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**UNIDAD ACADÉMICA DE INFORMÁTICA,
CIENCIAS DE LA COMPUTACIÓN E
INNOVACIÓN TECNOLÓGICA**

CARRERA DE SOFTWARE

TÍTULO

**BRAIN MAP: Implementación Web para la Administración,
Visualización y Segmentación de Tumores Cerebrales en
Imágenes de Resonancia Magnética.**

**TRABAJO DE TITULACIÓN PREVIO A LA OBTENCIÓN DEL
TÍTULO DE INGENIERO DE SOFTWARE**

AUTOR: JUAN PABLO ORELLANA GUAMÁN

**DIRECTOR: ING. ANDRÉS SEBASTIÁN QUEVEDO SACOTO,
MGS**

CUENCA – ECUADOR

2024

DIOS, PATRIA, CULTURA Y DESARROLLO



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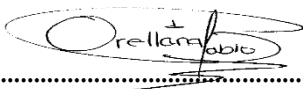
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Declaratoria de Autoría y Responsabilidad

Juan Pablo Orellana Guamán portador(a) de la cédula de ciudadanía N° 0105435457. Declaro ser el autor de la obra: “**BRAIN MAP: Implementación Web para la Administración, Visualización y Segmentación de Tumores Cerebrales en Imágenes de Resonancia Magnética**”, sobre la cual me hago responsable sobre las opiniones, versiones e ideas expresadas. Declaro que la misma ha sido elaborada respetando los derechos de propiedad intelectual de terceros y eximo a la Universidad Católica de Cuenca sobre cualquier reclamación que pudiera existir al respecto. Declaro finalmente que mi obra ha sido realizada cumpliendo con todos los requisitos legales, éticos y bioéticos de investigación, que la misma no incumple con la normativa nacional e internacional en el área específica de investigación, sobre la que también me responsabilizo y eximo a la Universidad Católica de Cuenca de toda reclamación al respecto.

Cuenca, 24 de junio de 2024

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C.I. 0105435457

CERTIFICO:

Certifico que el presente Trabajo de titulación fue desarrollado por **Juan Pablo Orellana Guamán** con el título “**BRAIN MAP: Implementación Web para la Administración, Visualización y Segmentación de Tumores Cerebrales en Imágenes de Resonancia Magnética.**”, bajo mi supervisión.



F:

Mgtr. Andrés Sebastián Quevedo Sacoto

DEDICATORIA

Con profundo cariño y gratitud, dedico este logro a mi familia, que ha sido mi constante compañía en cada etapa de este viaje. A mis hermanos, Erika, Madison y Sebastián, y a mis abuelos, Ayda, Rafael y Rosa, quienes han sido fundamentales en mi vida.

Este trabajo, sin embargo, lo dedico en especial a mis padres, Juan Pablo Orellana y Marisol Guamán Mejía. Con todo mi amor, reconozco que ustedes son la inspiración detrás de cada desafío superado y cada meta alcanzada. Este triunfo es tanto suyo como mío.

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RESUMEN

Con la constante evolución de la medicina digital en un mundo más interconectado, donde la convergencia de datos y la protección de la información son esenciales, surge "Brain Map", un marco web diseñado específicamente para mejorar la gestión y visualización de tumores cerebrales a través de imágenes médicas. Este marco aborda directamente el problema de los sistemas heredados fragmentados, que limitan la gestión eficiente, el análisis y la transferencia de imágenes médicas. La metodología empleada en Brain Map integra soluciones tecnológicas para el back-end y el front-end e incorpora protocolos robustos para la transferencia segura de datos clínicos. Como resultado, el sistema demuestra su capacidad para centralizar y visualizar con precisión las imágenes médicas, facilitando la integración armónica de diversas tecnologías complementarias. Este desarrollo representa un avance en la evolución tecnológica de la gestión de registros médicos, superando las limitaciones de los métodos tradicionales. Al hacerlo, aborda efectivamente preocupaciones sobre la interoperabilidad, la privacidad y el acceso a información clínica sensible y sirve como fundamento para futuras investigaciones y aplicaciones clínicas, contribuyendo al avance de la modernización del cuidado de la salud.

Palabras Clave: Tecnología de la Salud, Arquitectura de Microservicios, Marco Integrativo, Segmentación de Imágenes Médicas, Protocolos de Transferencia

ABSTRACT

With the constant evolution of digital medicine in a more interconnected world, where data convergence and the safeguarding of information are essential, "Brain Map" emerges, a web framework specifically designed to improve the management and visualization of brain tumors through medical images. This framework directly addresses the problem of fragmented legacy systems, which limit the efficient management, analysis, and transfer of medical images. The methodology employed in Brain Map integrates technological solutions for the back-end and front-end and incorporates robust protocols for the secure transfer of clinical data. As a result, the system demonstrates its ability to centralize and accurately visualize medical images while facilitating the harmonious integration of various complementary technologies. This development represents a breakthrough in medical record management's technological evolution, overcoming the limitations of traditional methods. In doing so, it effectively addresses concerns about interoperability, privacy, and access to sensitive clinical information and serves as a foundation for future research and clinical applications, contributing to the advancement of healthcare modernization.

Keywords: Healthcare Technology, Microservices Architecture, Integrative framework, Medical Image Segmentation, Transfer protocols.

