Basic Metabolic Panel Test: Information system to manage and consult user information and results

Examen Panel Metabólico Básico: Sistema de información para administrar y consultar información de usuarios y resultados

DOI: http://dx.doi.org/10.17981/cesta.05.02.2024.03

Scientific Research Article.
Date of Receipt: 25/09/2024 Date of Acceptance: 20/11/2024.

Albeiro Cortes-Cabezas
Universidad SurColombiana. Neiva, (Colombia)
albecor@surcolombiana.edu.co

How to cite:
A. Cabezas "Basic Metabolic Panel Test: Information system to manage and consult user information and results", J. Comput. Electron. Sci.: Theory Appl., vol. 5 no. 2, pp. 36-55, 2024. DOI: https://doi.org/10.17981/cesta.05.02.2024.03

Abstract

This article presents the implementation of an information module that allows users of a health service provider to register, consult, and edit the results of basic metabolic panel tests. The objective of the work is to facilitate and streamline the processes of service provision in health care providers and hospitals. To achieve this goal, software tools and technologies were used to develop enterprise web applications such as Spring Framework, Object Oriented Programming (OOP), and the HL7 FHIR standard, which is fundamental for exchanging clinical information between information systems. Their administration will be done through a web browser or a mobile Android Operating System (OS) application. The module will ensure that results can be managed effectively, making them more accessible to patients and medical staff. It also allows new developments to reuse the code.

Keywords--- e-health, Object-Oriented Programming, Spring Framework, HL7 FHIR

Resumen

En este artículo se presenta la implementación de un módulo de información que permite a los usuarios de una institución prestadora de servicios de salud registrar, consultar y editar los resultados de pruebas de panel metabólico básico. El objetivo del trabajo es facilitar y agilizar los procesos de prestación de servicios en instituciones prestadoras de servicios de salud y hospitales. Para lograr este objetivo se utilizaron herramientas y tecnologías de software para el desarrollo de aplicaciones web empresariales como Spring Framework, Programación Orientada a Objetos (OOP) y el estándar HL7 FHIR, son fundamentales para el intercambio de información clínica entre sistemas de información. Su administración se realizará a través de un navegador web o una aplicación móvil para el Sistema Operativo (OS) Android. El módulo garantizará que los resultados puedan ser gestionados de manera efectiva, haciéndolos más accesibles para los pacientes y el personal médico. Además, permite que los nuevos desarrollos reutilicen el código.

Palabras clave--- e-health, Programación Orientada a Objetos, Spring Framework, HL7 FHIR

I. INTRODUCCIÓN

The boom in services provided today on Internet platforms, technological progress, and the need to access information at any time are the determining factors for the emergence of systems that interact with users from any device, including smartphones and tablets [1].

Information technologies can be a valuable tool to improve efficiency in providing health services, such as registering and consulting the results of Basic Metabolic Panel tests, which detect organ function. This blood test obtains the necessary information for the patient's "chemical" status: electrolytes, glucose, urea nitrogen, and creatinine [2].

- Glucose, a type of sugar that the body uses as energy. The glucose level can reveal one of the most frequent diseases in our country: diabetes. Having elevated "sugar" in the blood without proper control can start a chain of other fatal disorders in our body, such as heart and kidney diseases. Glycemia is a simple and inexpensive test; through it, we can know our blood sugar levels, which helps us monitor our condition. Glucose is a type of sugar that the body uses for energy [3].
- Electrolytes include calcium, sodium, potassium, carbon dioxide and chloride:
  - Calcium plays a vital role in the functioning of bones, muscles, and nerves.
  - Sodium, potassium, carbon dioxide, and chloride help regulate fluid concentrations in the body and acid-based balance. Typical concentrations of these electrolytes help keep the body's cells working correctly.
- Blood Urea Nitrogen (BUN) and creatinine are waste products of the blood filtered by the kidneys. These concentrations show how well the kidneys are working [4].

The reports include reference values for each analysis. These ranges are based on population-based studies under controlled conditions of regular patients analyzed on reliable equipment. Normal ranges differ for women, men, children, and neonates[5].

Object-oriented programming (OOP) is used to implement the HL7 FHIR standard, which is based on a set of essential modular components that describe the content of clinical and administrative information that can be exchanged. That is one more reason why this work is part of a solution through the HL7 FHIR standard, which is appropriate and effective for ensuring system interoperability [6].

II. RELATED WORKS

Healthcare personnel must have information about their patients available 24 hours a day, specifically about the results of laboratory tests. Therefore, information systems are required to store, maintain, manage, and update information on specialized test results and general patient information. Several systems allow patient information management using different technologies for implementation and maintenance. The following is a series of papers related to the proposed solution and allows a clearer understanding of the background of the work presented:

Direct Access Testing (DAT) is an emerging care model that offers laboratory services for preventive, diagnostic, and follow-up indications.[7]. Another paper presents a data set, applies the distribution of questionnaires in Indonesia, and uses descriptive and verification methods to analyze clinical data [7].

Another paper presents a data set that applies the distribution of questionnaires in Indonesia and uses descriptive and verification methods to analyze clinical data.[8]. Other papers also examine the evolution of electronic health record (EHR) software implementations and their role in optimizing medical services [9].

Moreover, this study relates how the quality of medical care provided can influence patients' perceptions and ideas about the effectiveness of their health insurance and the relationship between the quality of care through the availability of geographic information systems [10]. Virtual Hospital (VH) is a model that can increase effectiveness and efficiency in delivering socio-medical services; it has helped to acquire a multidisciplinary expert consensus in the Veneto region of Italy [11].

Electronic Health Record (EHR) systems take on more critical challenges, including technological security vulnerabilities, and analyze how American healthcare professionals view susceptibility to technology as a health threat [12]. Clinical data management has

fostered informatics research, and the amount and robustness of data have led to new artificial intelligence (AI) techniques to analyze it. This allows data to be managed and shared efficiently and effectively [13].

III. METHODOLOGY

The system consists of several layers, each with a specific function. This allows better control over the operation of the applications, which is vital for implementing an information system.

Data processing layer

Receives the information sent by the application's layer, verifies it, and executes all the functions that can represent the data in the system and its persistence.

Data storage layer

This is where the data resides. The MySQL database manager, which stores all system data, forms it [14], [15].

Applications layer

These are the applications that are used in the end devices by users of any role; these are connected with the data processing layer since it delivers the data in a JSON object [16], [17] to be presented to the end-user and is formed by the main web application of exams, in which users with assigned roles can manage the information of results and users from a device with a web browser and on the other hand the mobile application in which users can authorize and register exams and view the information of results and users.

A. Spring Framework

Spring Framework provides a comprehensive programming and configuration model for modern Java-based enterprise applications on any deployment platform.

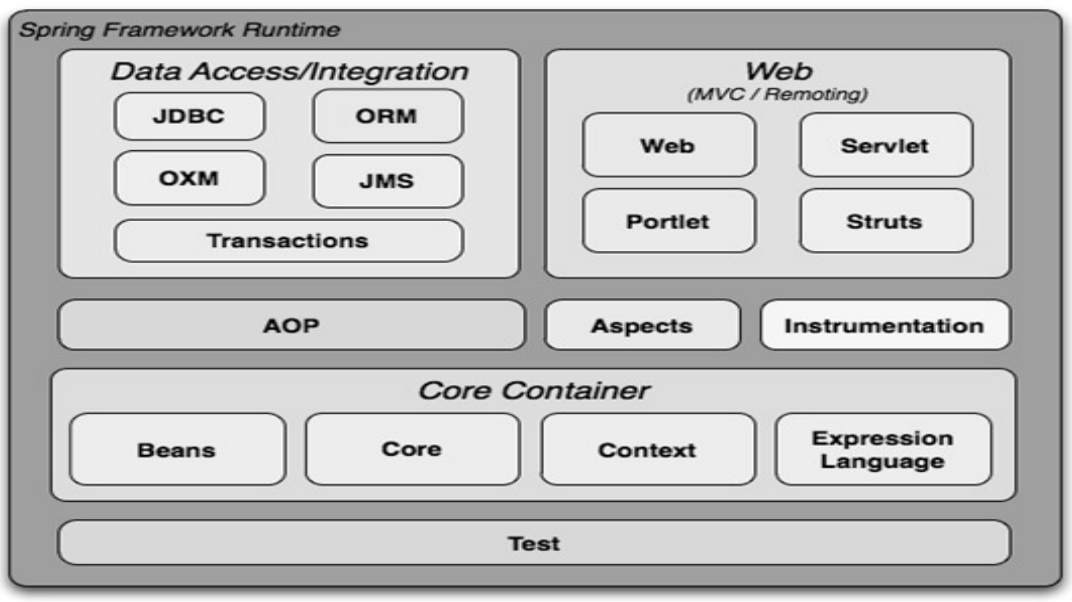


Figure 1. Spring Framework architecture

Spring Core

It is a central part of Spring and consists of the following modules: Core, Beans, Context, and Expression Language.

Data Access

It is a fundamental part of the database access layer and consists of the following modules: JDBC, ORM, OXM, JMS, and the transaction management module, described below.

- JDBC: provide a JDBC abstraction layer that eliminates the complexity of traditional JDBC code and the parsing of database vendor-specific error code.
- ORM: provides consistency/portability to your code regardless of data access technologies based on object-oriented mapping concepts such as Hibernate, JPA, JDO, and iBatis. It

includes code without worrying about catching exceptions specific to each persistence technology.

