UML Modeling and Full-Stack Implementation of a Teleconsultation Platform with Real-Time Management of Patients and Medical Procedures

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Abstract: In response to the rapid expansion of telemedicine services, this paper presents the design and implementation of a teleconsultation platform based on systematic UML modeling and a full-stack architecture. The design process includes the definition of functional requirements through use case diagrams, the structuring of business entities via class diagrams, and the orchestration of dynamic interactions using sequence diagrams. The developed infrastructure is supported by a relational database optimized for managing user profiles, teleconsultation sessions, and medical prescriptions. The back-end is designed to ensure data persistence and secure request processing, while the front-end, built around a reactive architecture, enables real-time visualization of biomedical parameters. The platform also handles authentication management and medical transactions, with automated generation of digital prescriptions. The results demonstrate the system's robustness, scalability, and compliance with the requirements of modern digital healthcare environments.

Keywords: *UML Modeling, Full-Stack Development, Patient Management, Real-Time Visualization, Medical Database.*

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I. INTRODUCTION

Telemedicine, which has seen significant growth since the global health crisis, has emerged as a viable alternative to enhance healthcare accessibility and alleviate the burden on traditional healthcare facilities [1]. With the rise of digital technologies and connected health, developing teleconsultation platforms with integrated real-time services has become a critical challenge [2], [3]. These platforms must not only meet high standards for data security, ease of use, and interoperability but also incorporate rigorous modeling tools to ensure their reliability [4], [5].

In this context, the use of UML (Unified Modeling Language) for modeling functional requirements and business processes has become a standardized practice for effectively structuring software development [5], [6]. Simultaneously, the full-stack architecture—combining both front-end and back-end development—offers an integrated approach to building robust and scalable solutions that meet the evolving needs of the healthcare sector [7]. The integration of features such as user management, teleconsultation conduct, real-time medical data visualization, and secure generation of electronic prescriptions are now essential components of a comprehensive solution [8].

This paper proposes the design and implementation of an interactive teleconsultation platform, based on rigorous UML modeling and a full-stack architecture, aiming to deliver an optimal user experience, enhanced security, and scalability in line with current digital health standards.

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II. METHODS

A. *Development Approach*

The design of the teleconsultation platform followed an incremental and iterative methodology inspired by Agile development practices [9]. This approach enabled the progressive evolution of the system, continuously integrating functional requirements and feedback from anticipated platform usage. The development process was structured into three main phases: modeling, implementation, and functional validation.

B. *UML Modeling*

The design phase was based on rigorous UML modeling, following the best practices recommended by Rumbaugh et al. [6]. Three main types of diagrams were developed:

- **Use Case Diagrams**: To identify system actors (patients, doctors, administrators) and specify the main functionalities (account creation, authentication, teleconsultation, prescription generation)[5].
- **Class Diagrams**: To model business entities, their attributes, and their relationships, ensuring database consistency[5].
- **Sequence Diagrams**: To dynamically describe interactions between users and the system, especially during teleconsultation sessions and the issuance of digital prescriptions[5].

C. *Technical Architecture and Full-Stack Implementation*

The technical implementation was carried out following a full-stack architecture, comprising:

- **Front-end**: Developed using modern technologies (React.js) to provide an ergonomic and responsive user interface, promoting a smooth and intuitive user experience [10].
- **Back-end**: Built with robust frameworks (Django), enabling secure management of authentications, medical data flows, and teleconsultation processes.
- **Database**: A relational database (PostgreSQL) was used to store user profiles, teleconsultation histories, and digital prescriptions, following normalization principles to ensure data integrity [11].

Communication between the different system layers was secured using the HTTPS protocol. For real-time biomedical data visualization, WebSocket technology was integrated, as recommended by modern connected health architectures [12].

D. *Security and Confidentiality*

Data security was considered from the early stages of design, following HIPAA (Health Insurance Portability and Accountability Act) standards for sensitive data encryption and access management [4]. Strong authentication techniques (using hashed passwords and JWT tokens) were implemented to protect access to critical resources.

E. *Functional Validation*

Platform validation was conducted through test scenarios covering all use cases. Each critical functionality—including account creation, teleconsultation, real-time data visualization, and prescription generation—was individually tested and assessed through complete workflows to ensure functional compliance and system stability.

F. *Summary Table of Technologies Used*

The following table summarizes the technologies employed within the platform as described.

Table 1: Summary Table of Technologies Used

Component	Technologies Used	Role
Front-end	React.js	Responsive and intuitive user interface
Back-end	Django	Management of authentication, medical data, and teleconsultation services
Database	PostgreSQL	Storage of user profiles, consultations, and prescriptions
Network Communication	HTTPS	Securing exchanges between client and server
Real-Time Communication	WebSockets	Real-time transmission of biomedical data
Authentication	JWT (JSON Web Token), hashed password	Secure access to functionalities
Security & Compliance	HIPAA Standards	Protection of sensitive data
UML Modeling	Use case, class, and sequence diagrams (standard UML)	Structured system design

III. RESULTS

A. *Conceptual Modeling*

The initial phase of development resulted in a rigorous modeling of the system through the UML formalism, enabling a clear structuring of requirements and interactions among system components. Three main types of diagrams were produced:

➢ *Use Case Diagrams*

These diagrams identified the main functionalities accessible to users (patients, practitioners, administrators), such as account creation, authentication, teleconsultation, and record management.

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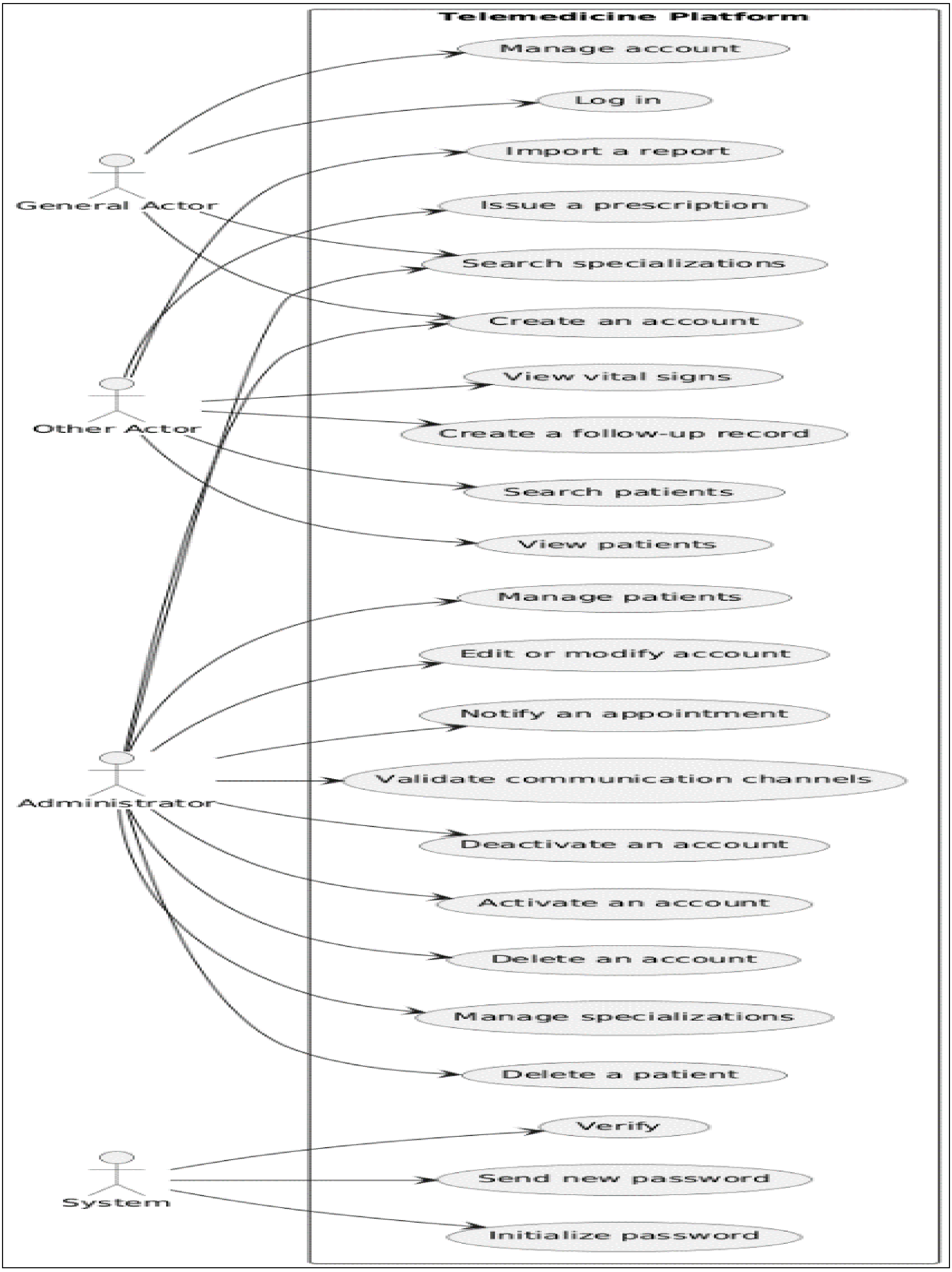

