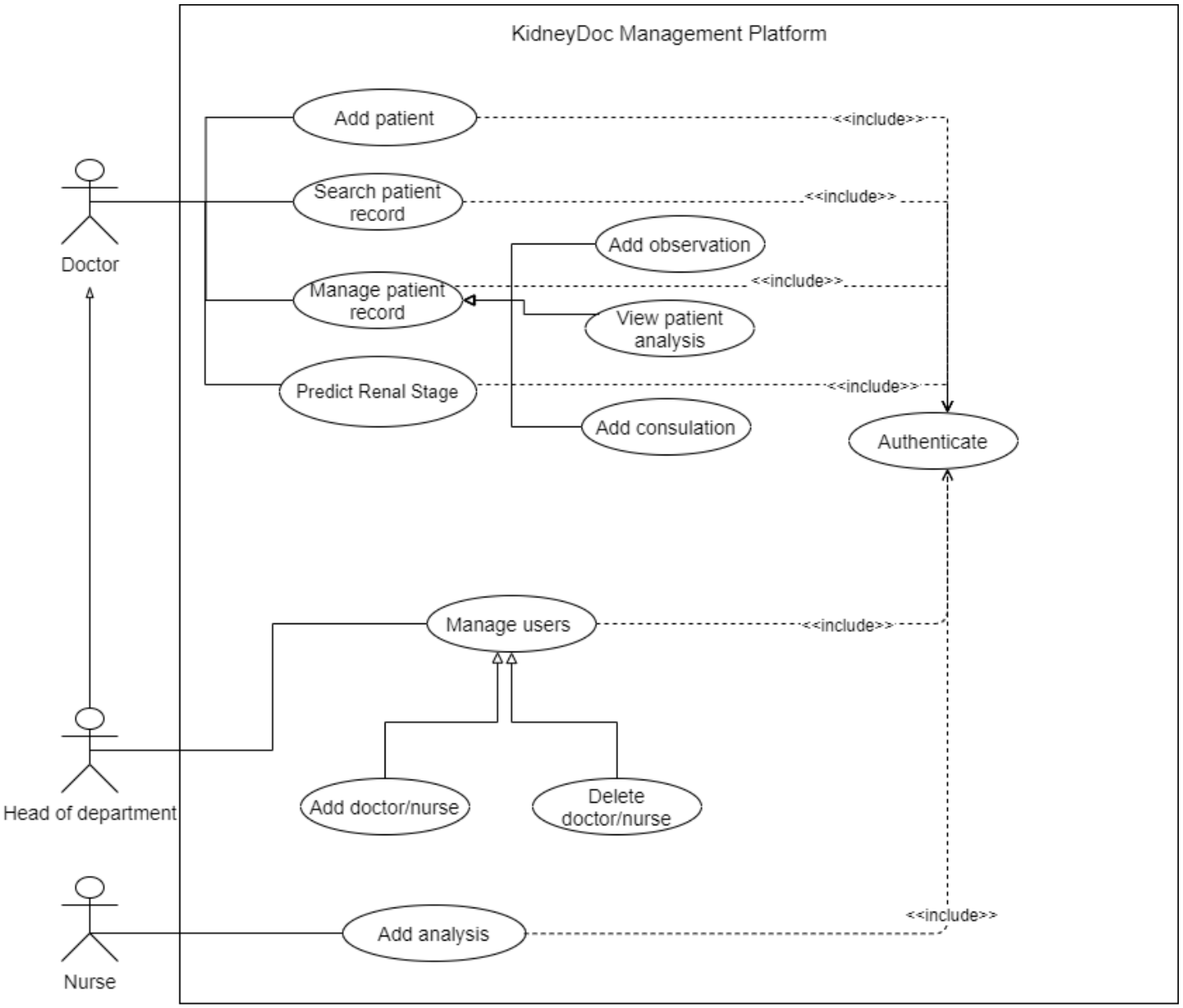


Figure 2.1: KidneyDoc use case diagram

The diagram 2.1 illustrates key interactions: **Doctors** can add patients, search and manage patient records, add observations, view analyses, and predict renal stages. **Heads of Department** manage users, including adding or deleting doctors and nurses. **Nurses** can add analyses. All users must authenticate to access these functionalities. This setup ensures efficient management and analysis of patient data within the system.

2.4.1.2 Class Diagram

The class diagram offers a static representation of the system by illustrating its classes, including their attributes, methods, and the relationships among them. Within our KidneyDoc application, this diagram showcases essential entities like Patient, Doctor, and MedicalRecord. Each class is detailed with its specific properties and functions, facilitating a clear understanding of the data structure and the interactions between different components of the system.

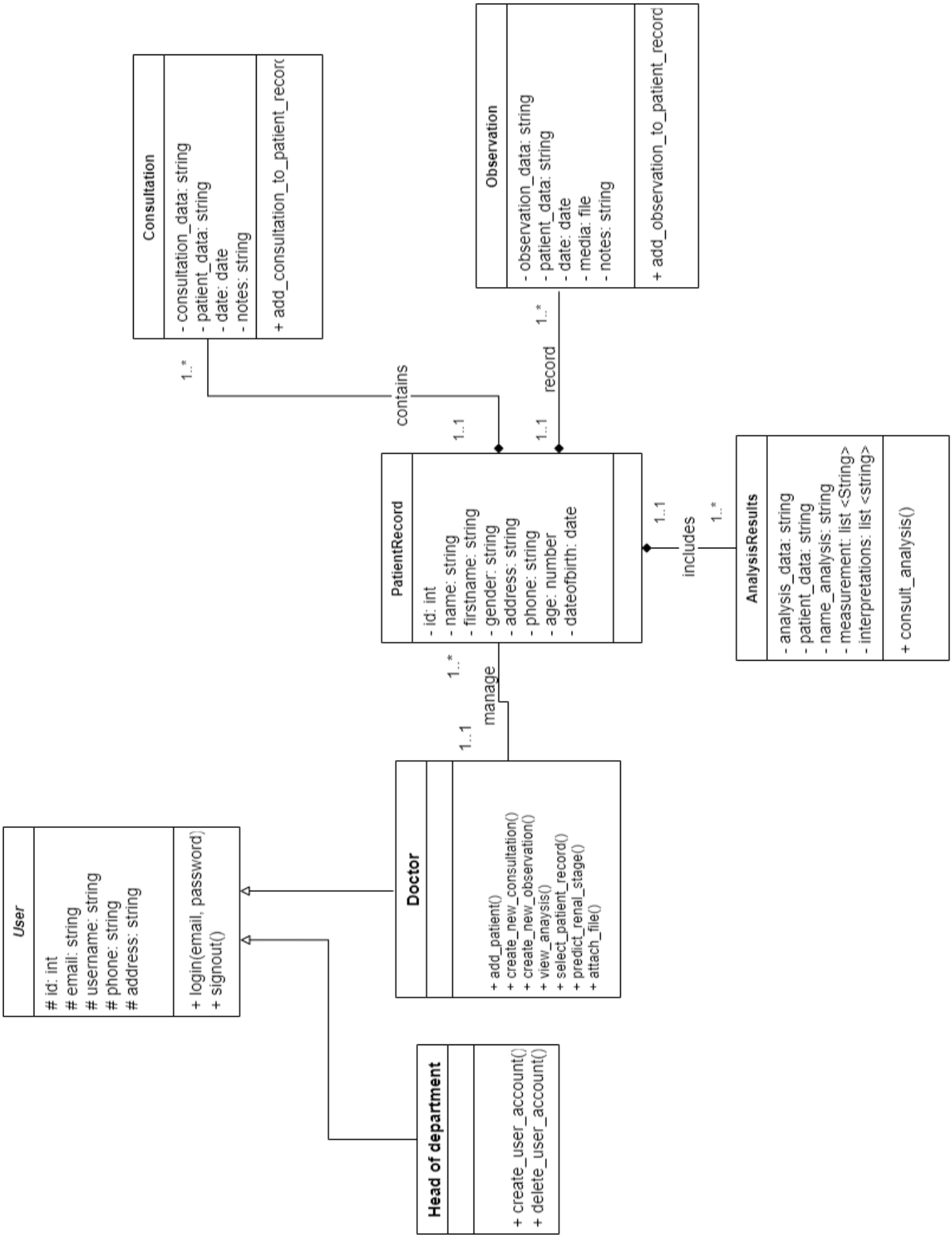


Figure 2.2: KidneyDoc class diagram

We can observe that we have seven (7) main classes in the figure 2.2: **User**, with attributes like email and username, and methods such as `login`. **Doctor** inherits from User and is responsible for managing patient records and medical activities. **Head of Department** can create or delete accounts. **PatientRecord** stores patient information and links to **Consultation** and **Observation**, which contain detailed data and notes about patient interactions. **AnalysisResults** holds data and interpretations from medical analyses. These classes illustrate how doctors manage records and integrate analysis results into the system.

2.4.1.3 Sequence Diagram

Focusing on the dynamic aspects, the sequence diagram represents the flow of messages exchanged between objects to accomplish particular functionalities. In the context of our KidneyDoc application, this sequence diagram relates to the use case "Add Consultation." It depicts a typical scenario where a doctor accesses a patient's medical record, adds a consultation, and saves it. This diagram aids in visualizing the sequence of interactions and the timing of events, enhancing comprehension of the operational flow.

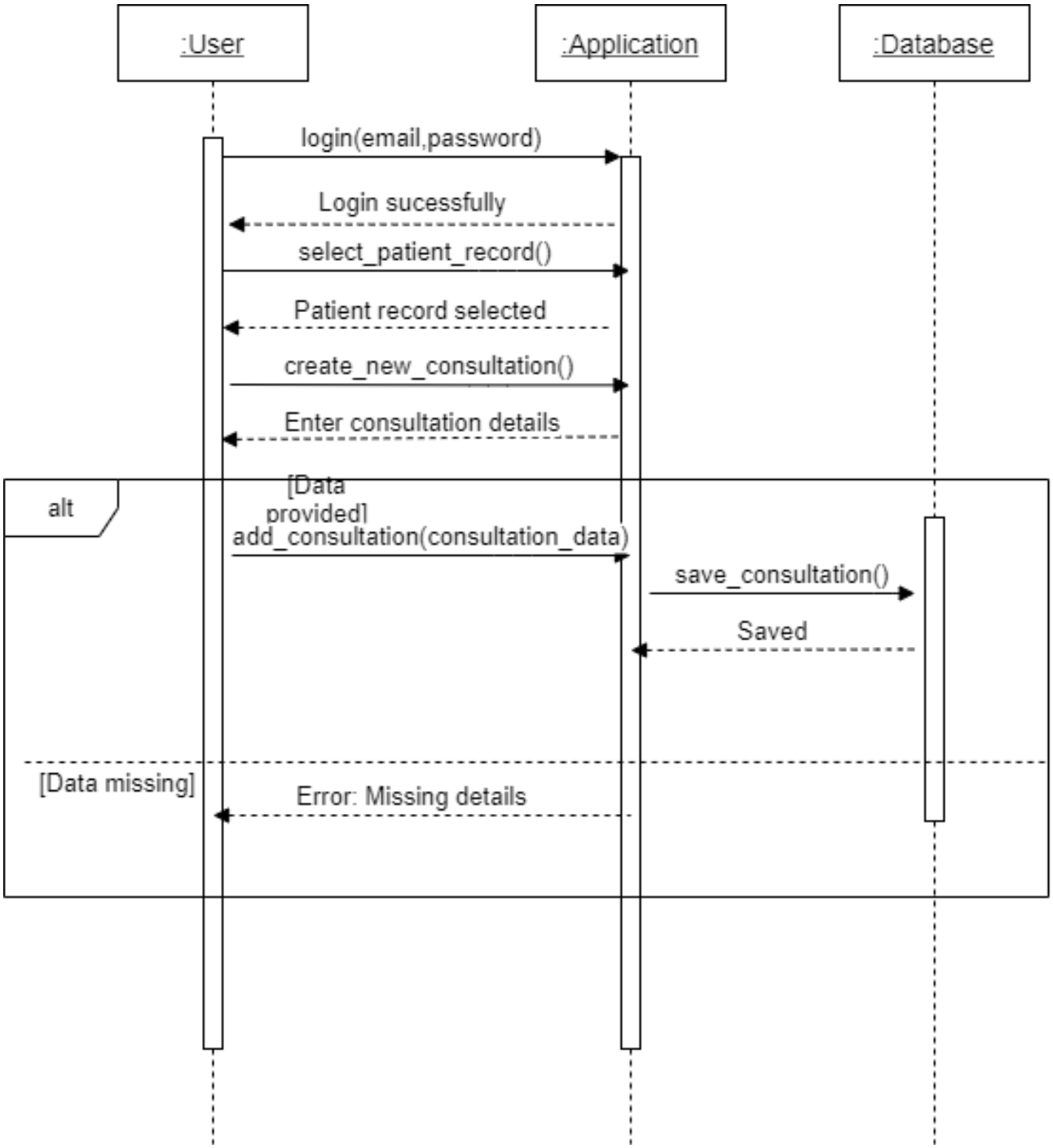


Figure 2.3: KidneyDoc modeling sequence diagram for the "Add Consultation" use case

The sequence diagram 2.3 involves three main components: User, Application, and Database. The process begins with the User logging in, followed by selecting a patient record. Once the record is selected, the User creates a new consultation and enters the details. If the data is provided, the Application adds the consultation and saves it to the Database. If data is missing, an error message is returned. This sequence illustrates the interactions and timing necessary for managing patient consultations.