- OXM: This is a separate module introduced in Spring 3.0. It converts objects into XML format and vice versa. Spring OXM provides a uniform API to access any of these OXM frameworks (Castor, XStream, JiBX, Java API for XML, and XML Beans).
- JMS: reduces the number of lines of code for sending and receiving messages. The API handles JMS workflow and exception handling.
- Transactions: The Transaction module supports programmatic and declarative transaction management for POJO classes. Spring can implement all the enterprise-level transaction implementation concepts.

B. Spring MVC [18]

It provides Model-View-Controller architecture and ready-made components for developing flexible and loosely coupled web applications. The MVC pattern separates the different application aspects (input logic, business logic, and UI logic) while providing flexible coupling between these elements.

- The Model encapsulates the application data and will generally consist of POJOs.
- The View is responsible for representing the data in the model and generally generates HTML output that the client browser can interpret.
- The Controller is responsible for processing user requests, creating the appropriate model, and passing it to the view for rendering.

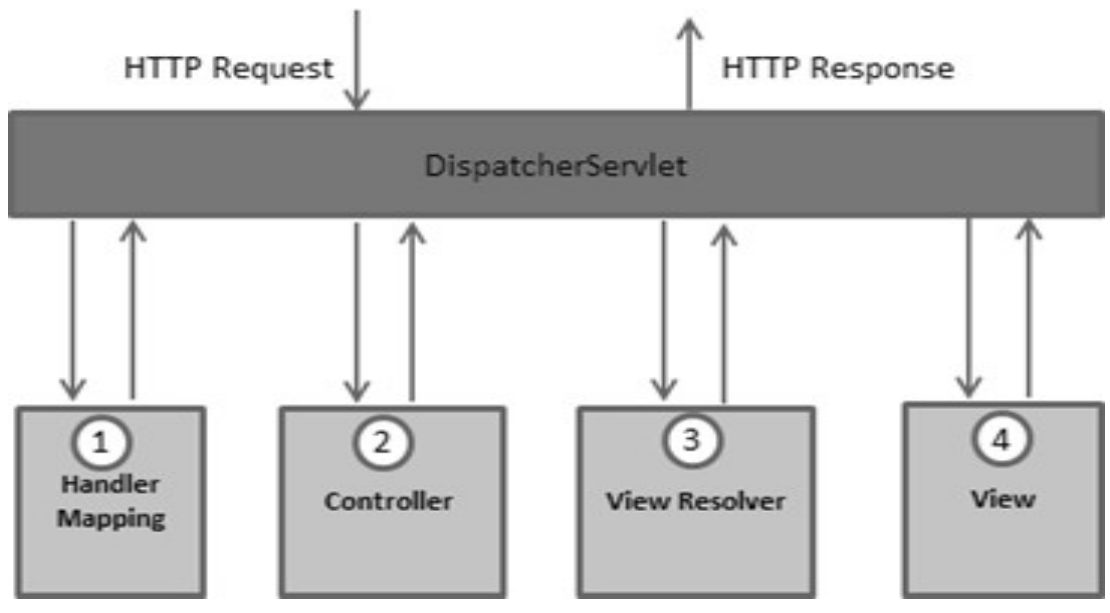


Figure 2. MVC Spring

C. HL7 Fast Healthcare Interoperability Resources Specification (FHIR)

Rapid Resources for Health Interoperability FHIR. This new approach was based on REST principles. The FHIR effort aims to simplify and accelerate the adoption of HL7 in an easy-to-consume yet robust manner and use open Internet standards wherever possible.

FHIR defines key entities involved in healthcare, such as resource information exchange, and offers many improvements over existing standards:

- A strong focus on the application: fast and easy to implement.
- The specification is free for unrestricted use
- Out-of-the-box resource base but can also be adapted to local requirements.
- Robust web-based standards XML, JSON, HTTP, OAuth, etc.
- Support for RESTful architecture and continuous information exchange via messages or documents. [19].
- Especificaciones concisas y fáciles de entender.
- A human-readable format for easy use by developers. [3]

FHIR defines a simple framework for extending and adapting existing resources. All Systems, regardless of how they are developed, can easily read these extensions and definitions, which can be retrieved using the exact implementation to retrieve other resources. In addition, each resource leads to a human-readable text representation using HTML as a display option.

D. Base de Datos MySQL

Once the system's information objects and their interaction with the users have been identified, they are modeled by indicating their attributes and placing them with the database fields from which the information is collected. The data from the database queries will be stored in these objects, which will later be modeled in FHIR resources according to the standard.

TABLE 1.
FHIR RESOURCES IDENTIFIED

FHIR Resource	Information Object
Patient	Patient
Practitioner	Healthcare staff
DiagnosticReport	Examination Report
Observation	Variable Measurement Record

JDBC helps manage the system's data, storing and retrieving data from and to the database.

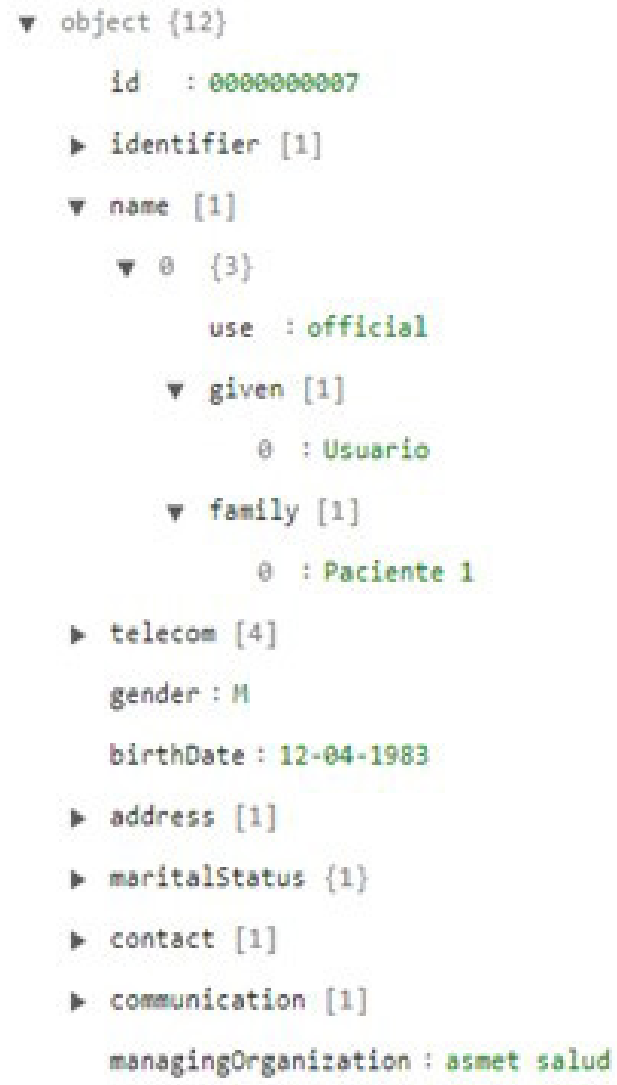


Figure 3. JSON Patient Resources

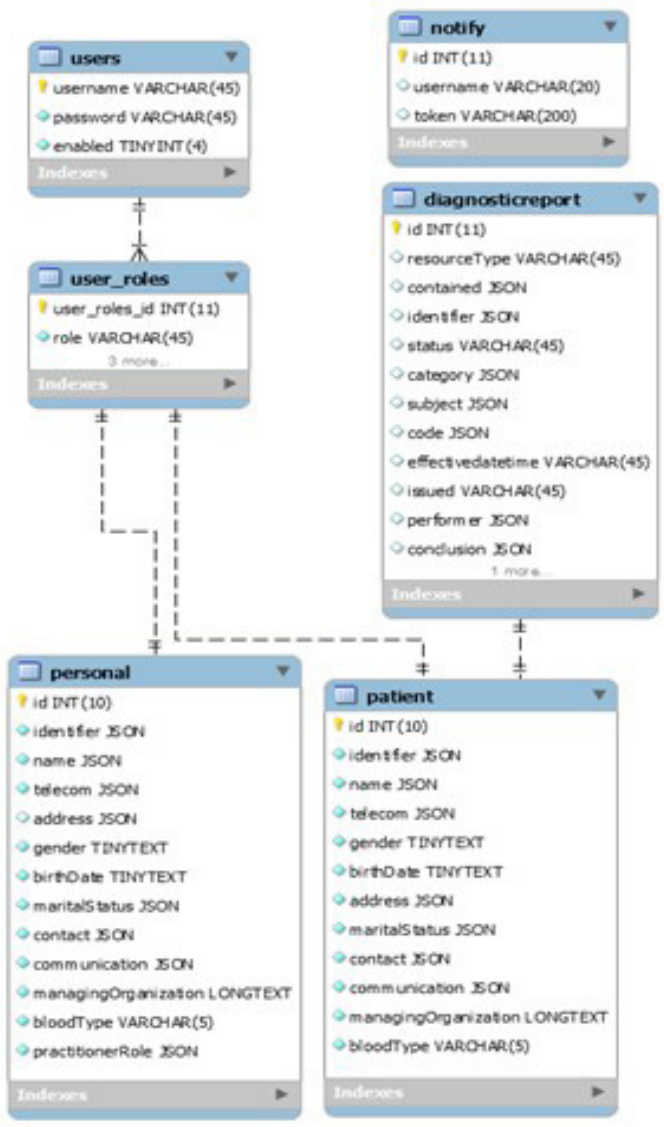


Figure 4. Database Diagram

IV. IMPLEMENTATION

A. Development environment

Free software tools are used for the development of applications.