Fig 1: Use Case Diagrams

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➢ *Class Diagrams*

They represented the core entities of the platform (User, Patient, Practitioner, Consultation, Prescription) along with their relationships.

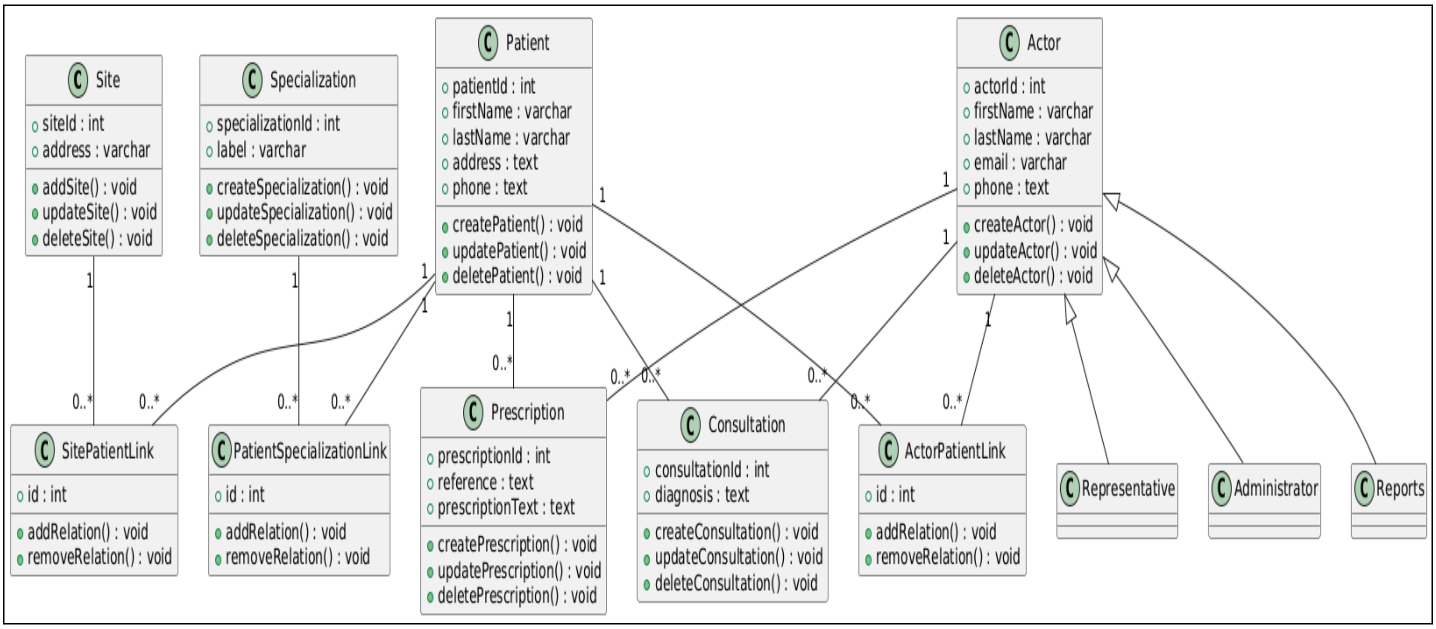

Fig 2: Class Diagrams

➢ *Sequence Diagrams*

These diagrams illustrated the sequences of interactions between system components for key scenarios, including:

- *Account Creation*

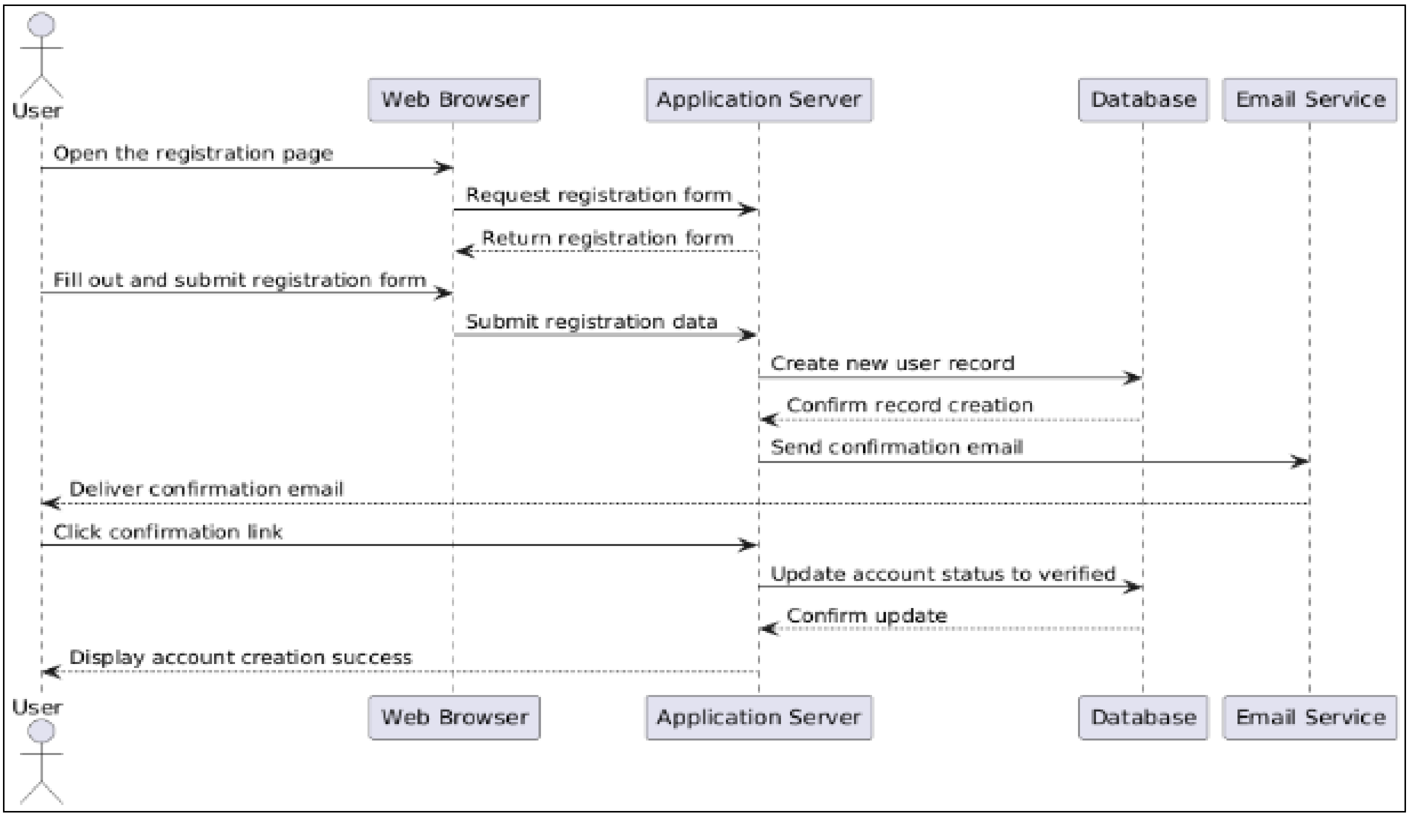

Fig 3: Sequence Diagrams: Account Creation

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- *Authentication*

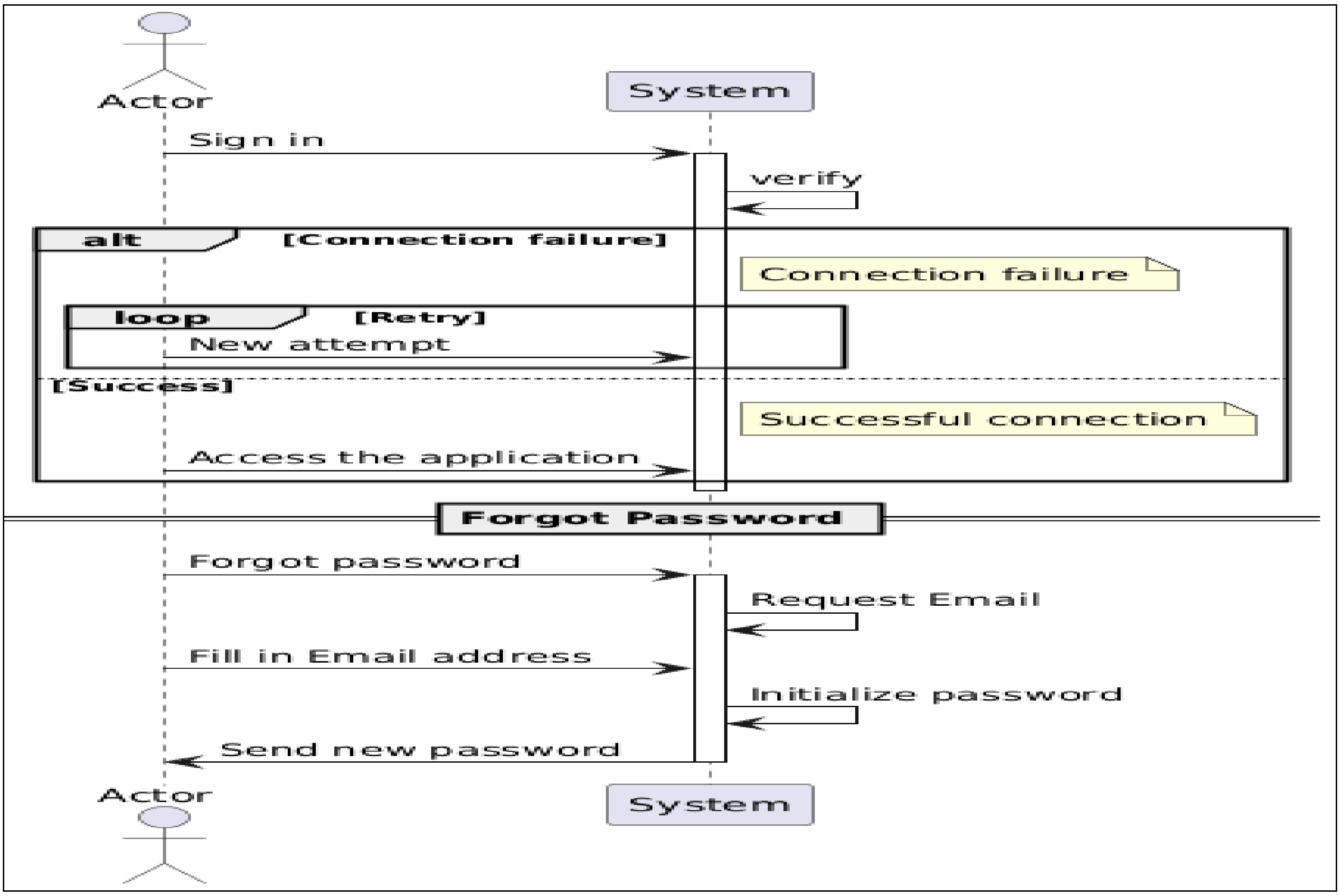

Fig 4: Sequence Diagrams: Authentication

- *Telemedicine Act*

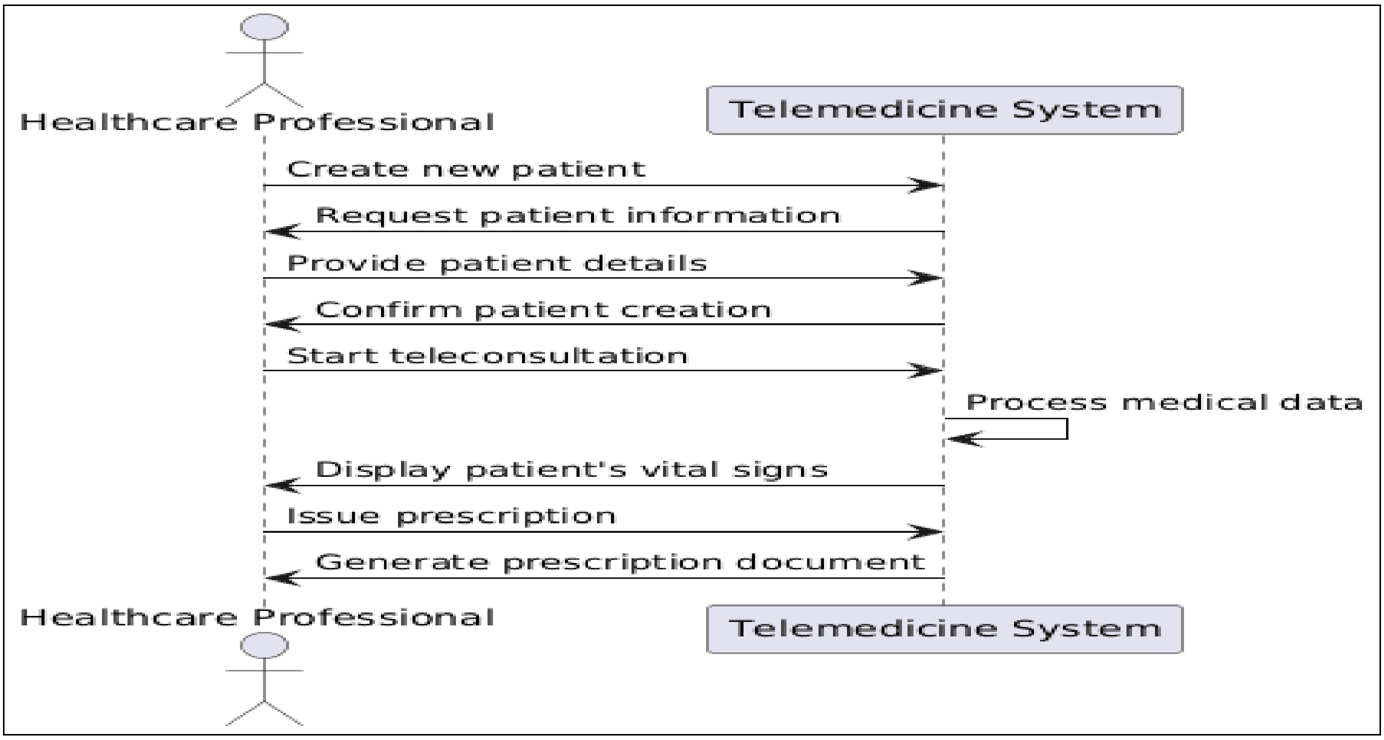

Fig 5: Sequence Diagrams : Telemedecine Act

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This conceptual modeling provided a solid foundation for the subsequent technical implementation.