2.4.1.4 Activity Diagram

The activity diagram emphasizes the dynamic elements of the process, illustrating the sequence of actions and decisions involved in adding a new patient to the system. Within the framework of our

KidneyDoc application, this diagram pertains specifically to the "Add Patient" use case. It serves as a visual representation of the logical flow of steps and decision points throughout the addition process, thereby enhancing our understanding of the overall workflow.

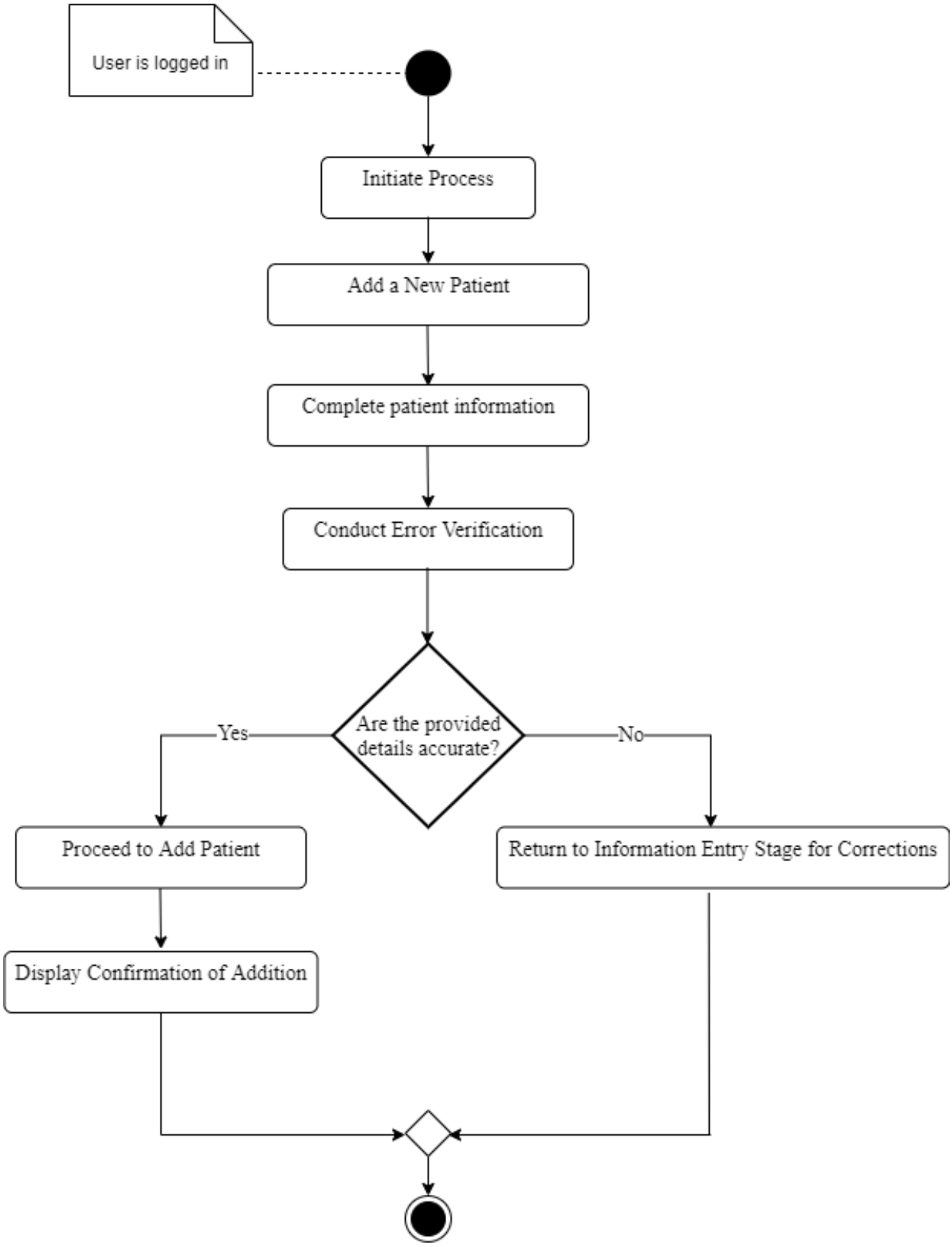


Figure 2.4: Modeling activity diagram for the "Add Patient" use case

The activity diagram 2.4 involves several key steps: starting the process by selecting the option to add a new patient, filling out the patient's information, and verifying the data for any errors. If any information is missing or incorrect, the system returns to the data entry phase, prompting the user to correct the errors. Once the data is validated, the patient is successfully added, and the system provides confirmation. This sequence of actions ensures data accuracy and smooth processing during patient addition, contributing to efficient patient management.

Conclusion

KidneyDoc delivers significant improvements in the management of patient records and data analysis within the nephrology department. By leveraging advanced AI and predictive analytics, the platform simplifies the process of managing medical information, allowing healthcare professionals to access critical data more efficiently. Patients' medical histories, test results, and treatment plans are integrated into a seamless, easy-to-use interface, empowering healthcare providers to make informed decisions.

Chapter 3

Results and discussion

Introduction

The previous chapters allowed us to present the state-of-the-art as well as the tools and methods used for the development of our predictive model in the context of patient management. In this chapter, we present the results obtained through the implementation of KidneyDoc, a web platform that centralizes patient data and integrates predictive analytics for kidney disease progression.

3.1 Overview of the solution

Our solution is centered around three main components. First, we integrated a pre-trained machine learning model to predict kidney disease progression. Second, the entire application was containerized using Docker, enabling ease of deployment and scalability. Lastly, we expose our system's functionalities through an API, which includes patient data management, authentication, and prediction endpoints. The platform provides a user-friendly interface allowing healthcare professionals to interact with the system efficiently.

3.2 Results

3.2.1 Patient Data Management and System Functionality

The KidneyDoc platform provides a comprehensive solution for managing nephrology patient data, including medical history, test results, and treatment plans. This system centralizes patient information and facilitates efficient healthcare delivery.

- **Data Centralization and Access**
  KidneyDoc offers a centralized platform where healthcare professionals can access and update patient data in real-time. It includes personal information, medical history, lab results, and previous consultations. This facilitates quick retrieval of records and ensures up-to-date patient information is always available, aiding in streamlined decision-making.

- **Patient Record Modification**
  The interface for modifying patient data is user-friendly and straightforward. Healthcare providers can easily update medical records, ensuring that any new information is quickly reflected in the patient's profile. Figures 3.9 and 3.10 demonstrate these interfaces.

- **Dashboard Overview**
  The dashboard serves as the central hub for managing patient data and administrative tasks. It provides key statistics such as the number of active patients and monthly trends, allowing healthcare professionals to monitor critical metrics effectively. Figure 3.7 showcases the KidneyDoc dashboard.

- **Patient Deletion and Archiving**
  Patient deletion is handled by department heads. Rather than removing patients from the system entirely, the records are archived, preserving essential historical data while limiting access to unauthorized users. Figure 3.11 illustrates the patient deletion interface.

- **Specific Patient Information Overview**
  The specific patient information page displays detailed medical histories, including past consultations, test results, and treatment records. Data is visualized through charts and graphs, allowing healthcare professionals to assess patient progress effectively. This interface is shown in Figure 3.16.

3.2.2 Tests

In software development, unit tests are essential for ensuring the quality and reliability of the code. They involve verifying the proper functioning of individual code units, such as functions or classes. Jest [6] is a a JavaScript testing framework designed to ensure correctness of any JavaScript codebase.



Figure 3.1: Login Test

This test validates the functionality of the login form submission. It ensures that user inputs are processed correctly and that validation errors are handled appropriately, thereby guaranteeing a smooth and seamless user experience.



Figure 3.2: Add Patient Test

This test assesses the function of adding a patient to the system. It verifies not only the correct creation of a new record but also the handling of cases where invalid data might be submitted, thus reinforcing the integrity of the data within the application.



Figure 3.3: AddUser Test

This test checks the process of adding a new user. It ensures that all prerequisites are met and that appropriate notifications are sent in case of success or failure, thereby contributing to a robust and responsive user management system.

After executing all the tests, we obtained the following results:

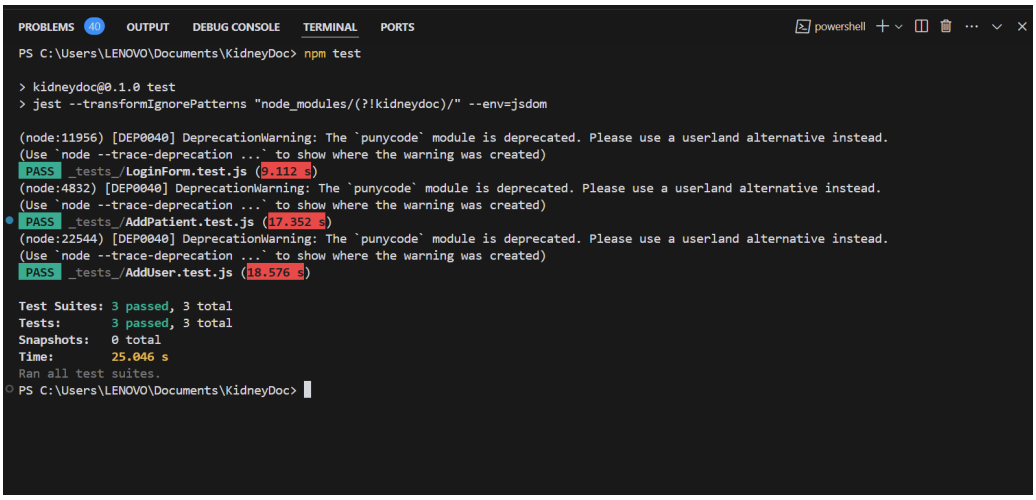


Figure 3.4: Test Results

All tests passed, confirming the proper functioning of the application. This success reflects the rigor of our development methodology and the effectiveness of our testing framework, thereby ensuring a reliable and high-performing application.

3.2.3 Security aspects

The security of web applications is a critical component, especially for applications managing sensitive data such as personal information. In this project, built using **Next.js 14**, several security measures were implemented to ensure the confidentiality, integrity, and availability of the data.