- Spring Tool Suite IDE version 3.8.1, for web application development.
- Pivotal TC Server in its version 3.1 to deploy the web application for testing.
- Android Studio IDE is in version 2.3 for mobile application development.
- MySQL Workbench in its version 6.3.9 for the database.

B. Projects Frameworks

- Spring Tool Suite IDE version 3.8.1, for web application development.
- Pivotal TC Server in its version 3.1 to deploy the web application for testing.
- Android Studio IDE is in version 2.3 for mobile application development.
- MySQL Workbench in its version 6.3.9 for the database.

Android platforms:

- Volley versión 1.0.0
- Gson versión 2.3.1
- Firebase-messaging versión 10.0.1
- Android-gif-drawable versión 1.2.8
- MaterialStyledDialogs versión 2.1
- MPAndroidChart versión 2.0.9
- Toasty versión 1.2.5
- Expansionpanel versión 1.0.6
- Indicatorseekbar versión 1.2.9

C. Platform Implementation

Figure 4 shows the tables created to store the necessary information for the correct system interaction with the users. For each field of each table, it is essential to determine the type of data it contains, adjust the database's design, and achieve optimal storage.

The focus of each table is an object on which information will be stored; therefore, the following tables are created:

- **Patient and Personal:** these tables store the information corresponding to the users registered in the system.
- **DiagnosticReport:** this table stores the information corresponding to the Basic Metabolic Panel test results reports.
- **Notify** that this table stores the users and the tokens of mobile devices.
- **Users**, this table stores users and passwords.
- **Users_roles**, this table relates the user to the role he/she fulfills in the system.

Interfaz de Usuario Aplicación Web

The website's development is oriented toward offering content and functionalities that help registered patients obtain information about the results of the Basic Metabolic Panel clinical laboratory and information from registered users in the system. The private part of the application (intranet) will be for the exclusive use of registered users and will contain specific information depending on the role assigned by the administrator.

- **The administrator** is the user in charge of registering, modifying, consulting, and deleting the information of any user in the system.
- **Medical staff** is the user in charge of authorizing a Basic Metabolic Panel test for a patient, viewing the results, and downloading a PDF file.
- **The laboratorian** is the user in charge of registering the results obtained in the laboratory for the Basic Metabolic Panel test, editing, viewing results, and downloading a PDF file.
- **Patient** user related to the Basic Metabolic Panel test, view results, and download a PDF file.

All system users can modify their personal information except for the type and number of documents.

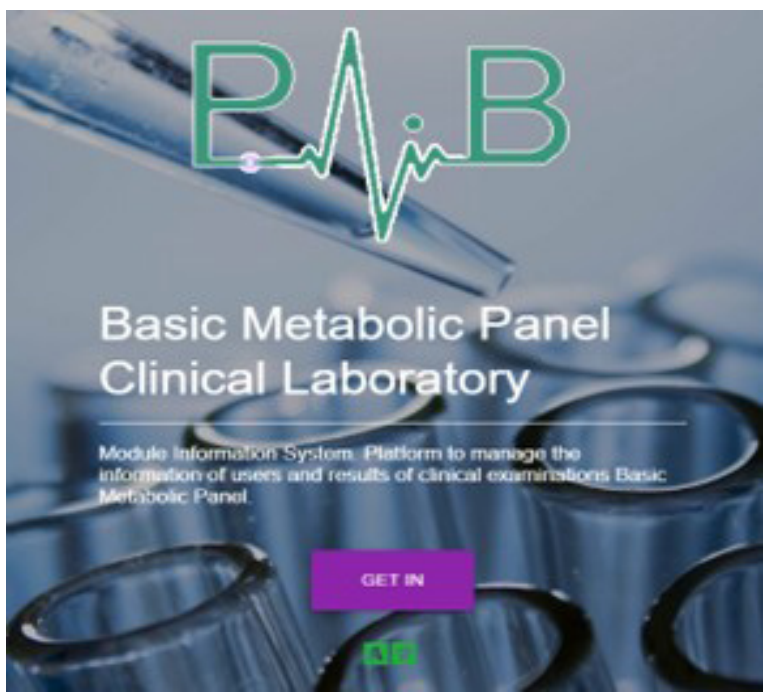


Figure 5. Application web start screen

Within the functional requirements, it is necessary to control User access to the application's intranet, for which the following single interface for access has been defined.

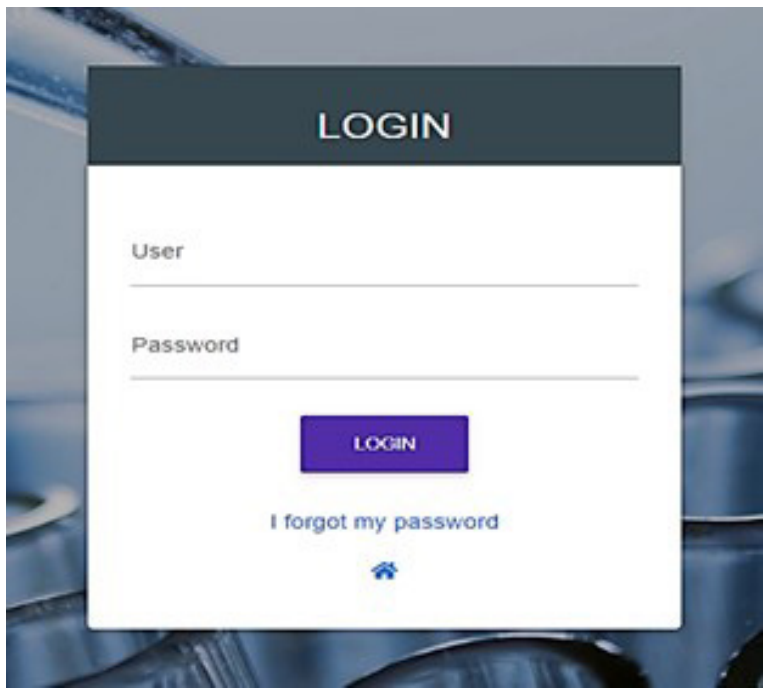


Figure 6. Login form.

Figure 7 shows the administrator's main interface to which he/she will be redirected after authentication. It contains a list of actions, located on the left side of the screen, as well as a text field to enter the document number of the user to search for and elements indicating the number of user records for each role. The main list contains links to the interface for creating new users and another to load a table with the list of registered users.

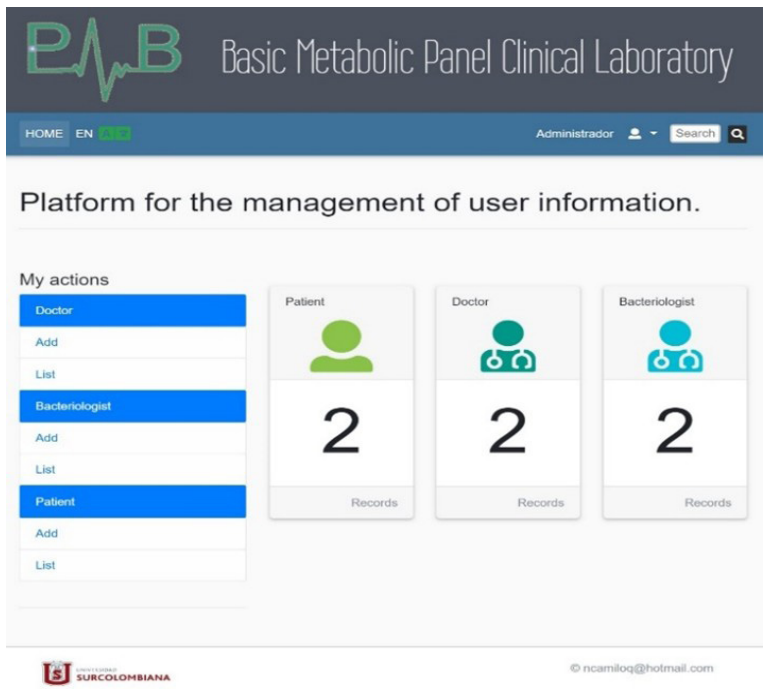


Figure 7. Administrator panel

Figure 8 shows the form where the administrator, once the form fields have been completed, can save the information of a new user in the database by clicking the send button.