B. User Interface Rendering

➤ *Stakeholders and Patient Management Platform*

The developed platform ensures centralized management of all information related to the stakeholders involved in the teleconsultation system. It allows easy access to healthcare professionals' data, categorized by specialization and site of practice. Similarly, patients can be quickly retrieved based on their name, geographic area, or required medical specialty.

Communication between actors is facilitated by the integration of a video call functionality, promoting medical assistance and collaborative expertise. Access rights (read, write, modify) are defined according to the role assigned to each user, ensuring data confidentiality and restricting access to only necessary information. Only the administrator holds extended privileges, allowing full access to all features and application settings.

Upon opening, the platform requires user authentication via a username and password. Access is granted only if the entered credentials match the database records, thereby ensuring secure access management.

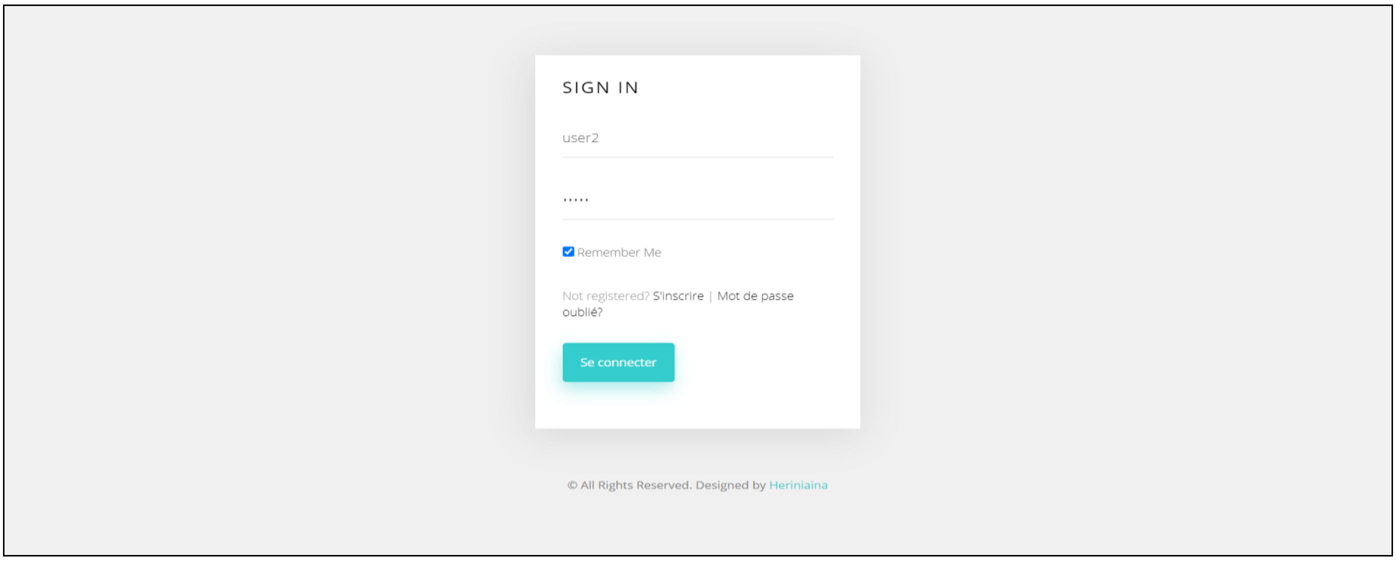

Fig 6: Login Form

➤ *For New Users, A Registration Interface is Available, Requiring the Following Information:*

- Profile picture
- Username
- Last name
- First name
- Email address
- Password and confirmation
- Specialization
- Site of practice
- Gender
- Assigned role

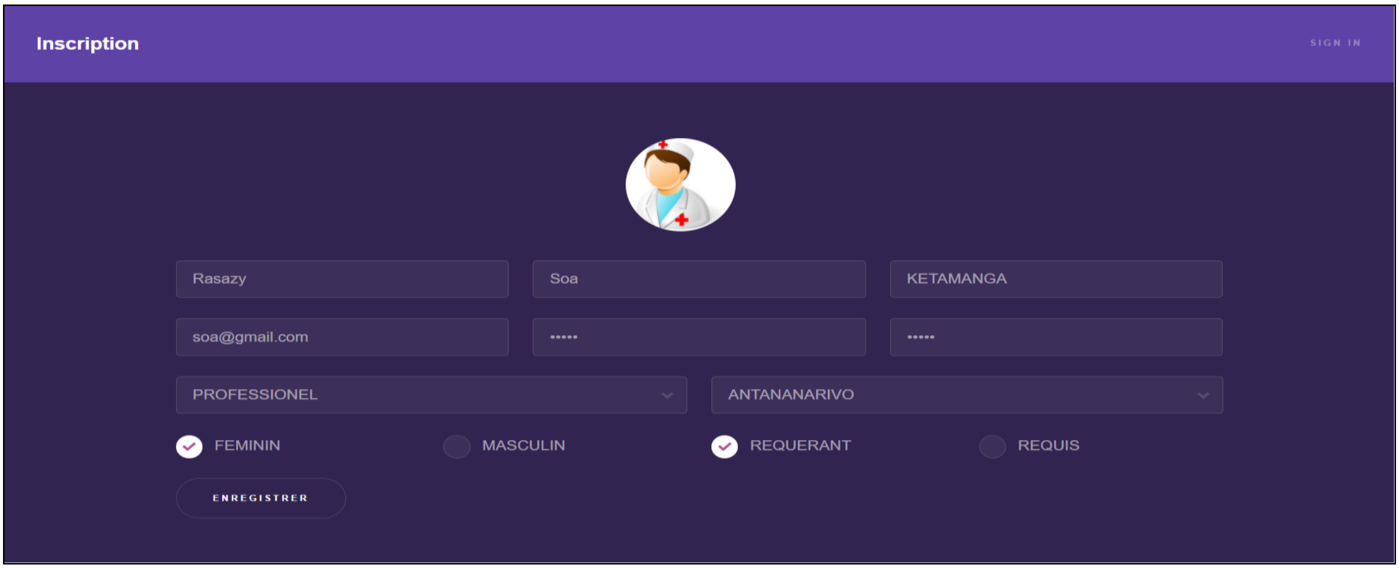

Fig 7: Registration Form

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Once registered, the account is created with an inactive status pending administrative approval. The email address serves as the primary login credential.

In case of forgotten passwords, a reset mechanism is available: the user submits a request via their recovery email and receives a system-generated temporary password.