- **Authentication and Authorization**: The authentication and authorization mechanism in this project is handled through **NextAuth** with credential-based login. This ensures that only authorized users can access specific parts of the application.
- **Password Hashing**: User passwords are never stored in plain text. Instead, the project uses the **bcrypt** algorithm to hash passwords before storing them in the database. During login, bcrypt compares the hashed password stored in the database with the one provided by the user, ensuring secure authentication.
- **Session Management**: Session management is handled through NextAuth's session callbacks. Upon successful authentication, additional user information such as *username*, *email*, *isAdmin* status, and profile image are added to the session token, which is securely stored and managed during the session lifecycle.
- **Protection against Common Attacks**: Several layers of protection are implemented against common vulnerabilities:
  - **MongoDB Injection**: The application uses secure queries with **MongoDB**, which helps mitigate injection attacks by escaping and sanitizing user inputs.
  - **Cross-Site Request Forgery (CSRF)**: CSRF protection is built-in with NextAuth. Additional CSRF tokens are issued during sensitive actions to ensure requests are legitimate.

With these security measures in place, the project guarantees secure access and robust protection of user data.

3.2.4 Predictive Model for Kidney Disease Progression

KidneyDoc integrates a predictive model that is designed to forecast the progression of kidney disease based on a patient's medical history and lab test results. The model aids nephrologists in providing personalized care by predicting the stages of chronic kidney disease.

- **Overview of Kidney Disease Progression**
  Chronic kidney disease is a long-term condition characterized by a gradual loss of kidney function over time. The disease progresses through five stages, ranging from mild kidney damage in stage 1 to complete kidney failure in stage 5. Identifying the stage of CKD early allows healthcare providers to manage the disease proactively and slow its progression.

- **CKD Stages Overview:**

Stage	Functional State of Kidneys (GFR %)	Description	Symptoms
Stage 1	$\geq 90\%$	Minimal kidney damage, normal renal function.	No obvious symptoms, Urea and Creatinine levels normal.
Stage 2	60-89%	Mild deterioration, kidneys function below normal but still working.	Urea and Creatinine levels may be slightly elevated, small amount of protein in urine.
Stage 3	30-59%	Moderate deterioration, lower kidney function. Patients may start noticing symptoms.	Tiredness, loss of appetite, high blood pressure, protein in urine.
Stage 4	15-29%	Severe deterioration, kidneys function poorly. Symptoms become more noticeable.	Persistent tiredness, swelling in limbs, increased creatinine, excess urea in blood.
Stage 5	$< 15\%$	End-stage renal failure, high risk of death.	Severe symptoms: fatigue, breathlessness, vomiting, blood in urine, frequent urination.

Table 3.1: CKD Stages Description

- **Prediction Process and Score**
  The model integrated into **KidneyDoc** uses machine learning algorithms trained on historical patient data to predict the progression of chronic kidney disease (CKD). It generates a risk score that indicates the likelihood of progression to the next stage.

  The risk score helps nephrologists prioritize patients who require more aggressive treatment plans and those who may benefit from lifestyle modifications to slow the disease's progression. The accuracy score for the model is approximately 0.4861 based on testing data. However, it is important to note that this model is not as effective as it could be due to a lack of sufficient training data, which limits its accuracy and overall effectiveness.

3.2.5 Deployment of the KidneyDoc Platform

The deployment of the KidneyDoc platform was designed to ensure scalability, reliability, and security. The application is containerized using Docker to allow for consistent deployment across different environments, including development, testing, and production. This approach simplifies the deployment process and ensures that the system behaves identically across all environments.

- **Containerization with Docker**
  The use of Docker ensures that the application and all its dependencies are packaged into lightweight containers. This allows for seamless deployment on cloud platforms such as AWS or Google Cloud, making it easy to scale the application as the number of patients and users increases.

- **Cloud Integration and Scalability**
  KidneyDoc is designed to be deployed in cloud environments, allowing for the platform to scale as needed. This is crucial for handling large volumes of patient data while maintaining optimal performance. The cloud infrastructure also ensures high availability and disaster recovery options.

- **Security and Compliance**
  Given the sensitive nature of medical data, KidneyDoc integrates strong security measures, including data encryption both in transit and at rest. The platform adheres to healthcare regulations such as HIPAA (Health Insurance Portability and Accountability Act), ensuring that patient data is handled with the highest standards of security and privacy.

3.3 Conclusion

KidneyDoc simplifies nephrology patient management through centralized access to data and analytics. While the current disease progression model requires more training data to improve accuracy, the platform's scalable and secure infrastructure ensures it can adapt to future needs. Overall, KidneyDoc is a valuable tool, with potential for further improvement in predictive capabilities and features.

3.3.1 Interfaces

- **Logo**
  The name KidneyDoc was chosen to clearly represent the platform's focus on nephrology, symbolized by "Kidney", and its role as a tool for medical professionals, symbolized by "Doc". It reflects the combination of specialized kidney care and professional medical guidance.
  The interface in Figure 3.5 presents the KidneyDoc logo.



Figure 3.5: KidneyDoc logo

- **Login**
  KidneyDoc is reserved for healthcare professionals, with account creation handled by the system administrator. The login page allows authorized users to securely enter their credentials. For security, users will be temporarily locked out after several failed login attempts and must wait a few minutes before trying again.
  Figure 3.6 illustrates the login interface.

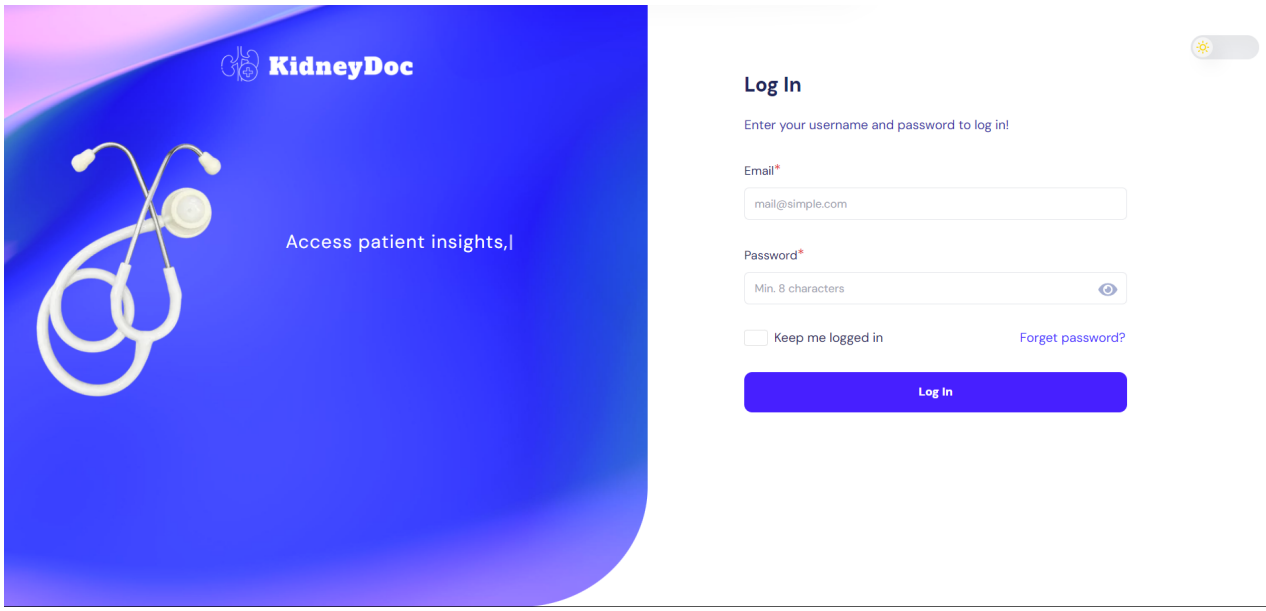


Figure 3.6: KidneyDoc Login Page

- **Dashboard**
  The dashboard is the central hub for managing patient data and performing administrative actions. It provides a comprehensive overview of key statistics, including the number of active patients, new patients this month, and overall health trends. From this interface, healthcare professionals and administrators can navigate between patient records, add new appointments, manage system settings, perform administrative actions, and monitor important updates in real-time.
  Figure 3.7 displays the KidneyDoc dashboard interface.

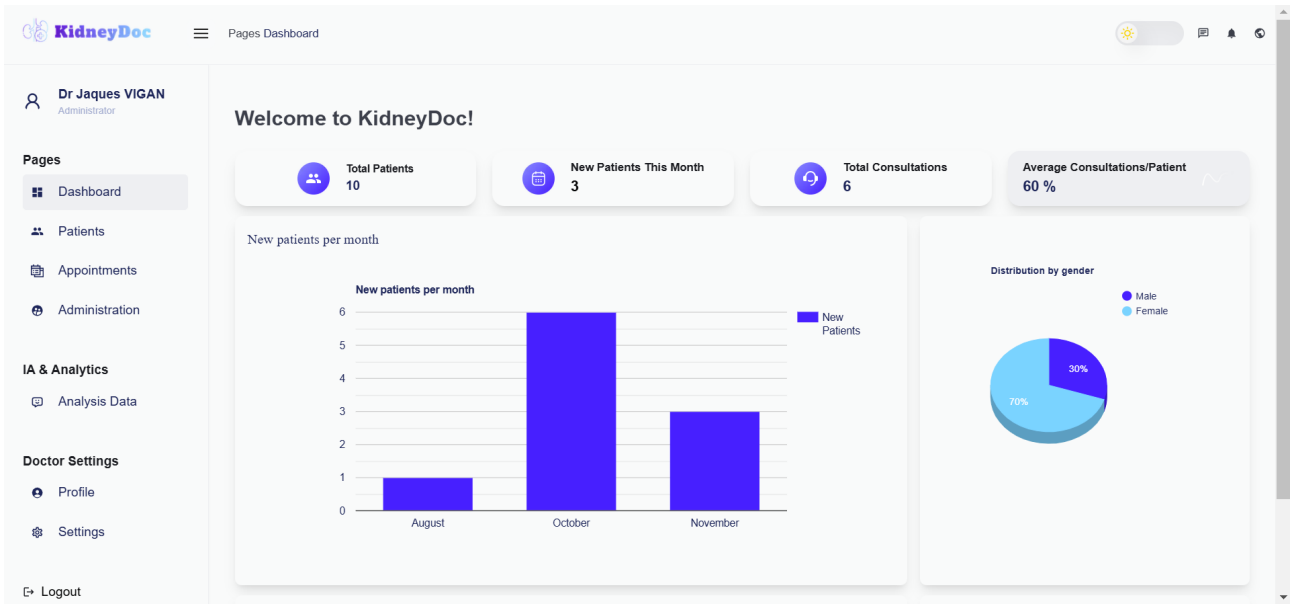


Figure 3.7: KidneyDoc Dashboard

- **Patient Page**
  This page provides an organized overview of patient data, allowing healthcare professionals to easily manage and access key information. The interface offers options for sorting, filtering, and performing various actions such as viewing, editing, or deleting records. This layout enhances efficiency, ensuring that patient information is readily available and up-to-date.
  Figure 3.8 shows the KidneyDoc Patient Page interface.