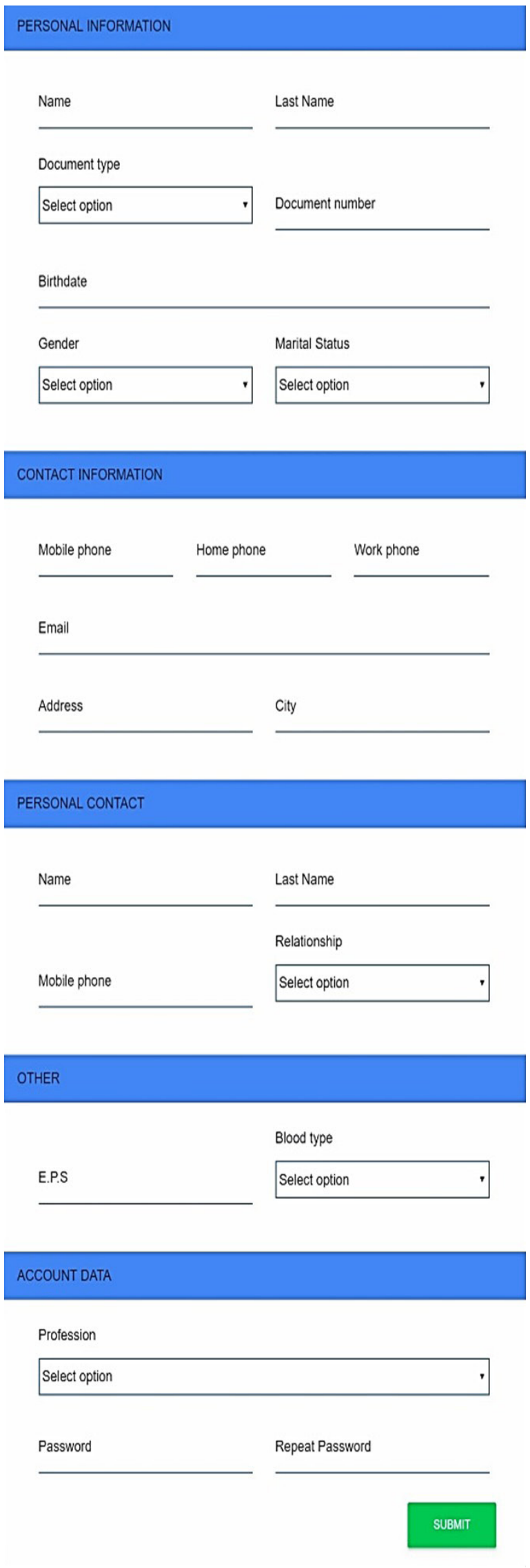


Figure 8. User information form

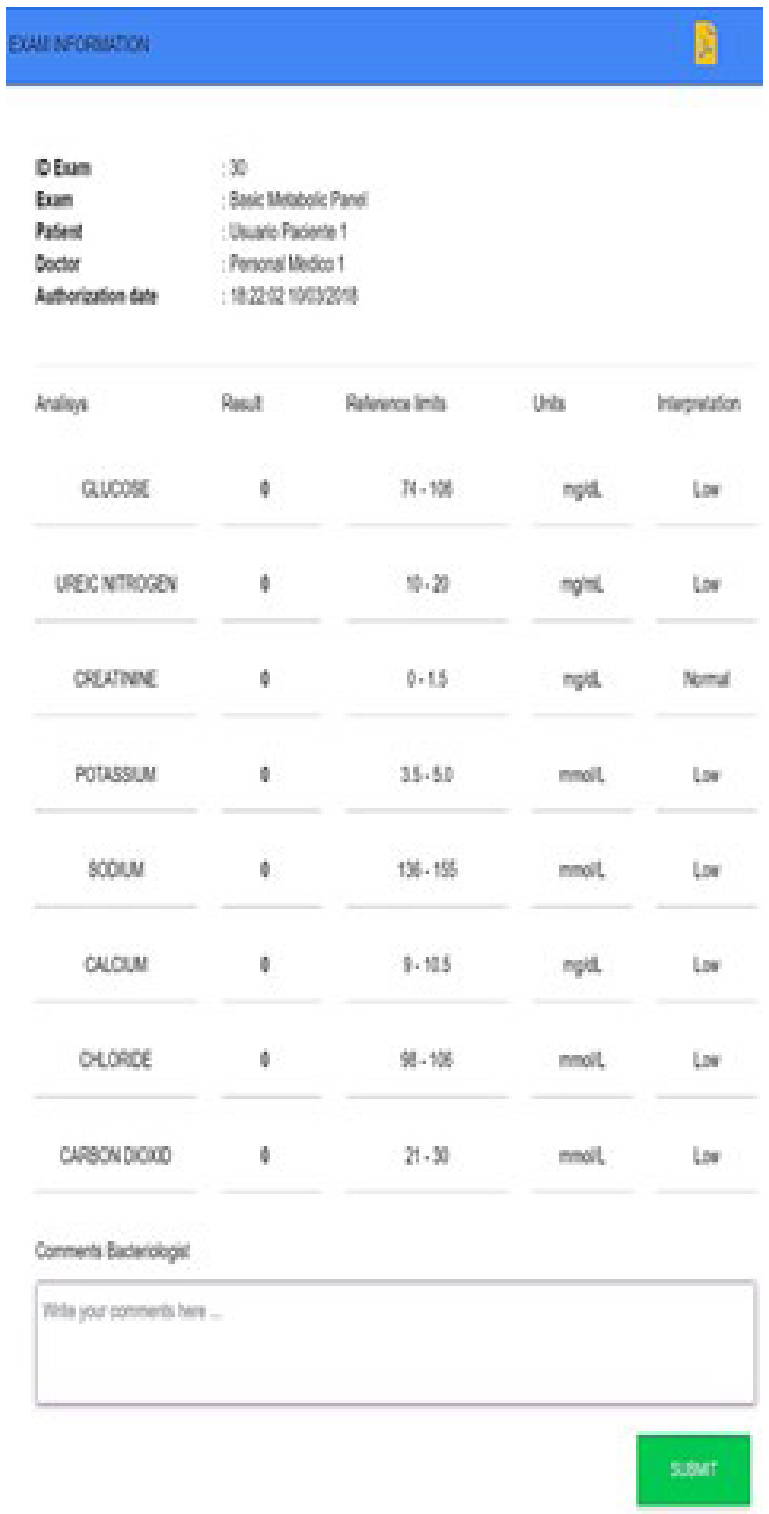


Figure 9. Form to record exam results

Figure 9 shows the result recording form accessible only to the laboratorian.

User Interface Android Application

The development of the Android application is oriented to offer contents and functionalities that help users registered in the system obtain information about the results of the Basic Metabolic Panel clinical laboratory. The application is designed for cell phones with the Android 4.4 version or higher, covering most mobile devices currently [20]. This application can be installed on users' mobile devices to examine a specific health entity.

Figure 10. Star-up Interface

Figures 10 and 11 show the application's initial interface when started by an unauthenticated user. To meet the requirements, user access to the application functions must be controlled, so a single interface for access must be defined.

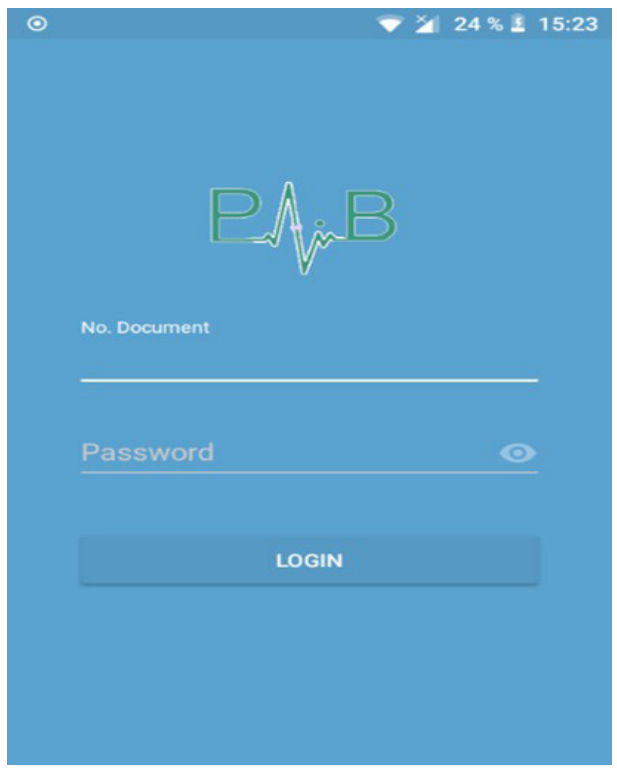


Figure 11. Login form

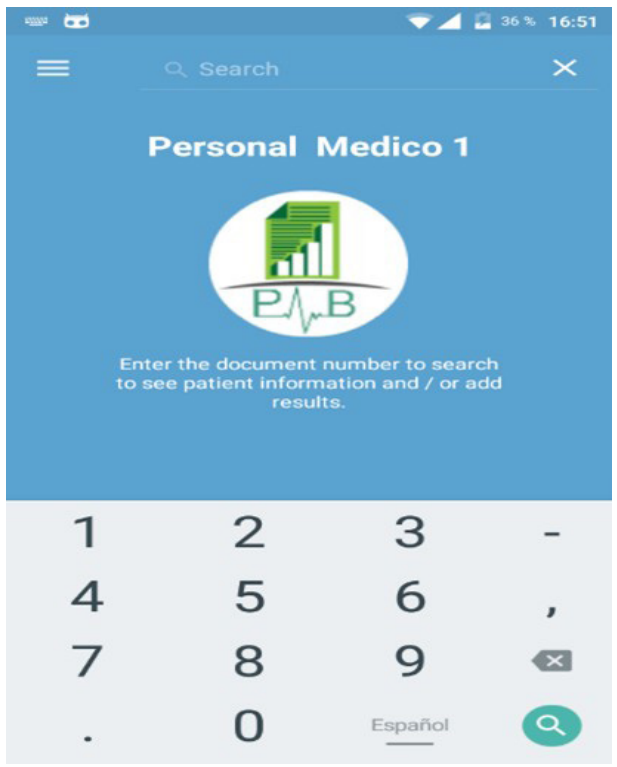


Figure 12. Patient User Search interface.

The medical staff can enter the document number of the patient to be searched as shown in Figure 12.