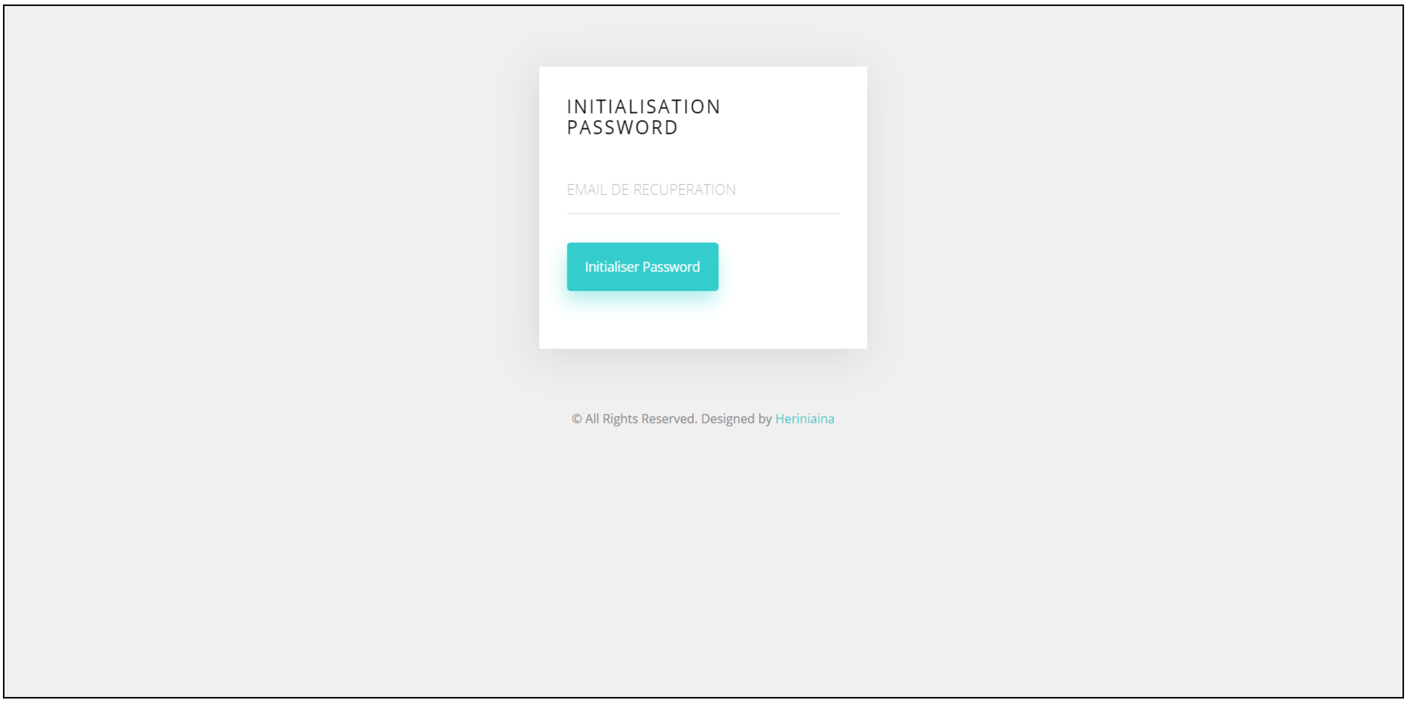

Fig 8: Password Reset Form

After successful authentication, the user is redirected to the home page, which displays a welcome message, a brief platform overview, personal account information, and a navigation menu for accessing different functionalities.

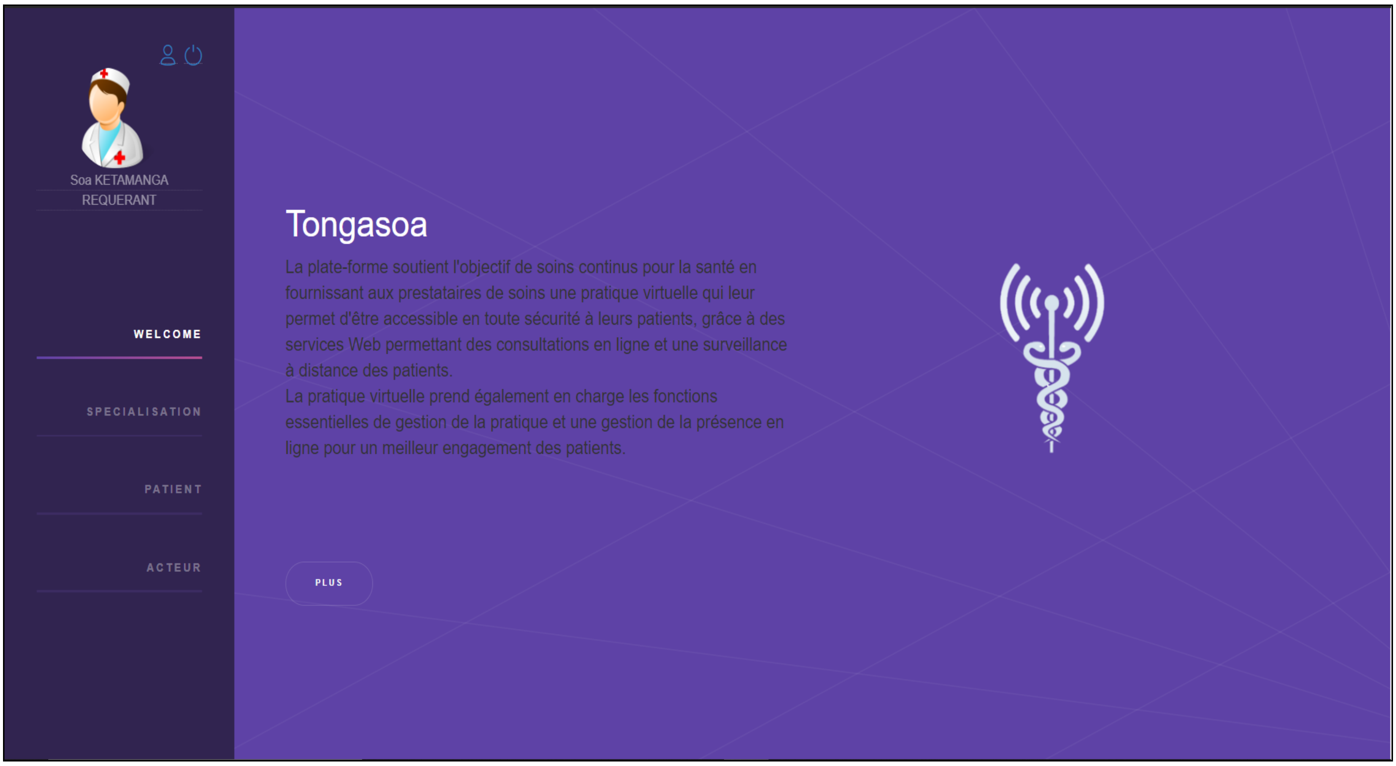

Fig 9: Home Page

The "Specialization" menu presents the list of available medical specializations. This section is accessible to all users, but only administrators can add, modify, or delete specializations.