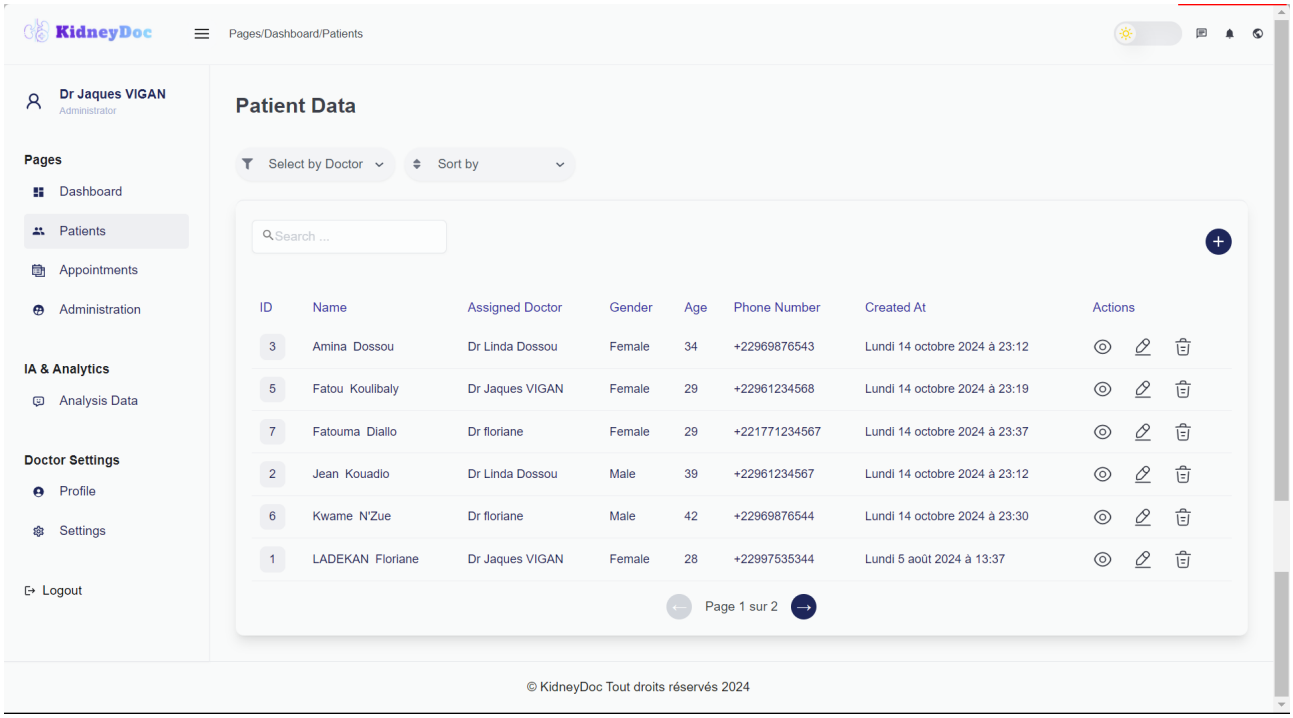


Figure 3.8: KidneyDoc Patient Page

- **Add or Modify Patient Information**
  The interface for adding or modifying patient information is straightforward and user-friendly. Healthcare providers can input new patient data, update existing records.

Figure 3.9 shows the interface used to add or modify patient data.

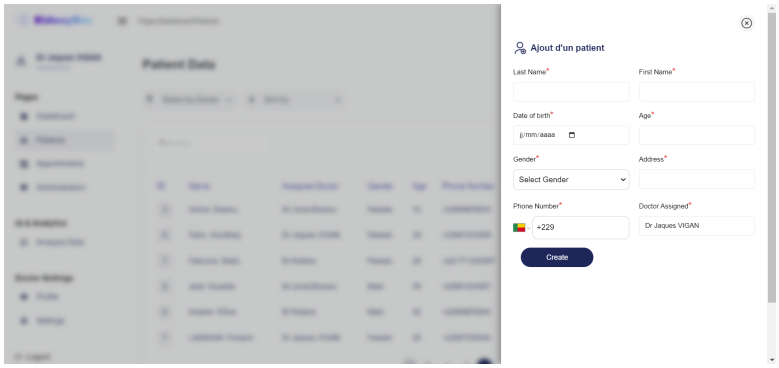


Figure 3.9: Add Patient Information

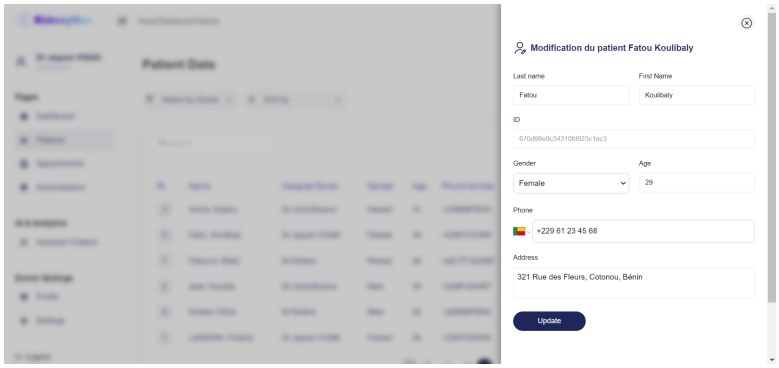


Figure 3.10: Modify Patient Information

- **Delete a Patient**
  The patient deletion interface is reserved for department heads. When a department head wishes to delete a patient, the patient is not actually removed from the database but archived. This allows for the preservation of patient history while making them inaccessible to regular users.
  Figure 3.11 shows the interface used to delete a patient.

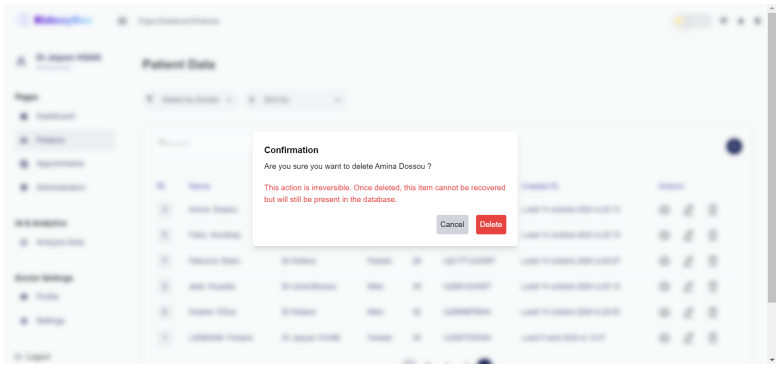


Figure 3.11: Delete Patient Interface

- **Administration Page**
  The administration page is where system administrators manage user accounts and permissions. Only authorized personnel, such as doctors and nurses, are given access to the platform. Administrators can assign roles, control user access, and monitor the activity of different users on the platform.

Figure 3.12 illustrates the administration page.

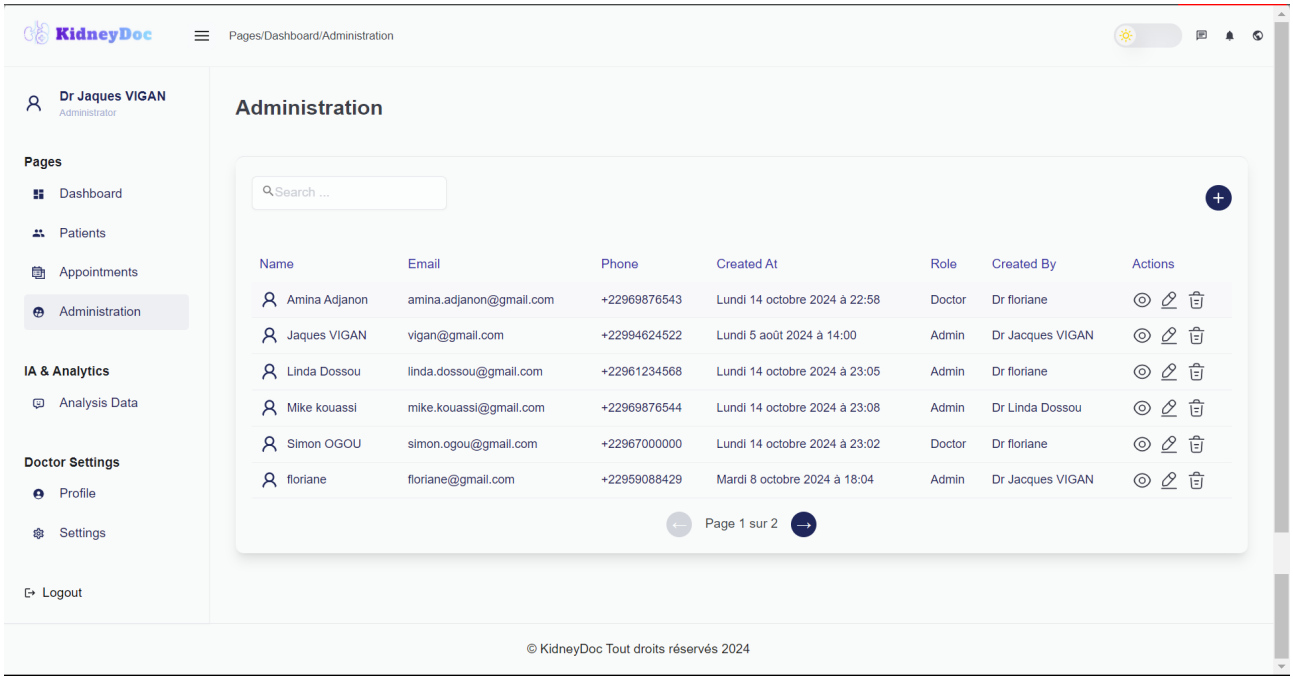


Figure 3.12: KidneyDoc Administration Page

- **Add or Modify Administrator/User Account**
  The interface for adding or modifying administrator or user accounts is straightforward and intuitive. Administrators can create new user profiles by entering relevant details such as name, email, and role. Additionally, they can update or correct information for existing users, ensuring the system remains up-to-date. This feature allows for efficient management of the platform's access control, ensuring that only authorized personnel have access to the application. Figure 3.13 and Figure 3.14 show the interfaces used to add or modify administrator or user accounts.

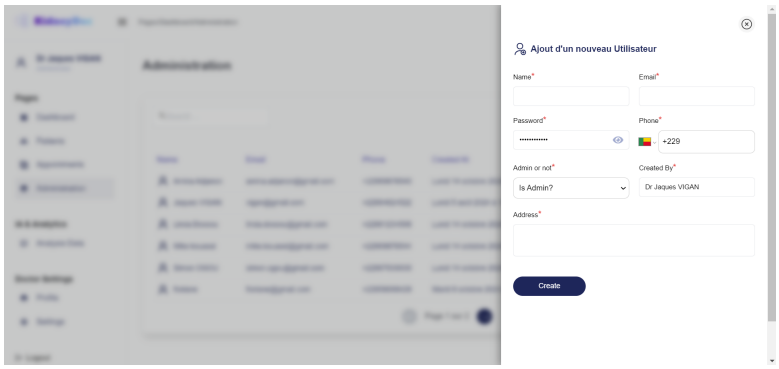


Figure 3.13: Add Administrator/User Account

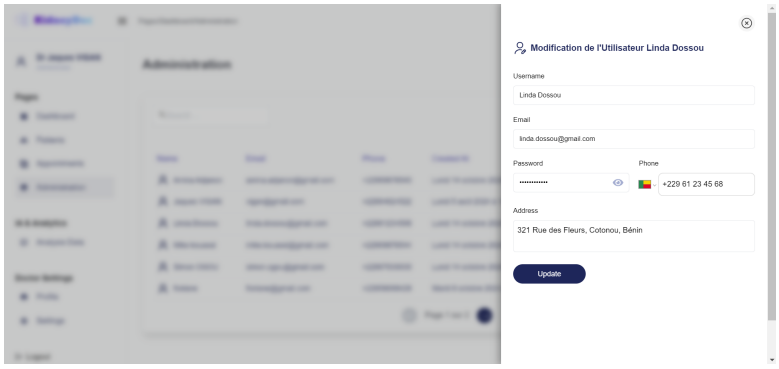


Figure 3.14: Modify Administrator/User Account

- **Delete Administrator/User Account**
  The interface for deleting administrator or user accounts is also managed by system administrators. When an administrator decides to delete a user account, the account is not permanently removed from the database but archived. This preserves the historical data associated with the account while preventing access to the platform.
  Figure 3.15 illustrates the interface used to delete an administrator/user account.