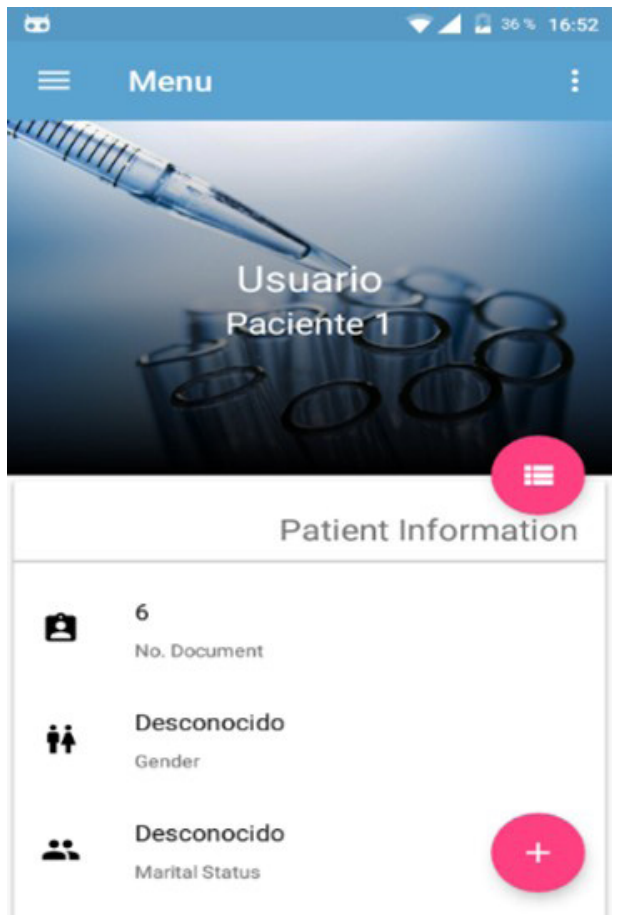


Figure 13. Patient user information interface.

Figure 13 shows the patient's information and two buttons to authorize and load the patient's exam list, as shown in Figure 14 and 15.

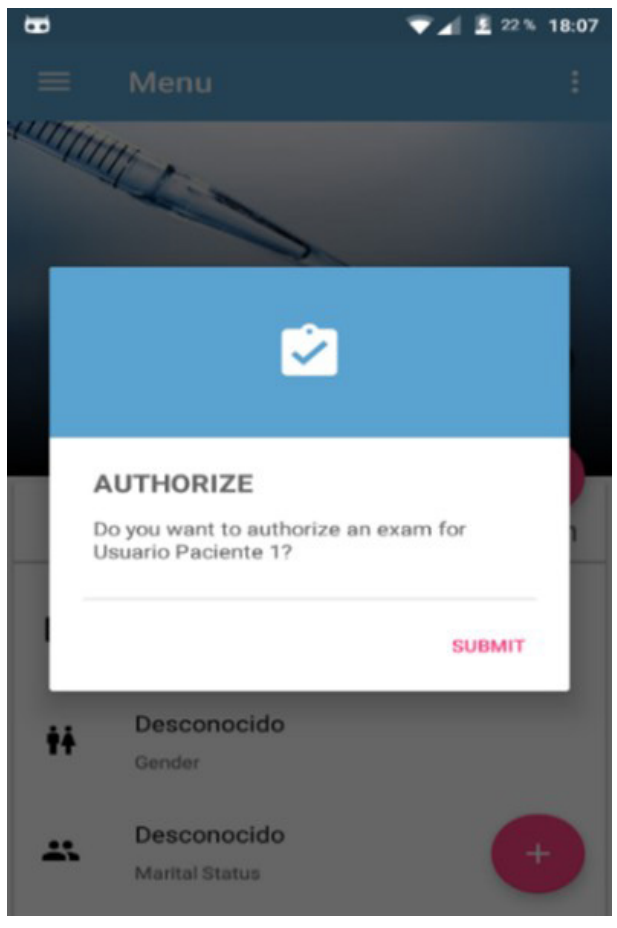


Figure 14. Examination authorization

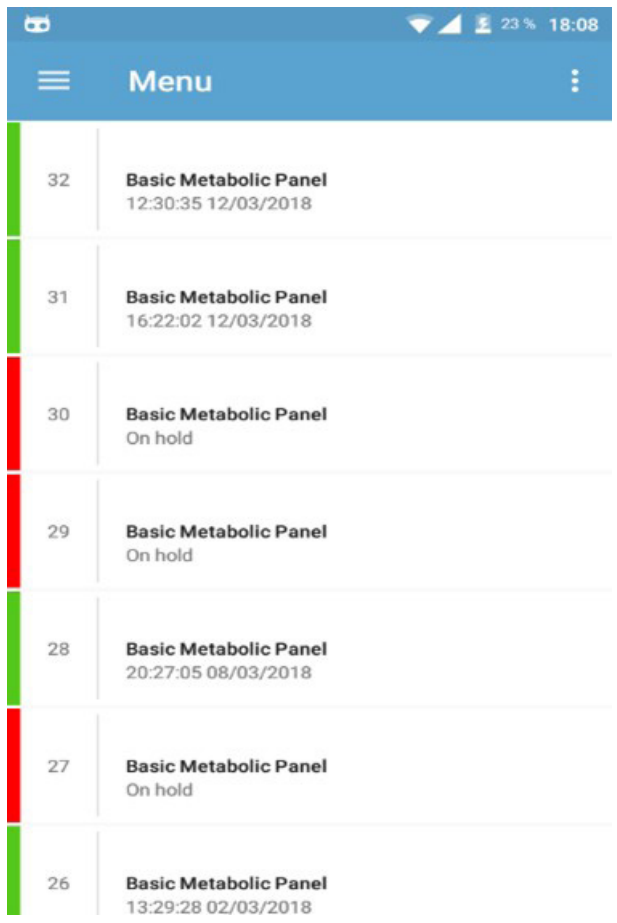


Figure 15. List of results

In Figure 16, once the medical staff authorizes the test, the laboratory technician loads the form and can record the result and add comments.