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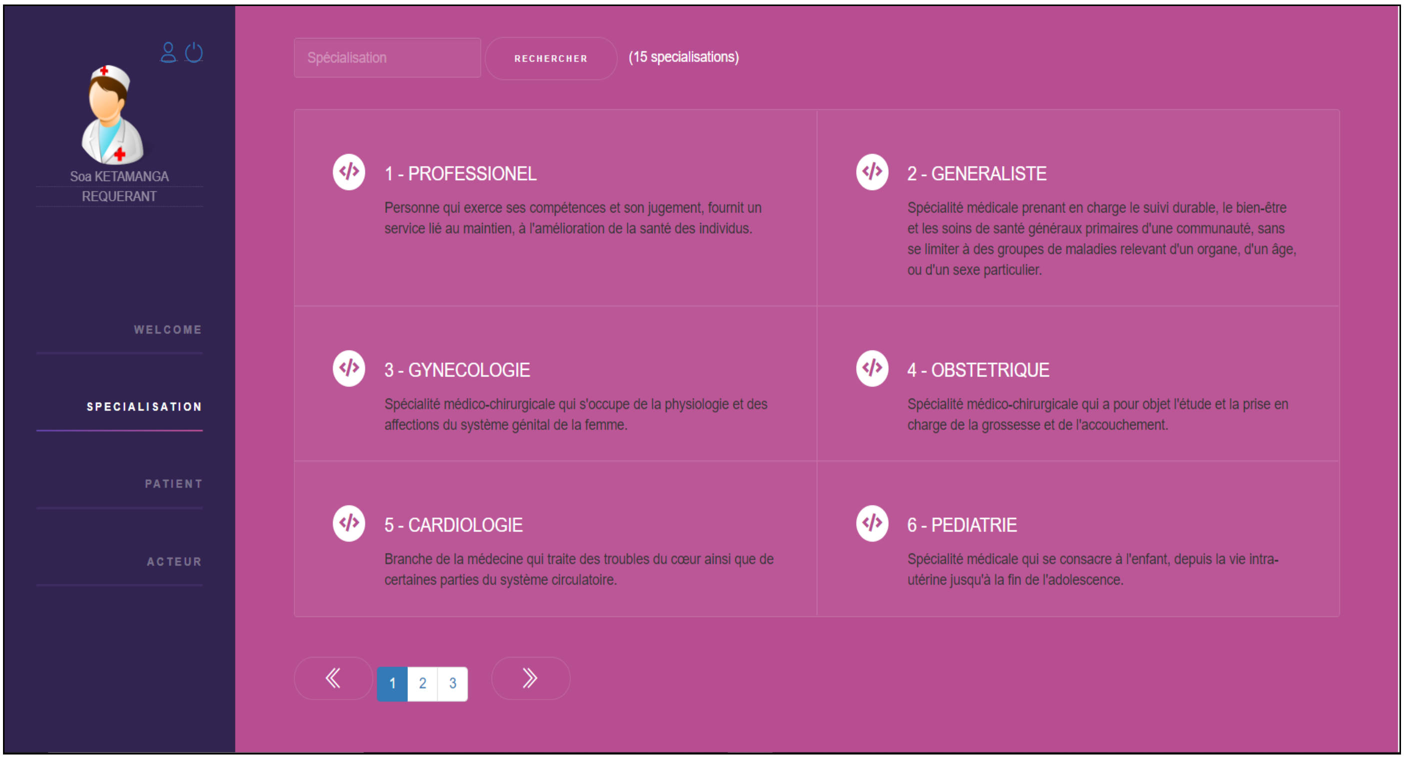

Fig 10: Specialization Section

Through the "Patient" menu, healthcare professionals can view and manage patient records. Each patient is associated with a unique identifier in the form of an automatically generated QR code, facilitating rapid identification. Options are also available to add or update information, generate medical prescriptions, and export them as PDF files.

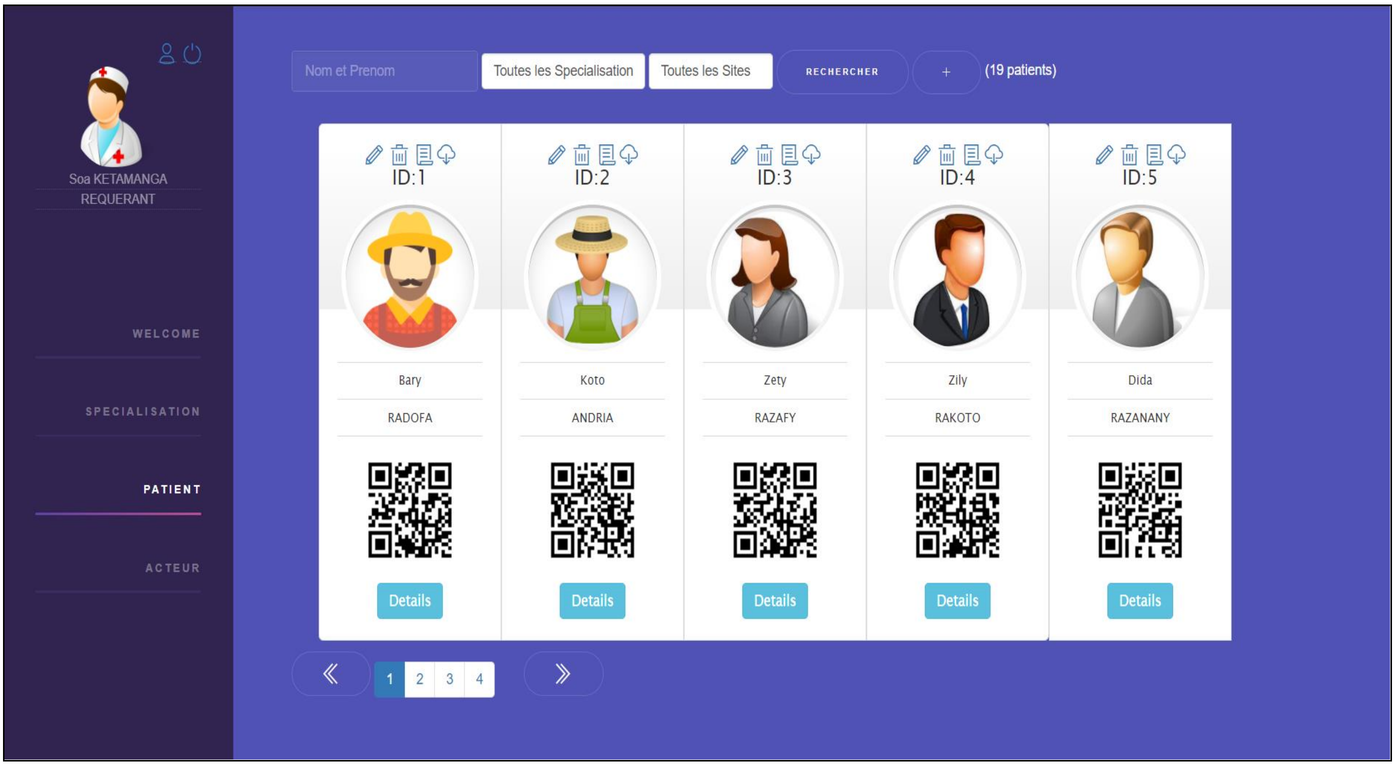

Fig 11: Patient Section

The "Stakeholders" menu gathers the directory of practitioners: requesting personnel, referred physicians, and administrators. These stakeholders can initiate video calls for conducting teleconsultations or expertise exchanges.