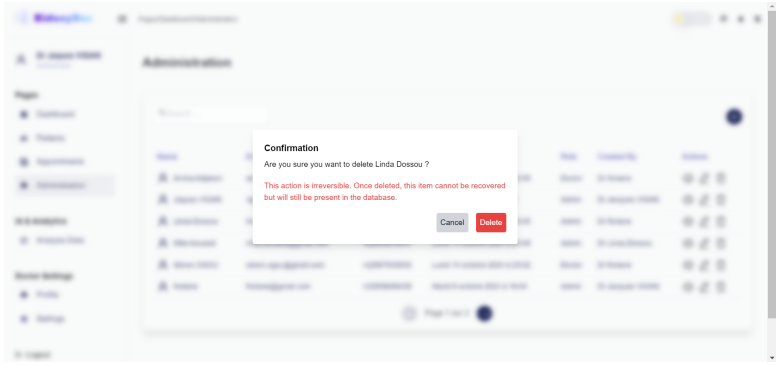


Figure 3.15: Delete Administrator/User Account Interface

- **Specific Patient Information**
  This page provides a detailed view of a patient's medical history, including past consultations, test results, and prescribed treatments. The interface uses graphs and charts to visually represent the patient's health over time, allowing healthcare professionals to easily track progress and make data-driven decisions.
  Figure 3.16 shows the detailed information page for a specific patient.

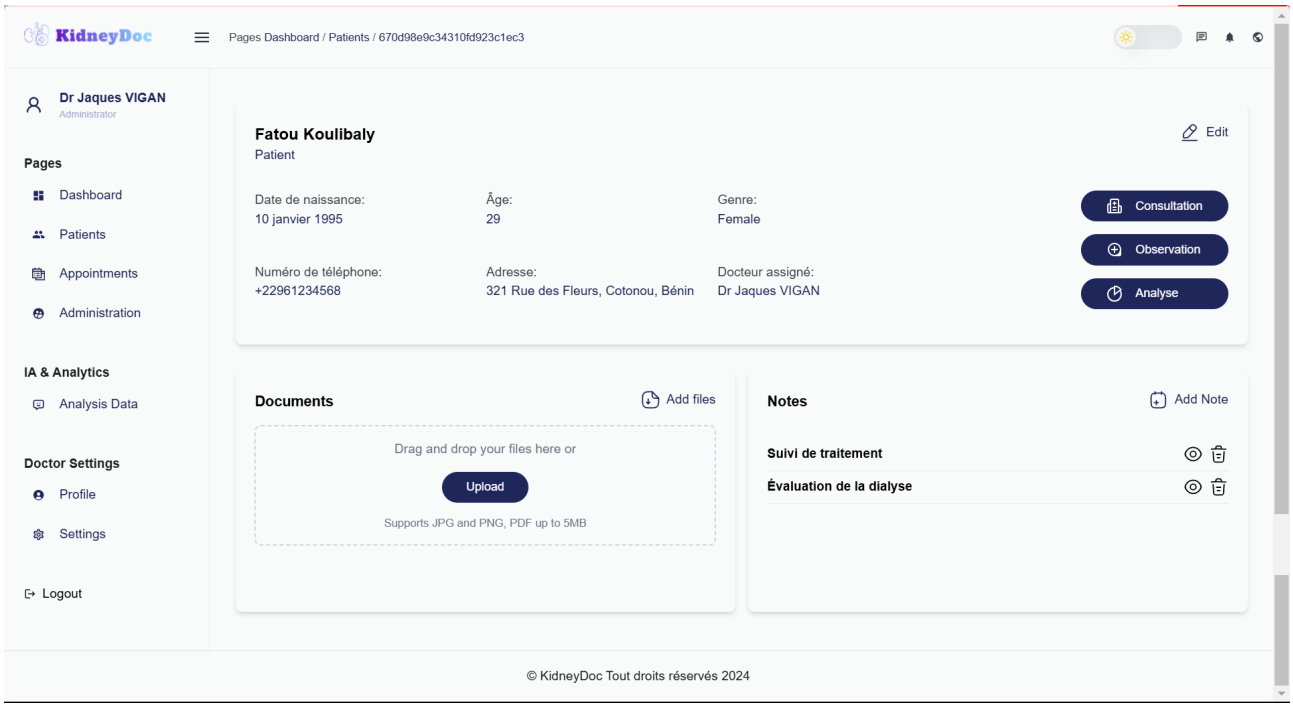


Figure 3.16: KidneyDoc Specific Patient Information

- **Patient Consultations Page**
  This page allows healthcare professionals to view a specific patient's consultation history. The interface displays a list of previous consultations. By clicking on a consultation, users can see more details, such as diagnoses, tests performed, and treatments prescribed, providing a comprehensive view of the patient's health.
  La Figure 3.17 illustre l'interface de consultation d'un patient.

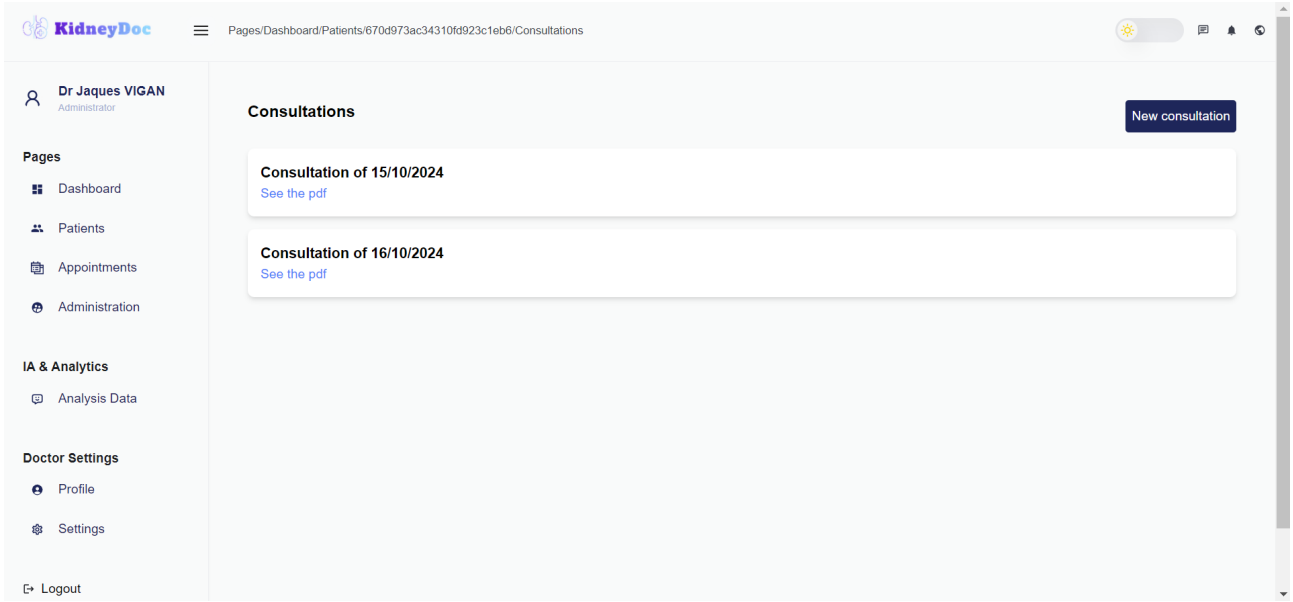
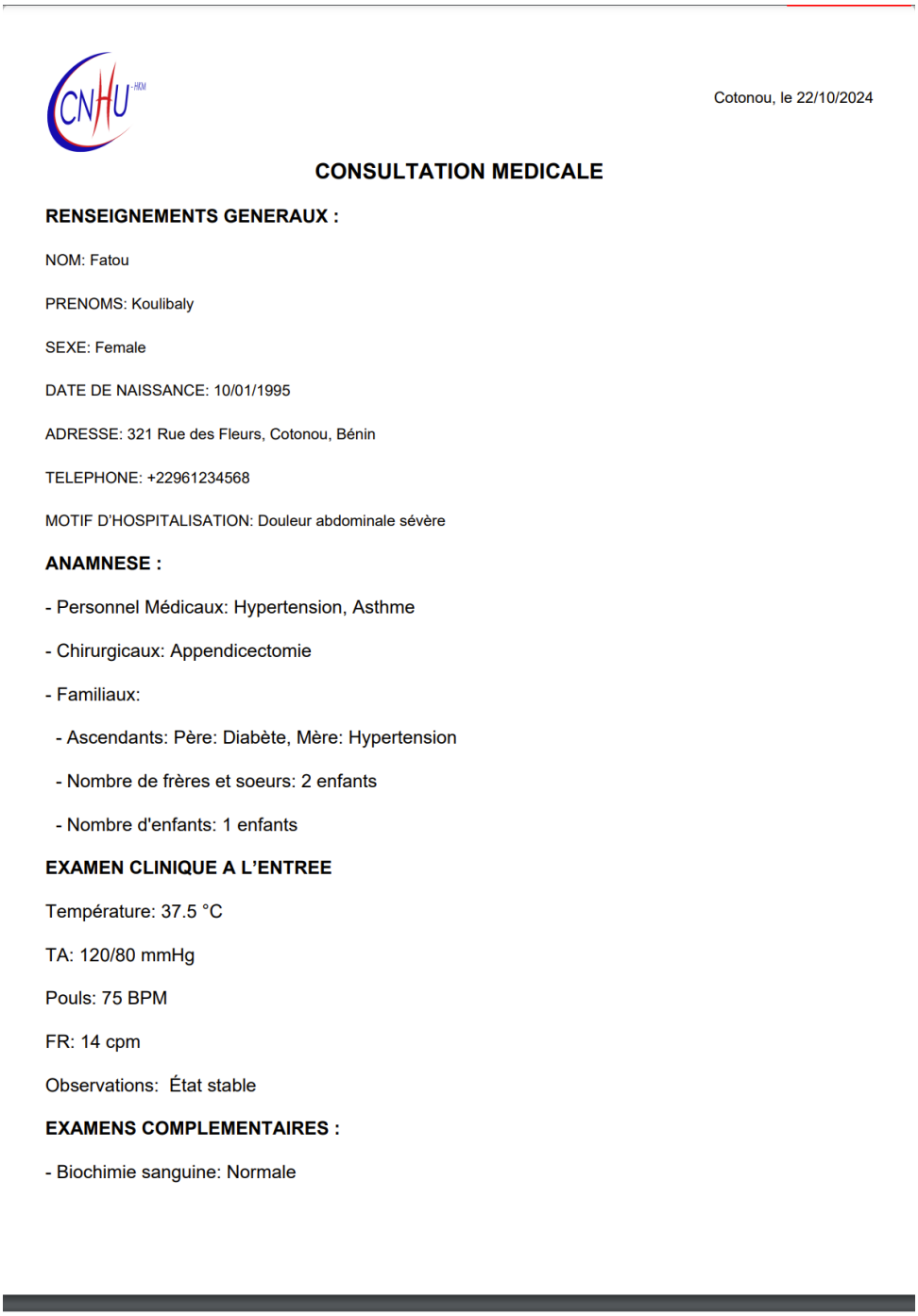


Figure 3.17: KidneyDoc Patient Consultations Page

- **Consultation PDF**
  Figure 3.18 shows the generated PDF for the patient's consultation. This document contains all relevant information regarding the patient's health status, including personal data, medical

history, and clinical examination results.