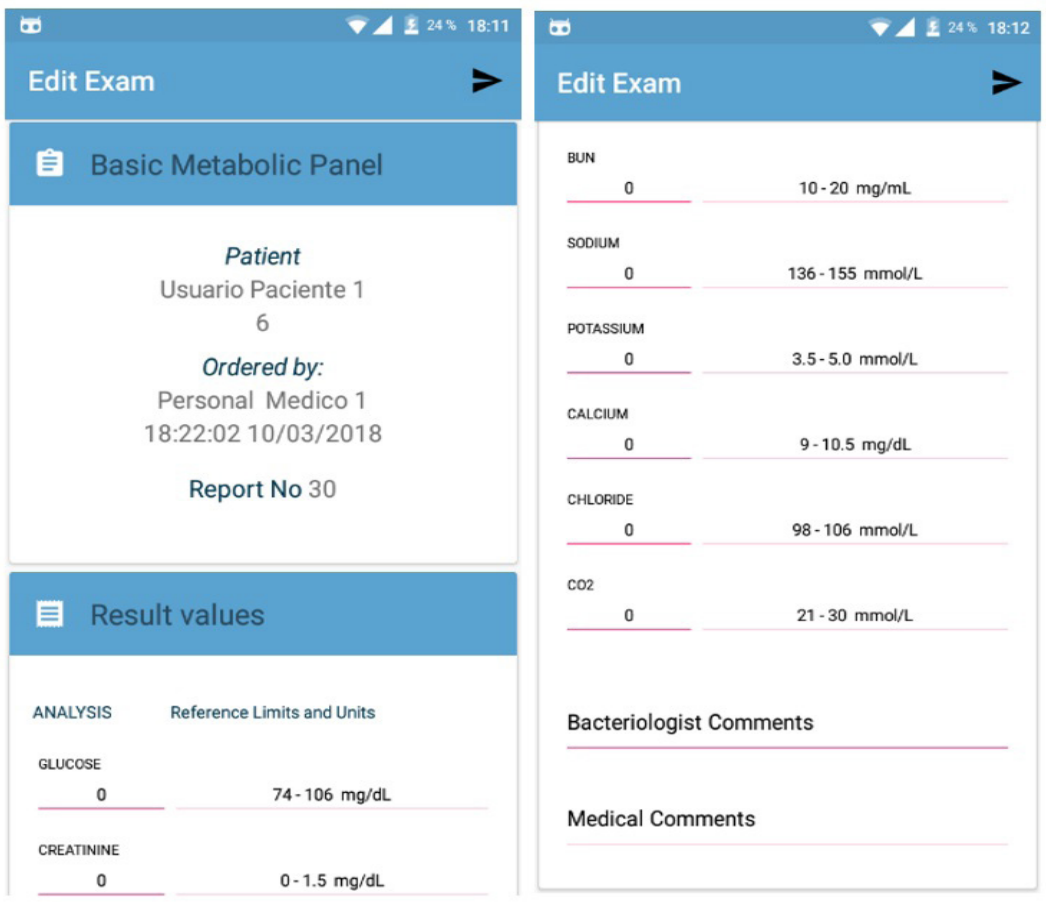


Figure 16. From registering results

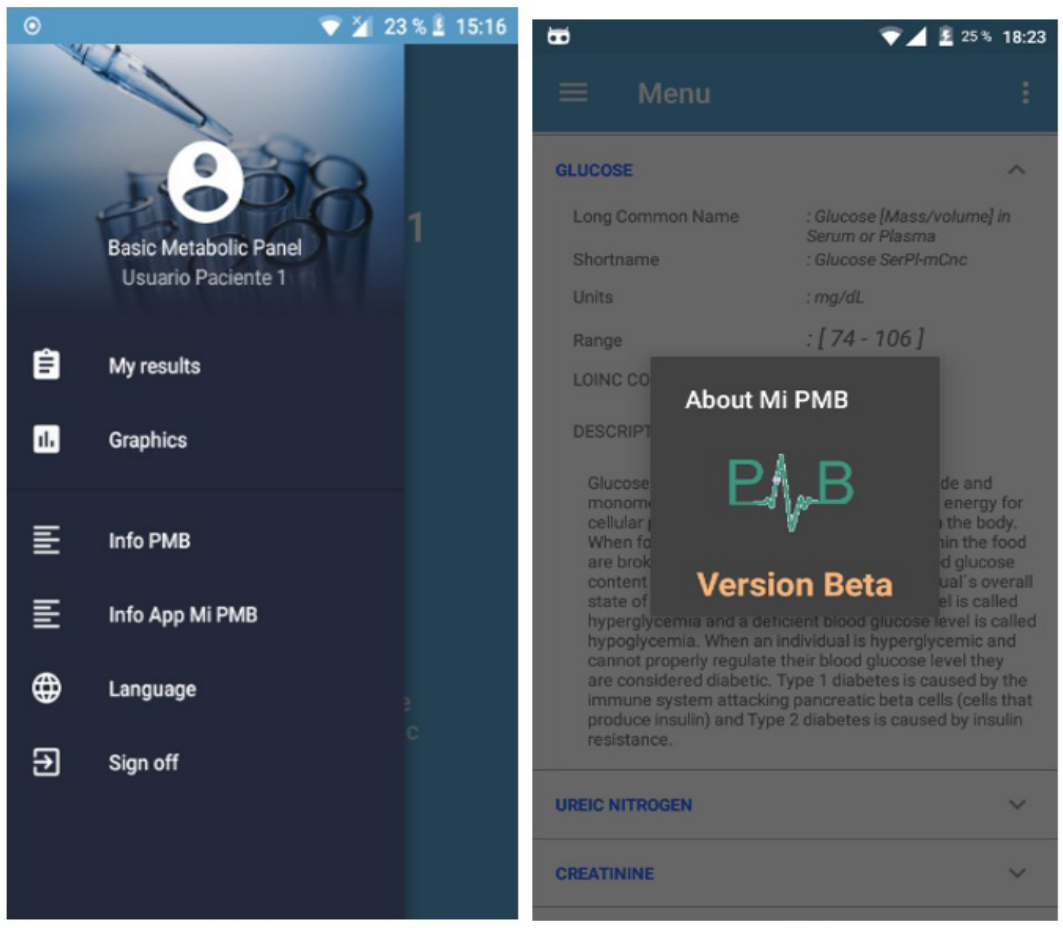


Figure 17. Language selection menu and About the application.

Internationalization provides applications with support for different languages, as seen in Figure 17a and Figure 17b. You can select between Spanish and English.

The Android client will consume the Spring-based REST web service, which returns a JSON data representation.

In the design of the web platform, Servlets were used to receive and respond to the requests sent by the JSP pages, and they were also created to respond to the requests received by the Android client.

V. RESULTS

Black box tests were performed, evaluating the result obtained from the data entered to verify the correct operation of each requirement. This testing stage corresponds to the development phase, after which the software component is implemented in a production server.

The system interacts with the users, allowing them to comply with the functionalities proposed for each registered user role. The Administrator user registers the users with the roles of Medical Staff, Laboratorian, and/or Patient. The Medical Staff searches and authorizes the Basic Metabolic Panel test for the patient.

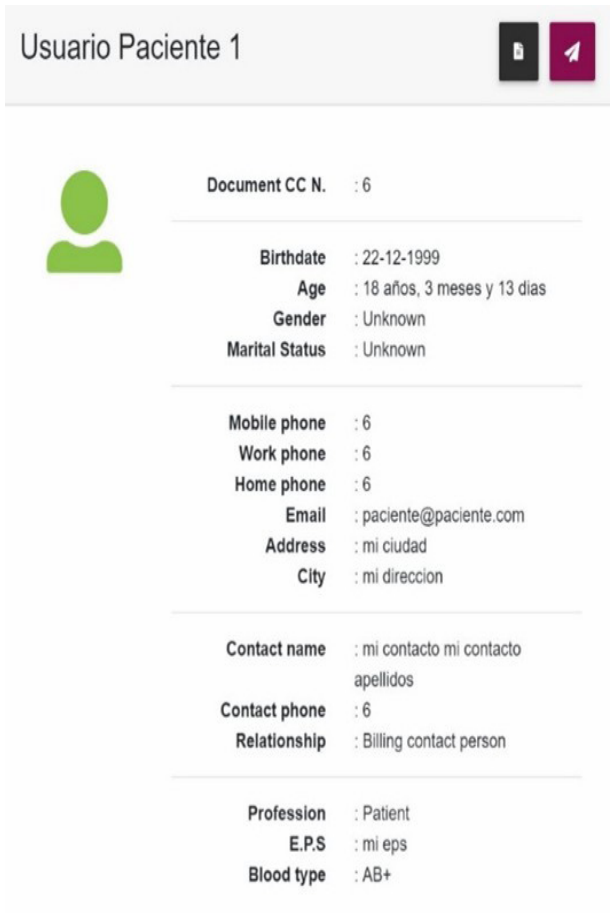


Figure 18. User information

Figure 18 shows the patient user's information on which actions the medical staff can perform, such as authorizing an examination and notifying the patient when a result is ready.

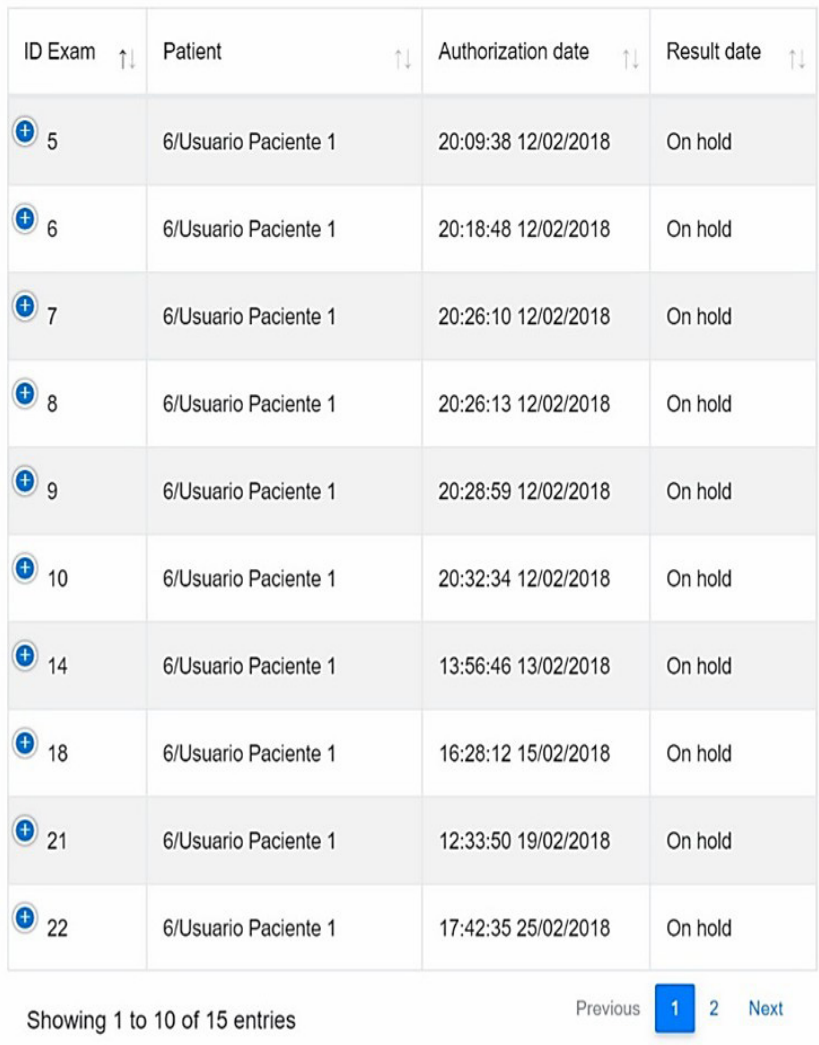
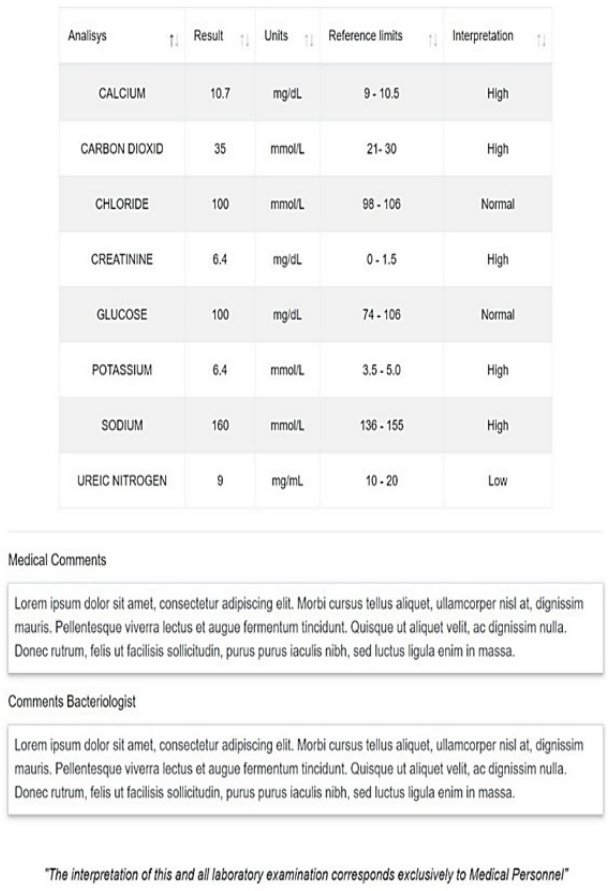


Figure 19. List of authorized tests.