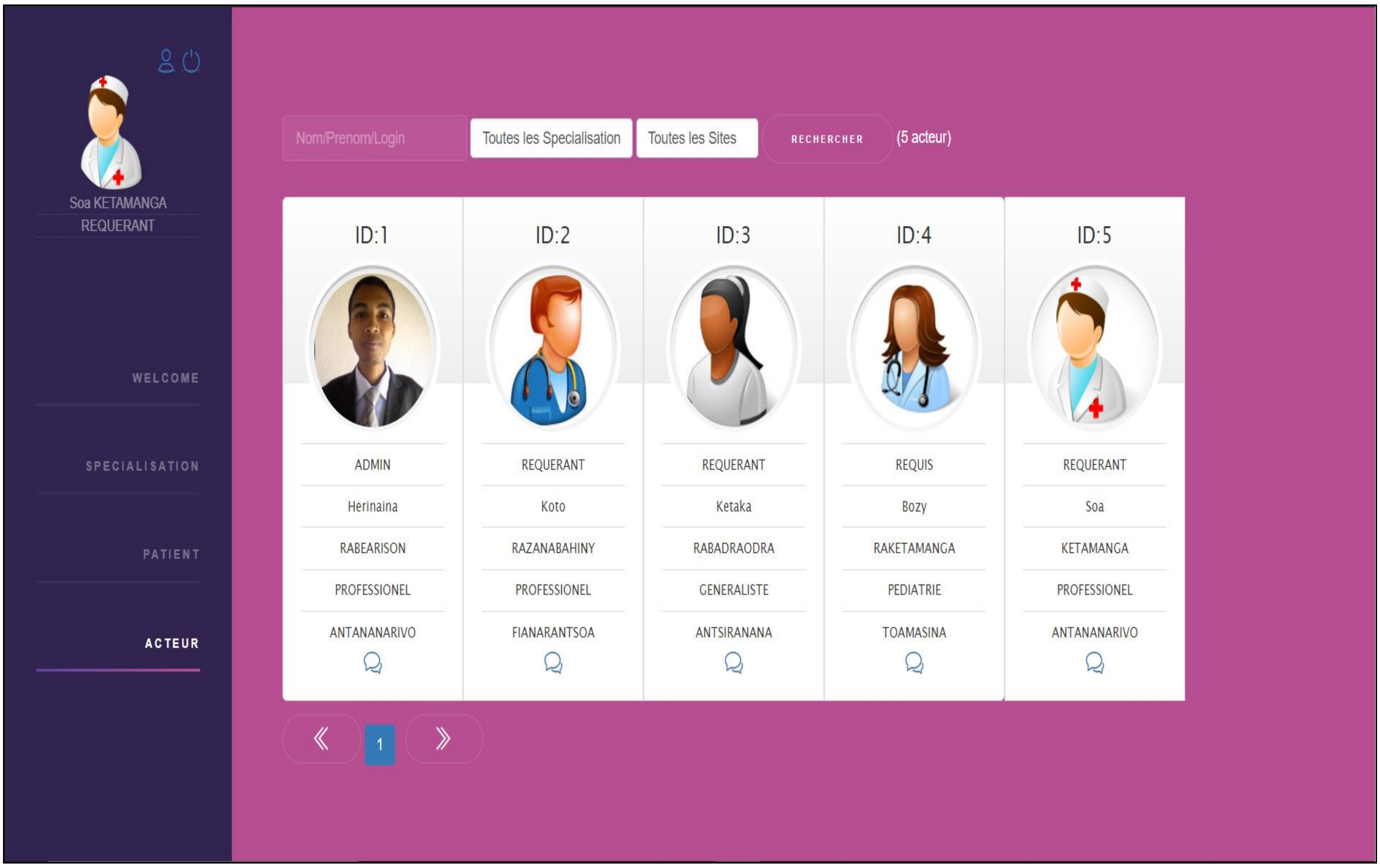

Fig 12: Stakeholder Section

Only the administrator can block, unblock, modify, or delete accounts other than their own.

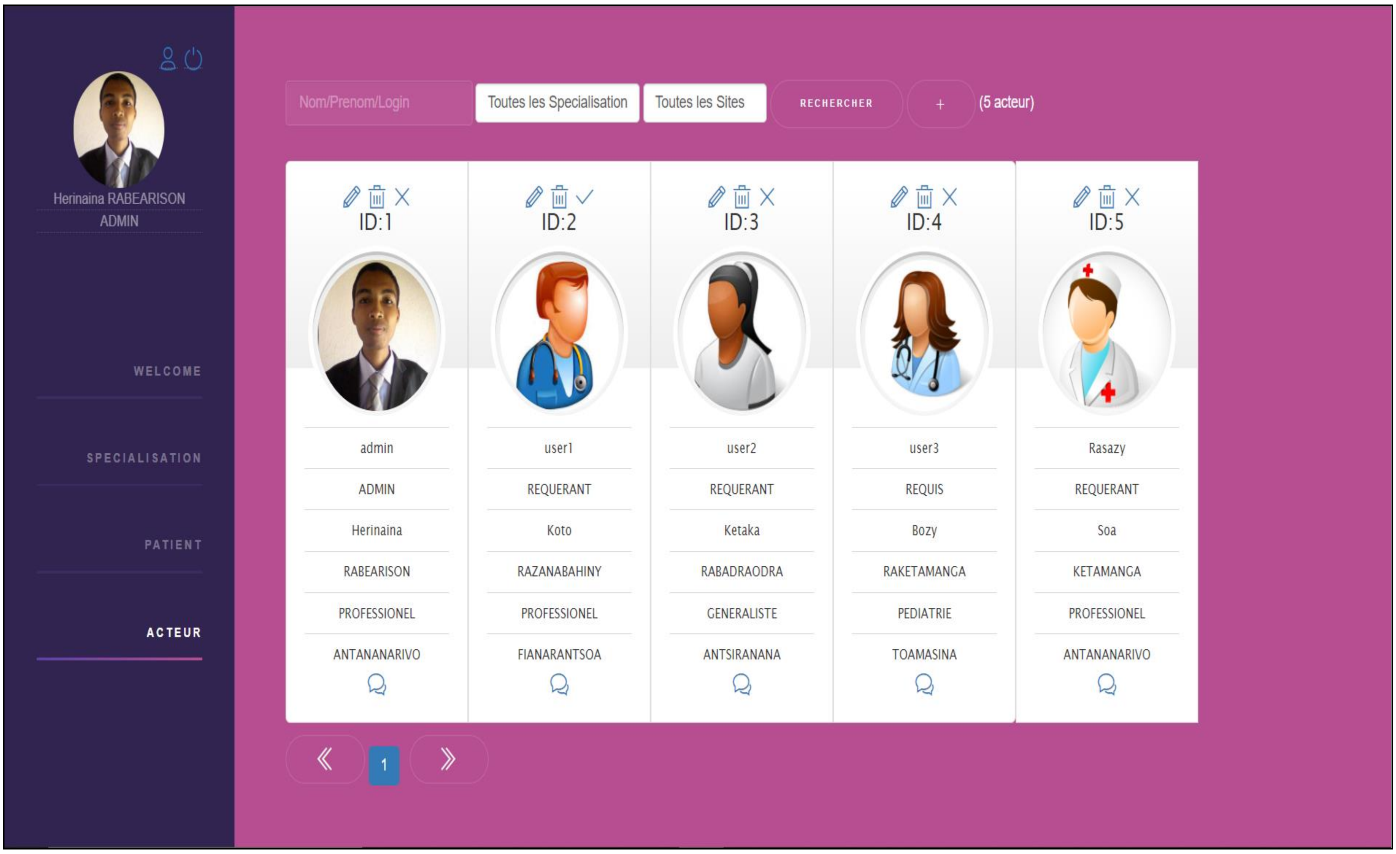

Fig 13: Administrator Interface

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➢ *Real-Time Data Visualization*

Prior to any teleconsultation, the requesting stakeholder inputs the patient's information and selects a physician according to the required specialization.