Cotonou, le 22/10/2024

CONSULTATION MEDICALE

RENSEIGNEMENTS GENERAUX :

NOM: Fatou

PRENOMS: Koulibaly

SEXE: Female

DATE DE NAISSANCE: 10/01/1995

ADRESSE: 321 Rue des Fleurs, Cotonou, Bénin

TELEPHONE: +22961234568

MOTIF D'HOSPITALISATION: Douleur abdominale sévère

ANAMNESE :

- Personnel Médicaux: Hypertension, Asthme
- Chirurgicaux: Appendicectomie
- Familiaux:
  - Ascendants: Père: Diabète, Mère: Hypertension
  - Nombre de frères et soeurs: 2 enfants
  - Nombre d'enfants: 1 enfants

EXAMEN CLINIQUE A L'ENTREE

Température: 37.5 °C

TA: 120/80 mmHg

Pouls: 75 BPM

FR: 14 cpm

Observations: État stable

EXAMENS COMPLEMENTAIRES :

- Biochimie sanguine: Normale
- Hémogramme: Normal
- Sérologie: Négative
- Analyse d'urine: Normale
- Échographie rénale: Normale
- Fond d'œil: Normal
- ECG: Rien à signaler

CONCLUSION :

Aucune information disponible.

Figure 3.18: Patient Consultation PDF

- **Add New Consultation**
  This interface allows healthcare professionals to add a new consultation for a patient. The form is organized into several steps, each covering different aspects such as symptoms, tests performed, diagnoses, and recommended treatments. A progress bar accompanies each step, updating as information is filled out.
  Figure 3.19 shows the Add New Consultation interface.

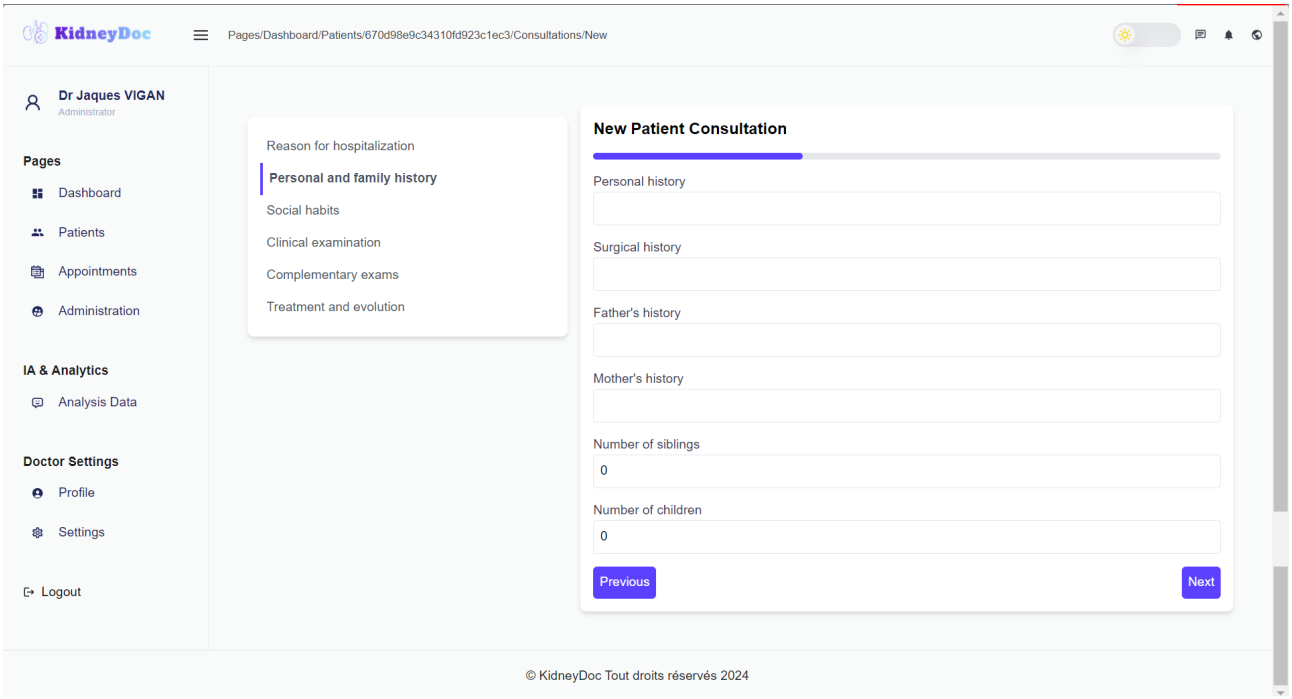


Figure 3.19: KidneyDoc Add New Consultation Interface

- **Add a New Note**
  This interface allows healthcare professionals to add a new note for a patient. The form includes fields for the title, type, and description of the note. Once the form is submitted, the note is added to the patient's list of notes.
  Figure 3.20 shows the interface for adding a new note.

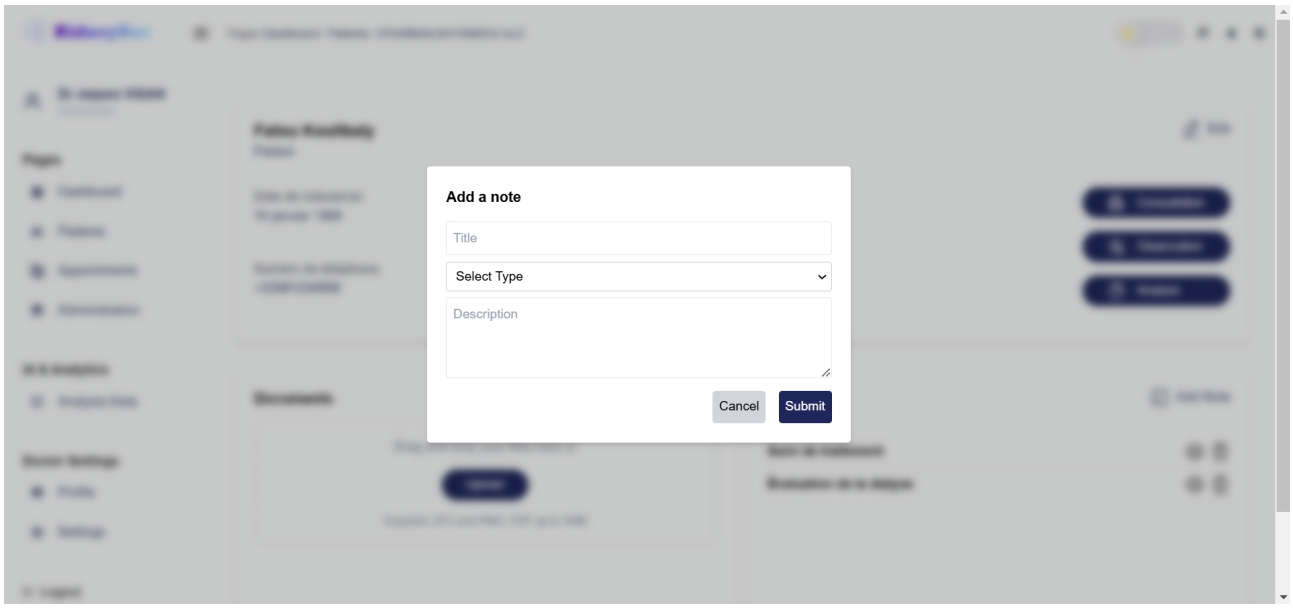


Figure 3.20: Add a New Note Interface in KidneyDoc

- **Note Visualization**
  This feature allows healthcare professionals to view the details of a specific note. By clicking on a note in the list, users can see the title, type, and description of the note in a PDF format.
  Figure 3.21 illustrates the note visualization interface.

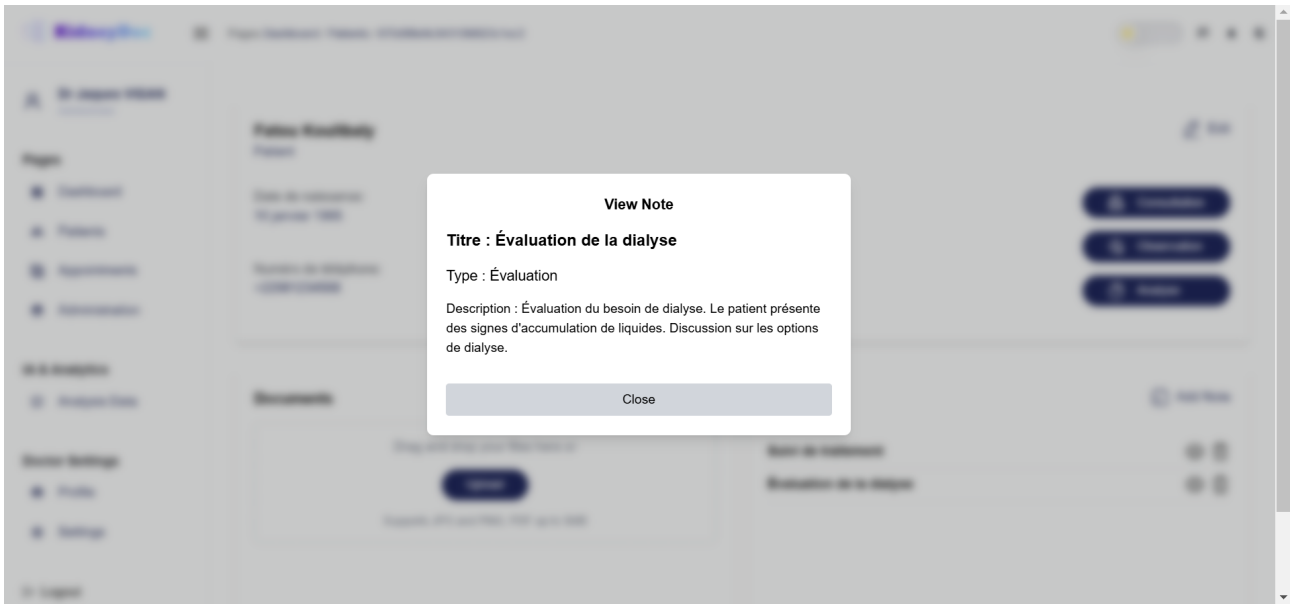


Figure 3.21: Note Visualization Interface in KidneyDoc

- **Appointment Page**
  The appointment page allows healthcare professionals to manage patient appointments efficiently. Users can view upcoming appointments, sort by date or doctor, and perform actions such as adding or canceling appointments. The interface is designed to streamline appointment scheduling and management, making it easier for healthcare providers to maintain an organized calendar.
  Figure 3.22 illustrates the KidneyDoc Appointment Page.

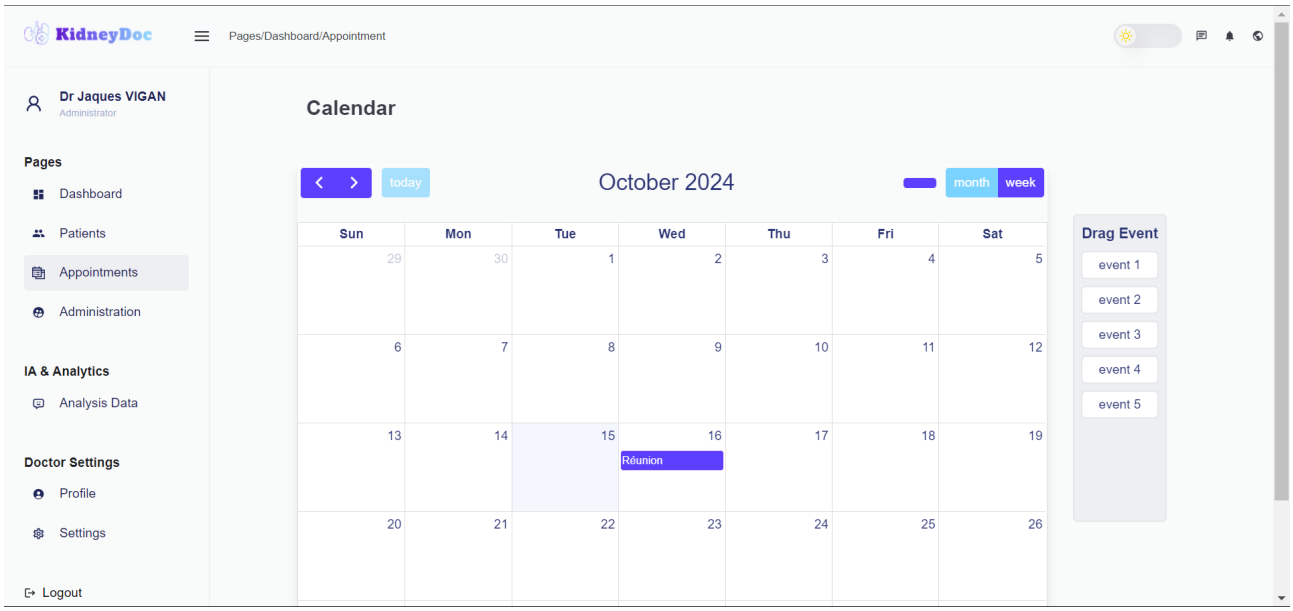


Figure 3.22: KidneyDoc Appointment Page

- **Add or Cancel Appointment**
  The interface for adding or canceling appointments is user-friendly and efficient. Healthcare providers can schedule new appointments by selecting the patient, doctor, and time slot, or they can cancel existing appointments with a simple action.
  Figure 3.23 and Figure 3.24 show the interfaces for adding or canceling an appointment.