The laboratorian has access to the list of authorized tests to complete the fields with the results given by the laboratory.



Analisys	Result	Units	Reference limits	Interpretation
CALCIUM	10.7	mg/dL	9 - 10.5	High
CARBON DIOXID	35	mmol/L	21- 30	High
CHLORIDE	100	mmol/L	98 - 106	Normal
CREATININE	6.4	mg/dL	0 - 1.5	High
GLUCOSE	100	mg/dL	74 - 106	Normal
POTASSIUM	6.4	mmol/L	3.5 - 5.0	High
SODIUM	160	mmol/L	136 - 155	High
UREIC NITROGEN	9	mg/mL	10 - 20	Low

Medical Comments

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi cursus tellus aliquet, ullamcorper nisl at, dignissim mauris. Pellentesque viverra lectus et augue fermentum tincidunt. Quisque ut aliquet velit, ac dignissim nulla. Donec rutrum, felis ut facilisis sollicitudin, purus purus iaculis nibh, sed luctus ligula enim in massa.

Comments Bacteriologist

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi cursus tellus aliquet, ullamcorper nisl at, dignissim mauris. Pellentesque viverra lectus et augue fermentum tincidunt. Quisque ut aliquet velit, ac dignissim nulla. Donec rutrum, felis ut facilisis sollicitudin, purus purus iaculis nibh, sed luctus ligula enim in massa.

"The interpretation of this and all laboratory examination corresponds exclusively to Medical Personnel"

Figure 20. Result

Figure 20 shows the result accessible to the patient and medical staff.

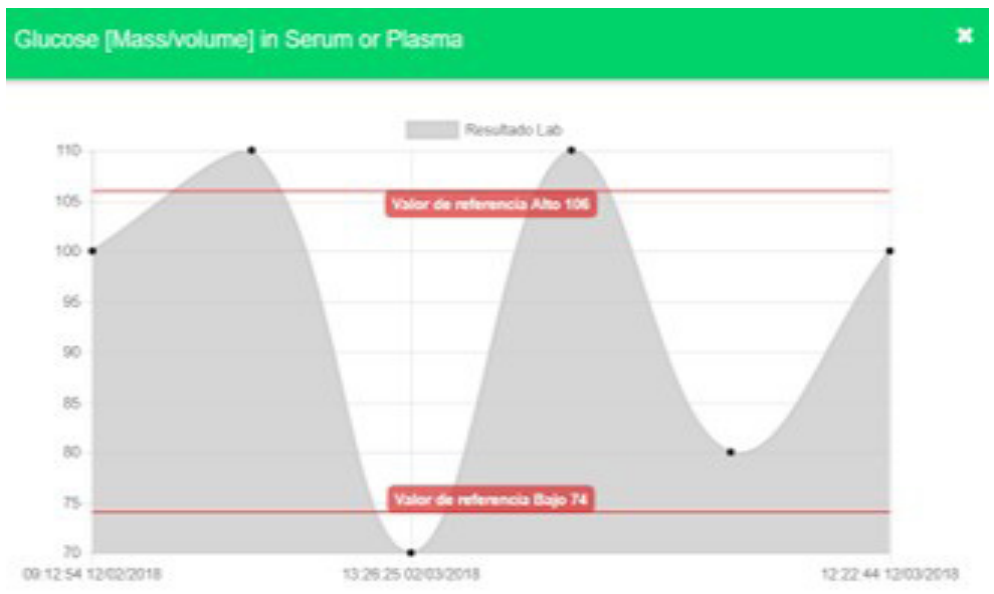


Figure 21. Glucose variable graph.

Here's an example of a Graph for the web application showing the results of the Glucose variable: the graph is loaded in a MODAL element, indicating the reference values in red lines.

The figures for the Android application results are shown below.

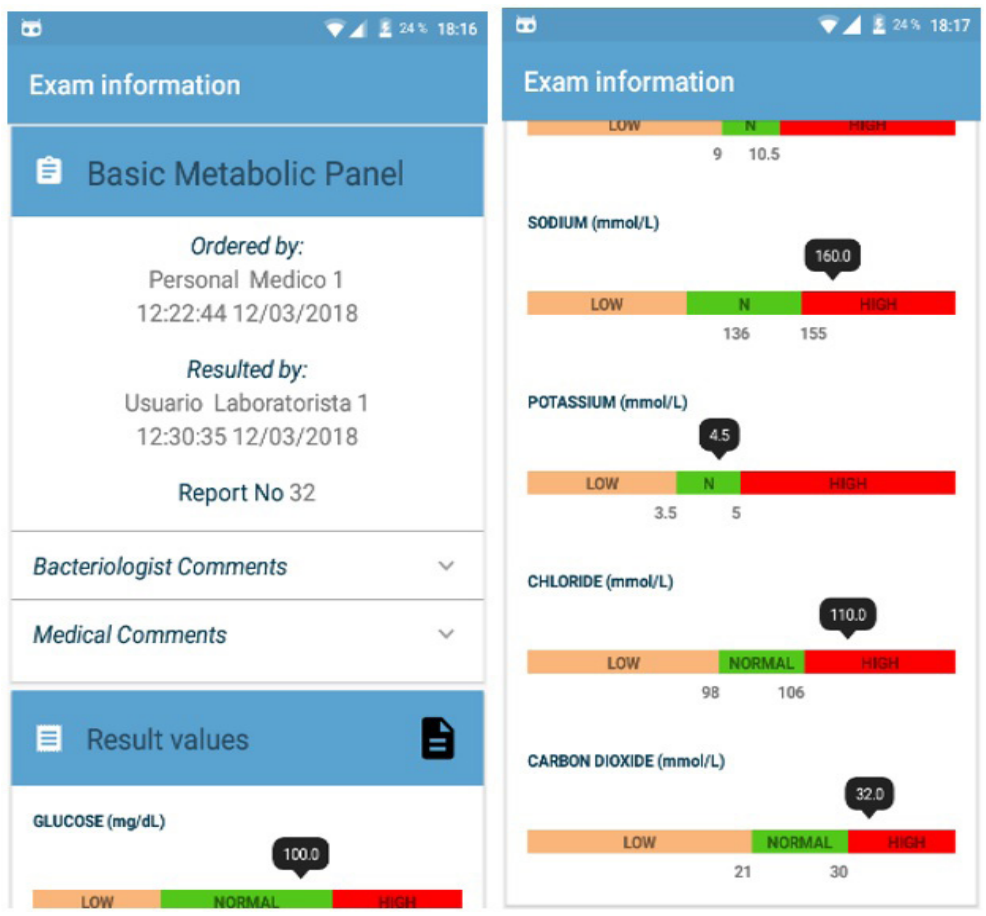


Figure 22. Examination result interface.

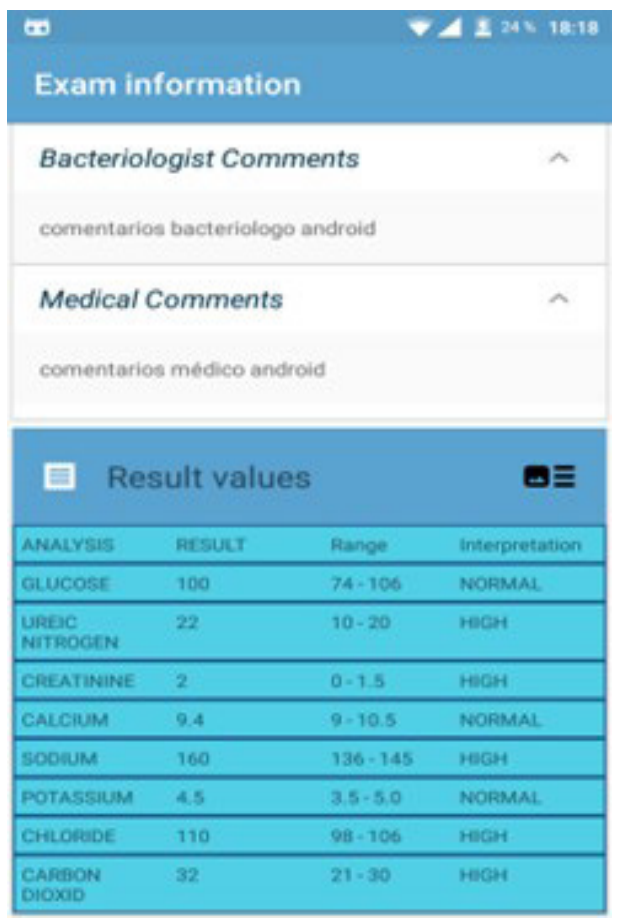


Figure 23. Examination result interface.

Figure 22, 23, and 24 show the presentation of a result in graphical and tabular form.