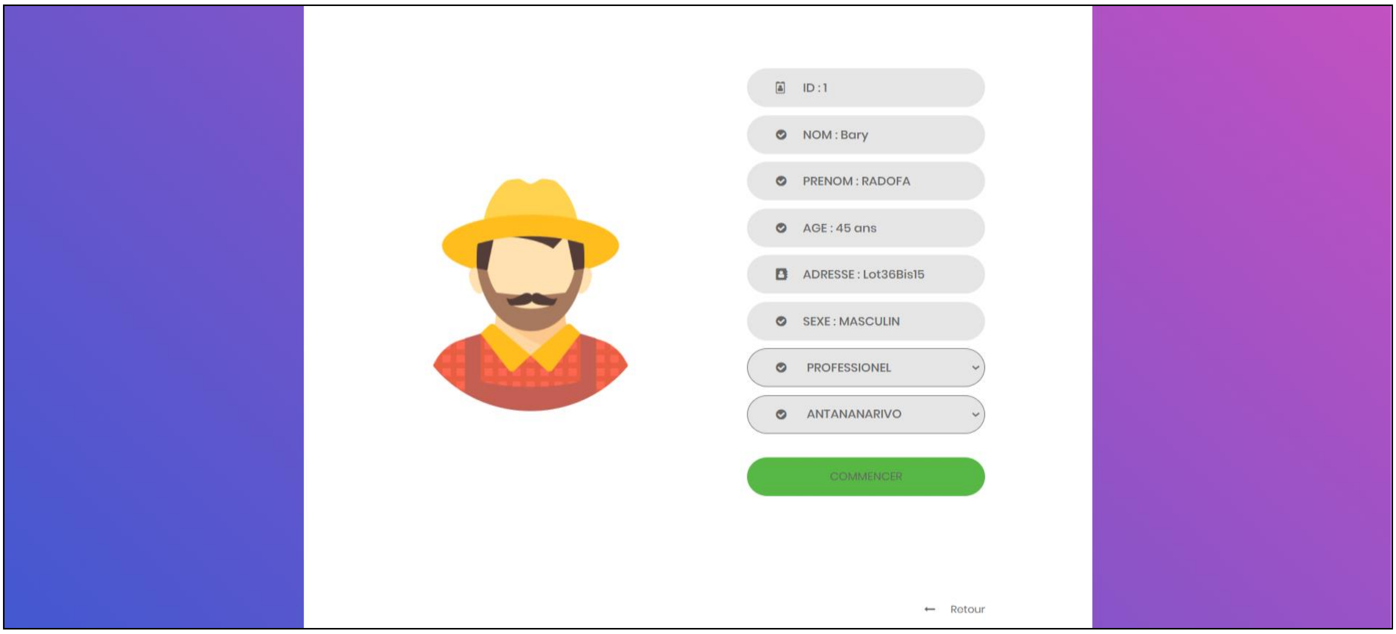

Fig 14: Patient Information Overview

The next step involves connecting biomedical sensors to the patient, allowing real-time visualization of their physiological parameters. The dedicated interface displays data such as electrocardiogram (ECG), auscultation, body temperature, heart rate, blood oxygen saturation (SpO_2), and blood pressure.

➢ *Real-Time Vital Signs Visualization Interface*

Fig 15: Real-Time Vital Signs Visualization Interface

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➢ *Medical Prescription*

At the end of the teleconsultation, the attending physician can issue a digital prescription. This document includes patient and prescriber information, clinical observations, and prescribed medications. An embedded QR code encodes the prescribed medication list and associated recommendations, contributing to treatment traceability and combating self-medication and illegal drug purchasing.


ORDONNANCE

Patient ID : 1
Nom et Prénom : BARY RADOFA
Adresse : LOT36BIS15

DIAGNOSTIC - OBSERVATIONS

-maux de gorge
-diarrhée
-conjonctivite
-maux de tête

PRESCRIPTIONS

-Azithromycine
-MAGNE B6
-ACE Sélénium Zinc
-Vitamine C
-CVO +
-Mivavaka tsara

Consultation du 16/04/2021
Par Dr. Bozy RAKETAMANGA

Fig 16: Model of a Medical Prescription

➢ *Main Functionalities Achieved*

The developed platform successfully met all the functional objectives defined during the design phase:

- **Account creation and secure authentication**: Users can create accounts and authenticate securely (passwords hashed with Bcrypt, JWT tokens for session management).
- **Patient and practitioner management**: Each stakeholder has a personal space tailored to their role (medical profile for patients, dashboard for practitioners).
- **Interactive teleconsultation**: A real-time teleconsultation module was implemented, enabling the exchange of medical information and direct transmission of biomedical parameters.
- **Real-time data visualization**: Through the use of WebSockets, dynamic updates of biomedical data were made possible, offering practitioners instant patient monitoring during consultations.

➢ *Implemented Functionalities*

- **Digital prescription issuance**: Upon completing a teleconsultation, the practitioner can generate and send a digitally signed prescription to the patient via the platform.

➢ *Compliance with Security Requirements*

The application complies with the specified security standards, including:

- Encryption of communications via HTTPS.
- Protection of access through strong authentication mechanisms.
- Secure storage of sensitive data without retaining plaintext passwords.

At this stage, several major functional modules have been implemented and tested:

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Table 2: Implemented Functionalities

Functionality	Status	Description
Account creation	Functional	Registration via form with validation and database recording
Secure authentication	Functional	Login with email/password, JWT tokens for session management
Teleconsultation	In testing	Patient-practitioner communication module supporting data exchange
Real-time data visualization	Partially functional	Display of biomedical data received via WebSockets
Patient and practitioner management	Functional	Interface for tracking, modifying, and archiving profiles
Digital prescription generation	Functional	Automatic generation of digital prescriptions after consultation

IV. DISCUSSION

A. *Critical Analysis of the Developed System*

The proposed platform meets a set of essential functional requirements for any modern teleconsultation solution: user management, security, interactivity, and digital prescription generation. Thanks to rigorous UML modeling, the development process was based on a clear conceptual foundation, fostering coherent, modular, and extensible implementation. The use of a full-stack architecture also ensures a proper separation of concerns among the front-end, back-end, and database layers, which is recognized as a best practice in the design of critical systems [6].

However, despite its strengths, the current solution presents some limitations. Scalability has not yet been tested under large-scale production environments. Moreover, although security measures such as HTTPS, JWT, and password encryption have been implemented, a thorough compliance analysis with healthcare data protection standards (e.g., GDPR, HIPAA) remains to be conducted. Lastly, interoperability with third-party systems (EHRs, hospital software) requires the implementation of standards such as HL7 or FHIR [13], [14].

B. *Comparison with Existing Platforms*

Many teleconsultation platforms have emerged in recent years, particularly in the post-COVID-19 context. The Doctolib solution (Europe), for instance, relies primarily on a user-centered approach with limited transparency regarding conceptual modeling or software modularity. More academic works, such as those of Fezzani & Hamadi [15], have explored the development of a teleconsultation application through UML modeling, yet without deep integration of real-time functionalities or dynamic prescription management.

More recently, Plazas Pemberthy proposed a UML profile for IoT-based healthcare systems [16], although this work remains focused on the sensor/network aspects. In another study, Ait Saadi et al. introduced a self-adaptive medical platform based on ontologies [17], which is highly powerful but requires a complex infrastructure.

➢ *Compared to these approaches, the platform presented in this article stands out through:*

- A complete integration of UML models (use cases, class diagrams, sequence diagrams) directly translated into software functionalities;
- The use of modern full-stack technologies ensuring system fluidity and maintainability;
- Real-time visualization of medical data, often absent in existing academic solutions;
- Automatic generation of digital prescriptions, a key function to streamline medical workflows.

C. *Specific Contributions of the Proposed Approach*

➢ *The Main Contributions of our Approach are:*

- A clear and structured UML-based modeling, facilitating collaboration between developers, designers, and healthcare professionals;
- A reactive and modular technical architecture, making the system scalable to accommodate new features (e.g., tele-expertise module, integration of biomedical sensors);
- A smooth user experience, designed from the early stages to consider real-world constraints and expectations of both patients and practitioners;
- A foundation for future integration of medical artificial intelligence, through the analysis of collected data (e.g., for suggesting diagnoses or personalized treatments).

V. CONCLUSION

This work led to the design and development of an interactive medical teleconsultation platform based on rigorous UML modeling and a modern full-stack architecture. The adopted approach ensured strong consistency between functional specifications and technical implementation, resulting in a stable, ergonomic system adapted to current e-health needs. The platform supports patient and practitioner management, real-time data visualization, and the secure generation of digital prescriptions.

➢ *Future Directions for Development Include:*

- Interoperability: Integrating HL7 and FHIR standards to allow connection with third-party systems (EHRs, hospitals, laboratory information systems).
- Mobility: Developing a native or hybrid mobile application to improve user access in low-connectivity contexts.

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- Artificial Intelligence: Incorporating modules for automatic health data analysis to assist with diagnosis or treatment personalization.
- Advanced Security: Implementing fine-grained role management, audit logging, and compliance with GDPR/HIPAA standards.
- Accessibility: Enhancing the user experience with inclusive interfaces adapted for elderly or visually impaired users.

These development paths offer concrete levers to enrich the platform while consolidating its adoption potential in various clinical contexts, especially in medically underserved areas.

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