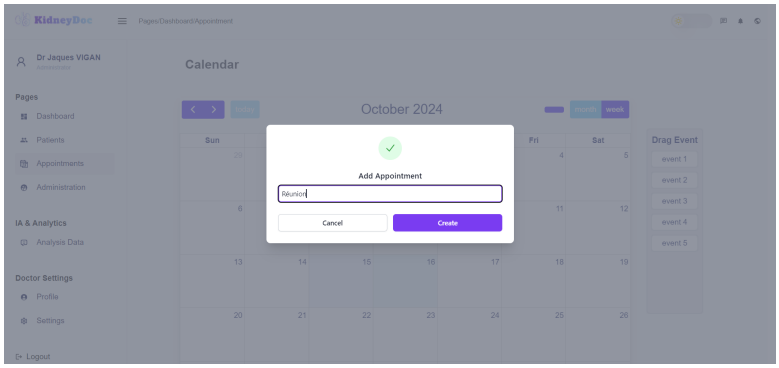


Figure 3.23: Add Appointment

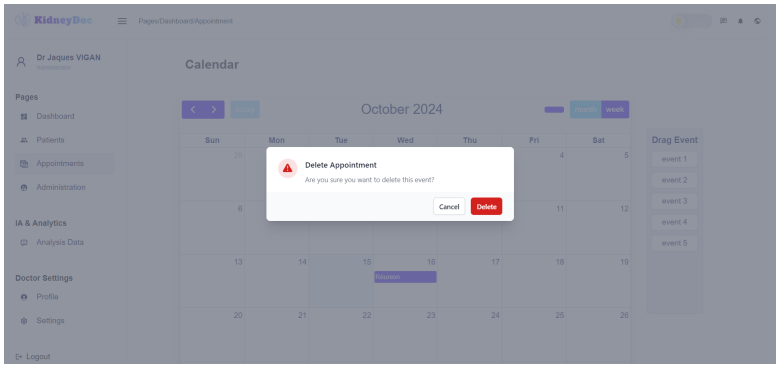


Figure 3.24: Cancel Appointment

- **Kidney Disease Stage Prediction Page**
  This page allows healthcare professionals to input patient data and receive predictions on the

stage of kidney disease. The interface is designed to be intuitive, allowing users to enter relevant clinical data such as blood pressure, glucose levels, and creatinine levels. The system processes the input and provides a prediction of the current stage of kidney disease, helping doctors in their decision-making process.
Figure 3.25 shows the interface for the Kidney Disease Stage Prediction Page.

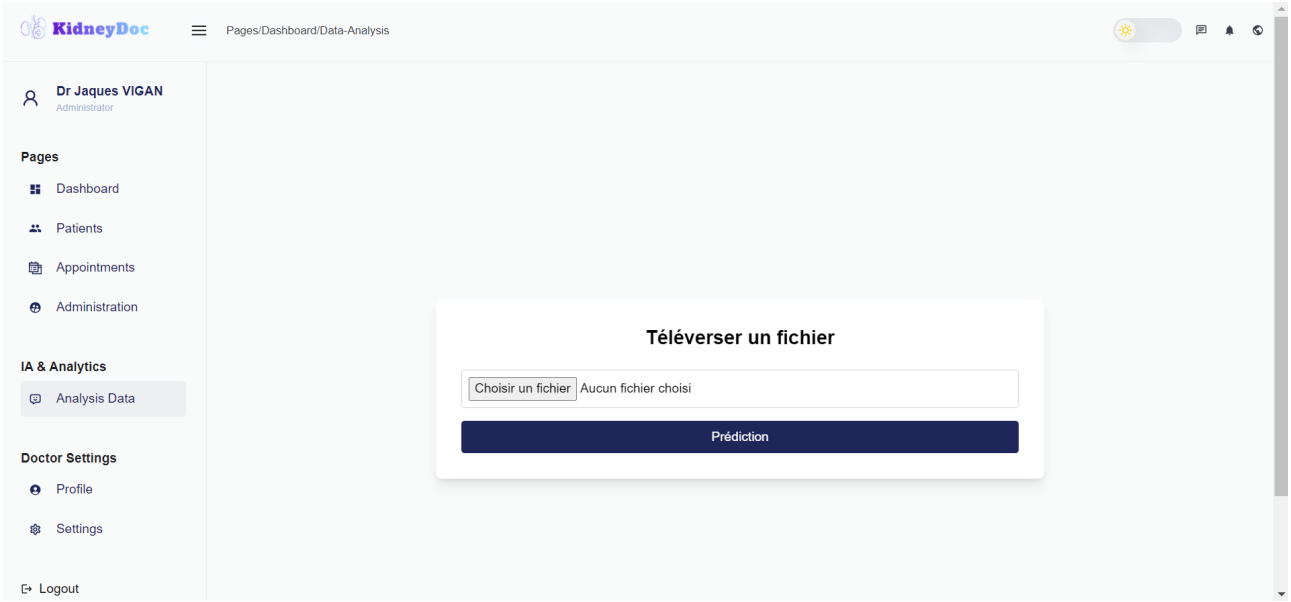


Figure 3.25: KidneyDoc Disease Stage Prediction Page

- **Input Data and View Prediction**
  The interface for entering patient data and viewing predictions is straightforward. Healthcare providers can input clinical variables, and after submitting the data, the system provides a predicted stage of kidney disease. This feature assists healthcare professionals by offering a fast and reliable prediction based on the latest medical data models.
  Figure 3.26 and Figure 3.27 show the interfaces for inputting patient data and viewing the prediction.

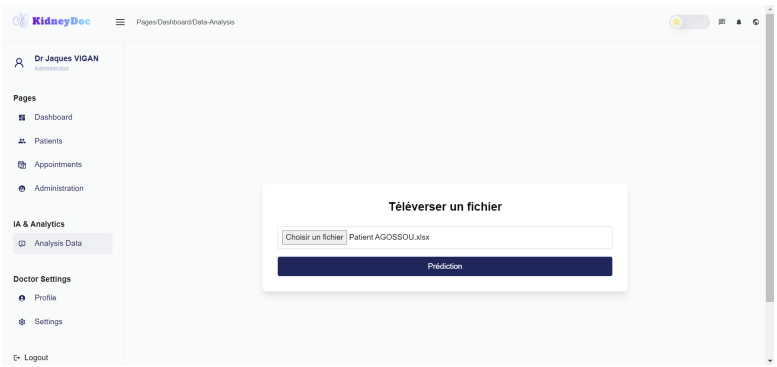


Figure 3.26: Input Patient Data for Prediction

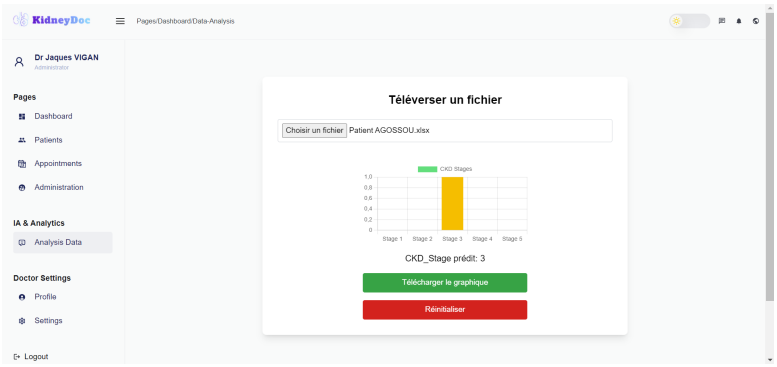


Figure 3.27: View Kidney Disease Stage Prediction

3.4 Discussion

3.4.1 System Architecture

The KidneyDoc platform is designed to support nephrology healthcare professionals in managing patient data, scheduling appointments, predicting kidney disease progression, and monitoring patient health. The architecture integrates critical features such as patient management, chronic kidney disease (CKD) stage prediction, and appointment scheduling to provide a streamlined, comprehensive solution for hospital operations.

The system is built using a modular approach, allowing for scalability and flexibility. Key components include:

- **Frontend Interface**: A user-friendly interface that allows healthcare providers to access patient records and manage appointments easily.
- **Backend Services**: Robust backend services that handle data processing, storage, and analytics for CKD predictions.
- **Database Management**: A secure database system designed to store large volumes of patient data efficiently while ensuring compliance with healthcare regulations.

3.4.2 Overall Difficulty

The development of the KidneyDoc platform faced several challenges. One significant issue was related to the CKD prediction model, which did not perform optimally due to limited historical data

samples. This limitation affected the model's ability to accurately forecast disease progression. Additionally, integrating various modules within the platform presented technical hurdles that required extensive research and troubleshooting.

Another challenge was the manual entry of patient data, which can be time-consuming and prone to errors. Furthermore, ensuring seamless integration with existing Electronic Health Records (EHRs) posed another layer of complexity.

Finally, maintaining security and privacy standards in compliance with regulations such as HIPAA required continuous assessment and updates to address evolving cybersecurity threats.

3.4.3 Evaluation Method

The KidneyDoc platform was evaluated by integrating data from a single source: the physical consultation records of patients. Healthcare professionals used the system to manage patient records efficiently. The platform's data centralization significantly streamlined record access and updates. Additionally, we tested the CKD prediction model using historical patient data. While the model's accuracy was lower due to limited training data, the system demonstrated strong performance in handling simultaneous queries and providing real-time insights for patient care.

3.4.4 Limits

While KidneyDoc demonstrates strong performance in managing nephrology patients, it is not without limitations. One significant limitation is the reliance on the quality of historical data for CKD predictions; limited datasets may reduce accuracy. Furthermore, full integration with external systems like Electronic Health Records (EHRs) remains a challenge. Security concerns also persist; although encryption measures are in place, ongoing assessments are necessary to address evolving cybersecurity threats. Lastly, the platform currently requires stable internet access for optimal functionality.

Conclusion

This chapter provides an overview of our findings regarding the KidneyDoc platform. We initially presented the results obtained from our work and then assessed both the achievements and limitations of our system. The platform effectively manages nephrology patients through its core functionalities, including patient data management and appointment scheduling. However, challenges such as data integration and prediction model accuracy need addressing to maximize its potential.

Future enhancements including improved CKD prediction models through expanded datasets and real time monitoring capabilities are planned to further solidify KidneyDoc's role in providing high-quality patient care. The integration of telemedicine features will also broaden access to healthcare services, making KidneyDoc an invaluable resource for nephrology practices aiming to improve outcomes for patients with chronic kidney disease.

General conclusion

In conclusion, KidneyDoc represents a transformative step in the digital management of patient information. By providing a comprehensive platform that integrates data handling, analytics, and user-friendly interfaces, we empower healthcare professionals to manage patient data more effectively. The application facilitates secure access to patient records, supports the creation of new consultations, and allows for the addition of analyses and observations, ultimately streamlining workflows in nephrology care.