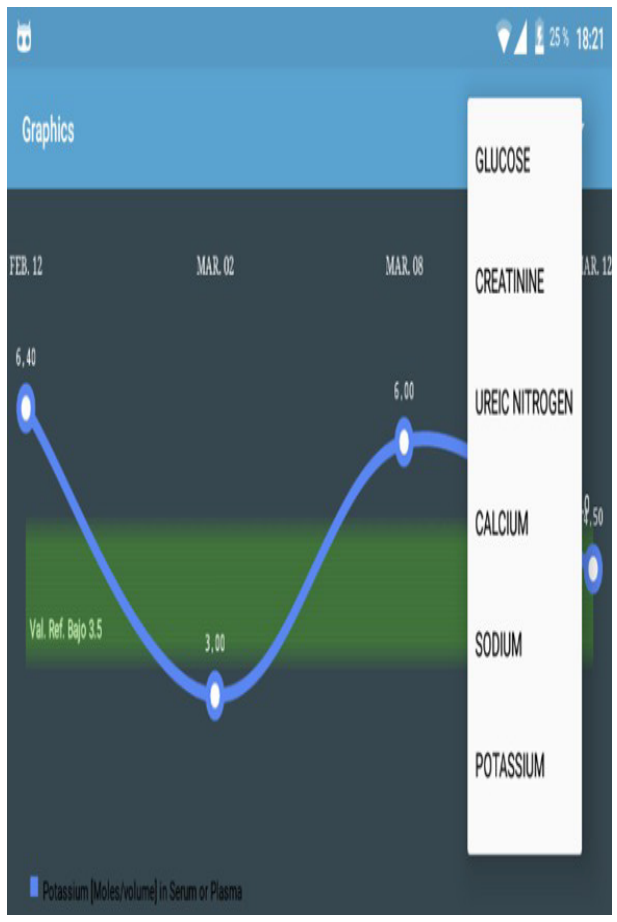


Figure 24. Graph interface.

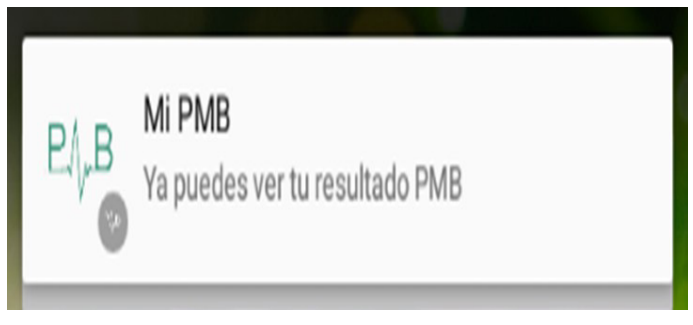


Figure 25. Notification

Figure 25 shows the notification sent from the server by the medical staff indicating that the result is ready.

VI. CONCLUSIONS

The system's architecture is a web application based on a three-tier client/server model. This allows the client to access the system with a simple browser, which works with the most essential browsers on the market, such as Microsoft Edge, Google Chrome, and Firefox Mozilla.

Another critical aspect of developing the web application is its well-structured construction based on the MVC (Model View Controller) design pattern. This resulted in an easy-to-maintain and scalable application, extending its life.

The implemented system complies with the necessary requirements for the correct user-system interaction since it allows users with different roles to execute the functionalities of registering, consulting, modifying, and deleting user information and Basic Metabolic Panel test results from any device with an Internet connection and that has a web browser or mobile application.

Spring is a powerful framework for building enterprise web applications. It can also be easily integrated with other frameworks to develop efficient applications, and due to its lightweight feature, it is easy to use.

Android, being a free operating system, made it easy to implement mobile applications as it has many free software tools such as Android Studio IDE and Android SDK, among others;

also, somehow, it made it easy to use these as Android uses JAVA language with which it was familiar before.

FHIR combines the best features of the HL7 v2, v3, and CDA lines and takes advantage of the latest web standards, strictly focusing on applicability. Semantic interoperability in the healthcare environment is a possible solution to communicating health information between systems without losing meaning.

FUNDING

This research was developed using the resources of the Universidad SurColombiana.

AUTHOR CONTRIBUTION

The author's contributions to this article are as follows:

Albeiro Cortes-Cabezas: Research, software development, data analysis, visualization, writing, and editing.

The author participated in the review of the results and gave their approval to the final version of the article.

CONFLICT OF INTERESTS

The author hereby declares that there are no conflicts of interest about the reporting of this study.

REFERENCES

[1] E. F. Herrera, A. Franco, R. Cancino, and L. Levin, "Ciencia, tecnología y sociedad en América Latina: la mirada de las nuevas generaciones".

[2] A. L. Fierro González and A. L. F. González;CA1370178, "Cuidado nutricional metabólico en paciente con síndrome de respuesta inflamatoria sistémica: sepsis.," 2024, Accessed: Jan. 22, 2025. [Online]. Available: https://repositorioinstitucional.uaslp.mx/xmlui/handle/i/8555

[3] G. R. Manuell, J. Manuel Sanchez Gonzalez, and A. E. Rivera-Cisneros, "SINDROME METABOLICO," 2007, Accessed: Jan. 22, 2025. [Online]. Available: https://www.researchgate.net/publication/272791607

[4] L. E. Tarazona Manrique, R. Andrade, and O. A. Archila Barrera, "Variación del nitrógeno ureico en leche según la temporada del año y días en leche," *Revista MVZ Córdoba*, ISSN 0122-0268, ISSN-e 1909-0544, Vol. 26, No. 3, 2021, vol. 26, no. 3, p. 12, 2021, doi: 10.21897/rmvz.2012.

[5] "Cellbyte Portal - Login." Accessed: Jan. 22, 2025. [Online]. Available: https://www.hospitalsanfernando.com/cportalf/

[6] M. Ayaz, M. F. Pasha, M. Y. Alzahrani, R. Budiarto, and D. Stiawan, "The Fast Health Interoperability Resources (FHIR) Standard: Systematic Literature Review of Implementations, Applications, Challenges and Opportunities," JMIR Med Inform 2021;9(7):e21929 https://medinform.jmir.org/2021/7/e21929, vol. 9, no. 7, p. e21929, Jul. 2021, doi: 10.2196/21929.

[7] S. Hartono, Y. Ramli, R. Astini, C. C. Widayati, and A. J. Ali, "The Clinical Information System That Effects The Patients' Satisfaction Of The Healthcare Services," *Jurnal Manajemen*, vol. 28, no. 1, pp. 1–22, Feb. 2024, doi: 10.24912/JM.V28I1.1463.

[8] S. B. Nabijonovich and A. Muhammadyo'ldoshali, "Empowering Patient Diagnosis with Advanced Software in Healthcare," Miasto Przyszłości, vol. 48, pp. 201–205, May 2024, Accessed: Jan. 27, 2025. [Online]. Available: https://miastoprzyszlosci.com.pl/index.php/mp/article/view/3437

[9] R. Bommu, "Advancements in Healthcare Information Technology: A Comprehensive Review," *Innovative Computer Sciences Journal*, vol. 8, no. 1, pp. 1–7-1–7, Mar. 2022, Accessed: Jan. 27, 2025. [Online]. Available: https://innovatesci-publishers.com/index.php/ICSJ/article/view/80

[10] M. N. Alolayyan et al., "The Mediating Role of Medical Service Geographical Availability Between the Healthcare Service Quality and the Medical Insurance," pp. 281–296, 2025, doi: 10.1007/978-3-031-74220-0_21.

[11] C. Bidoli et al., "Virtual hospitals: The future of the healthcare system? An expert consensus," https://doi.org/10.1177/1357633X231173006, May 2023, doi: 10.1177/1357633X231173006.

[12] A. Woldeyohannis and M. Lind, "U.S. Healthcare System's Electronic Health Records Security Threat Avoidance," JISAR, vol. 17, no. 3, p. 16, Dec. 2024, doi: 10.62273/HLGE2976.

[13] C. L. Gruss and J. M. Ehrenfeld, "Information Management and Technology," *Cottrell and Patel's Neuroanesthesia*, pp. 531–538, Jan. 2025, doi: 10.1016/B978-0-323-93273-8.00029-8.

[14] "MySQL." Accessed: Jan. 27, 2025. [Online]. Available: https://www.mysql.com/

[15] D. Suárez, J. Solano, R. B. Martinez, M. A.- CESTA, and undefined 2020, "Sistema Inteligente para para la gestión automática de un generador eléctrico basado en la arquitectura del IoT," repositorio.cuc.edu.co, 2020, Accessed: Dec. 05, 2021. [Online]. Available: https://repositorio.cuc.edu.co/handle/11323/8721

[16] P. Bourhis, J. L. Reutter, F. Suárez, and D. Vrgoč, "JSON: Data model, Query languages and Schema specification," *Proceedings of the ACM SIGACT-SIGMOD-SIGART Symposium on Principles of Database Systems*, vol. Part F127745, pp. 123–135, May 2017, doi: 10.1145/3034786.3056120.

[17] C. Henriquez Miranda, J. Guzmán, and D. Salcedo, "Minería de Opiniones basado en la adaptación al español de ANEW sobre opiniones acerca de hoteles," 2016, Accessed: Jan. 22, 2025. [Online]. Available: http://rua.ua.es/dspace/handle/10045/53558

[18] "Spring | Home." Accessed: Jan. 23, 2025. [Online]. Available: https://spring.io/

[19] C. Pautasso, O. Zimmermann, and F. Leymann, "RESTful web services vs. 'Big' web services: Making the right architectural decision," *Proceeding of the 17th International Conference on World Wide Web 2008*, WWW'08, pp. 805–814, 2008, doi: 10.1145/1367497.1367606.

[20] M. Alecci, J. Samhi, T. F. Bissyande, and J. Klein, "Revisiting Android App Categorization," *Proceedings - International Conference on Software Engineering*, pp. 2518–2529, 2024, doi: 10.1145/3597503.3639094.

Author 1: I am an Associate Professor at the Electronic Engineering Department, Universidad Sur-Colombiana, Neiva, Colombia. where she has been a faculty member since 2004. He has an M.Sc. in Electrical & Computer and completed his Ph.D. in Engineering from the University of South Florida. Her research interests are primarily in wireless communications and networks. I also work in software development based on open-source platforms. He can be contacted at email: albecor@usco.edu.co