Our approach emphasizes the importance of usability and accessibility, ensuring that healthcare providers can interact with the system intuitively. As we look to the future, there are numerous opportunities for enhancement. We aim to expand the system's capabilities by incorporating additional features, such as advanced data visualization tools and automated reporting functionalities. Furthermore, exploring partnerships with healthcare institutions for real-world testing will provide invaluable feedback, guiding our ongoing development.

Overall, KidneyDoc is poised to significantly improve patient care management, offering a robust solution that meets the evolving needs of healthcare professionals while ensuring the highest standards of data security and patient confidentiality.

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Annexe

Annexe 1: Résumé en français

Mise en Contexte

La gestion des informations médicales est un enjeu majeur dans le domaine de la santé, particulièrement pour les professionnels de néphrologie qui doivent suivre l'évolution des patients atteints de maladies rénales chroniques. Les systèmes traditionnels de gestion des données sont souvent inefficaces, car ils requièrent une saisie manuelle chronophage, présentent des difficultés d'accès à l'information, et manquent d'outils prédictifs permettant d'anticiper l'évolution des maladies. Ces limitations entraînent des pertes de temps, des erreurs potentielles dans le traitement des données, et un suivi sous-optimal des patients. La centralisation et la numérisation des informations médicales apparaissent donc comme une solution essentielle pour améliorer la qualité des soins et l'efficacité opérationnelle des établissements de santé. KidneyDoc répond à ces enjeux en offrant une solution numérique intégrée pour la gestion des dossiers médicaux en néphrologie.

Introduction de KidneyDoc

KidneyDoc est une plateforme innovante conçue spécifiquement pour répondre aux besoins des professionnels de néphrologie. Son objectif principal est de faciliter la gestion des dossiers médicaux des patients atteints de maladies rénales chroniques, tout en optimisant la planification des rendez-vous et en prédisant l'évolution des maladies. Grâce à une interface utilisateur intuitive et à l'intégration de technologies avancées, KidneyDoc permet aux professionnels de santé de consulter, modifier et suivre facilement les informations relatives aux patients. Cela permet une gestion plus efficace et réactive, avec une réduction des erreurs liées à la manipulation des données. KidneyDoc améliore ainsi l'organisation des soins et permet de mieux coordonner les actions médicales, contribuant à un meilleur suivi des patients et à une prise en charge plus proactive.

État de l'Art et Avancées de KidneyDoc

Dans la gestion des données de santé, plusieurs solutions comme Epic Systems et Cerner Corporation offrent des systèmes de dossiers médicaux électroniques (DME) intégrés, mais présentent des limitations telles que des coûts élevés et une complexité d'utilisation. De plus, des initiatives en Afrique, comme Kea Medical et OpenMRS, montrent un intérêt croissant pour la numérisation des données de santé, bien qu'elles puissent souffrir de dépendances technologiques et de manque de support.

KidneyDoc se distingue par son interface intuitive et sa flexibilité, répondant spécifiquement aux besoins des professionnels de santé en néphrologie. Une avancée majeure est l'intégration de modèles prédictifs pour suivre l'évolution des maladies rénales, permettant aux médecins de prévoir les stades de la maladie et d'améliorer la qualité des soins prodigués aux patients.

Notre Approche avec KidneyDoc

L'approche de KidneyDoc repose sur une architecture pensée pour être à la fois intuitive et performante. L'objectif est de simplifier le quotidien des professionnels de santé en leur offrant un outil qui réduit le temps passé sur les tâches administratives et améliore la coordination des soins. Grâce à une interface utilisateur claire, les professionnels peuvent interagir avec la plateforme de manière naturelle, consulter les dossiers médicaux, planifier les rendez-vous, et recevoir des alertes en temps réel lorsque des anomalies sont détectées.

KidneyDoc intègre également des algorithmes d'apprentissage automatique qui, en se basant sur les données médicales, peuvent générer des analyses prédictives pour aider les médecins à anticiper l'évolution des pathologies. Ces analyses permettent d'adapter les plans de traitement en fonction des besoins spécifiques de chaque patient, garantissant une approche individualisée et plus efficace des soins.

Architecture du Système

La plateforme KidneyDoc est conçue pour soutenir les professionnels de la santé en néphrologie dans la gestion des données des patients, la planification des rendez-vous, la prédiction de la progression des maladies rénales, et le suivi de la santé des patients. L'architecture intègre des fonctionnalités critiques telles que la gestion des patients, la prédiction des stades de la maladie rénale chronique (MRC) et la planification des rendez-vous, fournissant ainsi une solution complète pour les opérations hospitalières.

Le système est construit sur une approche modulaire, permettant évolutivité et flexibilité. Les composants clés incluent :

- **Interface Frontend** : Une interface conviviale permettant aux professionnels de santé d'accéder facilement aux dossiers des patients et de gérer les rendez-vous.
- **Services Backend** : Des services robustes qui gèrent le traitement des données, le stockage et les analyses pour les prédictions de MRC.
- **Gestion de Base de Données** : Un système de base de données sécurisé conçu pour stocker efficacement de grands volumes de données patients tout en garantissant la conformité avec les réglementations de santé.

Méthodologie de Développement

Le développement de l'application **KidneyDoc** s'est déroulé en plusieurs phases clés pour assurer une mise en œuvre efficace :

- **Définition des Exigences** : Rassemblement des exigences fonctionnelles et non fonctionnelles avec les parties prenantes du département de néphrologie.

- **Identification des Fonctionnalités** : Décomposition des exigences en user stories, facilitant le développement de fonctionnalités spécifiques comme la gestion des consultations et l'analyse prédictive.
- **Modélisation UML** : Utilisation de l'UML pour visualiser l'architecture du système à travers des diagrammes (classes, séquences, cas d'utilisation).
- **Sélection de la Stack Technologique** : Choix de **Next.js** pour le frontend et **MongoDB** pour le backend, avec **FastAPI** pour les services backend et l'intégration de l'**IA**.
- **Développement de l'Application** : Mise en œuvre des fonctionnalités principales avec une interface utilisateur conviviale et des services backend sécurisés.
- **Validation des Fonctionnalités** : Tests et révisions par des professionnels de santé pour garantir l'adéquation aux besoins cliniques.
- **Tests Unitaires et d'Application** : Soumission de chaque fonctionnalité à des tests rigoureux et validation avec des données réelles.

Technologies Utilisées

Le projet KidneyDoc repose sur une architecture technologique moderne, garantissant sécurité, scalabilité et fluidité. Nous utilisons **FastAPI**, un framework web performant pour construire des API en Python, qui facilite l'intégration de modèles d'apprentissage automatique. **JavaScript** est utilisé pour créer des interfaces utilisateur interactives, tandis que **Next.js** assure un rendu côté serveur pour une expérience utilisateur rapide lors de l'accès aux dossiers médicaux.

MongoDB est choisi pour sa capacité à gérer efficacement des données complexes et variées, permettant une gestion sécurisée des dossiers patients. **Docker** est utilisé pour containeriser l'application, ce qui facilite son déploiement sur différentes plateformes. Enfin, **Visual Studio Code** est notre environnement de développement intégré, offrant des outils puissants pour le codage et le débogage.

Fonctionnalités

KidneyDoc offre plusieurs fonctionnalités clés :

- **Consultation des Dossiers Patients** : Accès rapide et sécurisé aux informations médicales.
- **Création de nouvelles consultations et d'observations** : Ajout de nouveaux dossiers et suivi des patients.
- **Recherche et Tri des Dossiers** : Outils de recherche avancée pour une gestion efficace des données.
- **Génération de Fiches de Consultation** : Création de documents récapitulatifs pour les consultations.
- **Analyse des Données** : Outils d'analyse pour visualiser les tendances et les résultats des patients.

Ces technologies et fonctionnalités permettent d'optimiser le parcours de soin, offrant aux professionnels de santé un accès rapide et efficace aux informations des patients, leur permettant ainsi de se concentrer sur l'essentiel : fournir des soins de qualité.

Résultats Obtenus et Limitations

Le projet KidneyDoc a permis la création d'une plateforme robuste et fonctionnelle, qui a démontré son efficacité lors des phases de tests. La gestion centralisée des dossiers médicaux et la planification des rendez-vous ont considérablement amélioré l'efficacité des services hospitaliers en néphrologie. Les prédictions sur l'évolution des maladies rénales se sont révélées utiles pour ajuster les traitements et mieux anticiper les complications.

Cependant, certaines limitations persistent. La précision des modèles prédictifs dépend fortement de la qualité et du volume des données disponibles. De plus, l'intégration complète avec d'autres systèmes hospitaliers, tels que les Dossiers Médicaux Électroniques (DME), reste un défi. Enfin, KidneyDoc nécessite une connexion Internet stable pour garantir son fonctionnement optimal, ce qui peut poser problème dans certains environnements hospitaliers.

Tests et Déploiement

Des phases de tests rigoureux ont été mises en place pour évaluer la performance et la fiabilité de KidneyDoc. Ces tests comprenaient des essais fonctionnels, des tests de charge et des évaluations de sécurité. Ce processus a permis de s'assurer que toutes les fonctionnalités étaient opérationnelles et que les utilisateurs étaient formés à l'utilisation de la plateforme.

Aspects de Sécurité

La sécurité des applications web est un composant critique, surtout pour celles gérant des données sensibles telles que les informations personnelles. Dans ce projet, construit avec **Next.js 14**, plusieurs mesures de sécurité ont été mises en œuvre pour garantir la confidentialité, l'intégrité et la disponibilité des données.

- **Authentification et Autorisation** : Le mécanisme d'authentification et d'autorisation est géré par **NextAuth** avec une connexion basée sur des identifiants, garantissant que seuls les utilisateurs autorisés peuvent accéder à certaines parties de l'application.
- **Hachage des Mots de Passe** : Les mots de passe des utilisateurs ne sont jamais stockés en texte clair. Au lieu de cela, le projet utilise l'algorithme **bcrypt** pour hacher les mots de passe avant de les stocker dans la base de données.
- **Gestion des Sessions** : La gestion des sessions est effectuée par les rappels de session de NextAuth. Après une authentification réussie, des informations supplémentaires sur l'utilisateur sont ajoutées au token de session, qui est stocké et géré en toute sécurité.
- **Protection contre les Attaques Courantes** : Plusieurs couches de protection sont mises en œuvre contre les vulnérabilités courantes :
  - **Injection MongoDB** : L'application utilise des requêtes sécurisées avec **MongoDB**, ce qui aide à atténuer les attaques par injection en échappant et en assainissant les entrées utilisateur.
  - **Protection CSRF** : La protection CSRF est intégrée avec NextAuth. Des tokens CSRF supplémentaires sont émis lors d'actions sensibles pour garantir que les requêtes sont légitimes.

Avec ces mesures de sécurité en place, le projet garantit un accès sécurisé et une protection robuste des données des utilisateurs.

Conclusion et Perspectives

KidneyDoc représente une avancée significative dans la gestion des dossiers médicaux en néphrologie. Grâce à ses fonctionnalités avancées et à son interface intuitive, la plateforme facilite le suivi des patients et l'organisation des soins. Pour garantir une sécurité accrue des données sensibles, l'intégration de la technologie blockchain est envisagée. Cela permettrait de créer un registre immuable des transactions et des accès aux dossiers médicaux, renforçant ainsi la protection des informations des patients.

Toutefois, des améliorations sont encore possibles, notamment en ce qui concerne l'intégration avec d'autres systèmes hospitaliers, l'optimisation des modèles prédictifs, et l'ajout de nouvelles fonctionnalités comme la télémédecine ou le suivi en temps réel des patients à distance. Ces développements futurs permettront à KidneyDoc de devenir un outil incontournable pour les professionnels de santé, contribuant à l'amélioration continue des soins aux patients atteints de maladies rénales.

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