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VISUALIZACIÓN Y SEGMENTACIÓN DE TUMORES CEREBRALES
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**BRAIN MAP: WEB IMPLEMENTATION FOR THE MANAGEMENT,
VISUALIZATION, AND SEGMENTATION OF BRAIN TUMORS IN
MAGNETIC RESONANCE IMAGING.**

Brain Map: Web Implementation for the Management, Visualization, and Segmentation of Brain Tumors in Magnetic Resonance Imaging

Juan Pablo Orellana, Sebastian Quevedo

Academic Unit of Informatics, Computer Science, and Technological Innovation, Research Group in Simulation, Modeling, Analysis, and Accessibility (SMA²), Catholic University of Cuenca, 010107, Cuenca, Ecuador
juan.orellana.57@est.ucacue.edu.ec, asquevedos@ucacue.edu.ec

Abstract

With the constant evolution of digital medicine in a more interconnected world, where data convergence and the safeguarding of information are essential, "Brain Map" emerges, a web framework specifically designed to improve the management and visualization of brain tumors through medical images. This framework directly addresses the problem of fragmented legacy systems, which limit the efficient management, analysis, and transfer of medical images. The methodology employed in Brain Map integrates technological solutions for the back-end and front-end and incorporates robust protocols for the secure transfer of clinical data. As a result, the system demonstrates its ability to centralize and accurately visualize medical images while facilitating the harmonious integration of various complementary technologies. This development represents a breakthrough in medical record management's technological evolution, overcoming the limitations of traditional methods. In doing so, it effectively addresses concerns about interoperability, privacy, and access to sensitive clinical information and serves as a foundation for future research and clinical applications, contributing to the advancement of healthcare modernization.

Category: Embedded Computing

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I. INTRODUCTION

In the era of technological transformation, the integration and management of medical data, the digitization of medical images, specifically those obtained through magnetic resonance imaging and chest X-rays, among others, have allowed advancements in modern medicine [1, 2]. However, the persistence of isolated legacy systems hinders its potential [3, 4]. These systems, designed to operate independently, severely limit the interoperability and accessibility of essential diagnostic data [5, 6]. The consequence of this limitation is not minor as it restricts the integration and analysis of data on advanced technological platforms, including websites, Virtual Reality (VR) and Augmented Reality (AR)

environments, or other technologies [7, 8].

This limited accessibility poses a challenge to the efficient visualization and management of medical images in modern, decentralized environments, as well as severe data privacy and security risks [9, 10]. The manual transfer of images from machine to machine, using USB devices or other means that require direct human intervention, increases the risk of security breaches [11] while also propagating the use of potentially obsolete information [12]. Additionally, this way of managing and using legacy systems significantly impedes the development of Artificial Intelligence (AI) systems [13, 14]. The AI's ability to transform disease diagnosis, treatment, and monitoring through advanced image analysis is vast [15], and its practical implementation requires

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* Corresponding Author

overcoming these technological barriers.

In light of this situation, this study proposes a new approach, an integrating system based on a web microservices architecture. This solution facilitates the visualization, secure, and efficient transfer of medical images across cutting-edge technological platforms. It seeks to improve the accessibility and visualization of medical images in various systems and open new guidelines for research and development within digital medicine. This approach addresses the current data privacy and security challenges, establishing a framework for effectively integrating emerging technologies focused on medical image analysis. Implementing this pipeline aims to overcome the technological obstacles that currently limit the potential of the imaging branch, thus marking a step in the evolution of diagnostic medicine toward a more integrated and technologically advanced future.

II. RELATED WORKED

Relevant and similar research is analyzed to strengthen the framework's development. This process aims to discover and adopt emerging trends, recent technologies, and effective methods, particularly those that enhance access and management of medical information in web applications. The goal is to enrich the system, improving its functionality and accessibility.

The first related work, "Design and Development of Backend Application for Public Complaint Systems Using Microservice Spring Boot" [16] uses a microservices architecture with Spring Boot to facilitate the management of public complaints through a backend application, highlighting its ability to decompose the application's functionality into multiple services based on specific business processes. This structure promotes modularity and scalability, allowing efficient integration into cloud environments and offering simplified user access through web browsers.

On the other hand, the study "Architecture of Web Applications based on Angular Framework: A Case Study" [17] focuses on integrating Angular with various technologies such as NodeJS, .NET, and Python to modernize the Web Application Programming course and the Faculty Information System (FIS) at the University of Belgrade - Faculty of Electrical Engineering. The article provides valuable guidance for selecting suitable technologies for web system development through a comparative analysis, concluding that Angular combined with NodeJS offers a practical solution due to its performance and scalability.

Another related study is "Deep Learning for Healthcare: A Web-Microservices System Ready for Chest Pathology Detection" [18] which implements a microservices-based web system to identify thoracic

pathologies. This system uses the Angular framework in the front-end development, Cornerstone.js is integrated for viewing and editing medical images in the browser. As for the back-end, Flask, a Python microframework, was chosen to facilitate the inclusion and management of deep learning models, specifically DenseNet-121, suitable for analyzing X-ray images. Hibernate and Postgres interact with the database, allowing efficient information management. In addition, AI explainability methods, such as GradCAM, are applied to visualize key areas in the images, thus fostering a clear understanding of AI-generated diagnoses. This set of technological tools highlights the application of a cohesive and protected method for advancing AI-assisted medical diagnostics.

In the study "M-HEALTH System for Detecting COVID-19 in Chest X-Rays Using Deep Learning and Data Security Approaches" [19] presents the improvement in the prediction of pathologies through medical images, highlighting the use of deep learning techniques. This approach has allowed the development of models with high sensitivity and specificity rates in detecting COVID-19 disease in thoracic radiographs. A critical aspect of this study is the integration of data security protocols, particularly the implementation of the OAuth 2.0 standard for system access authorization, thus addressing a joint gap in previous models that often omitted data security as a system requirement. The study's central proposal is to create a mobile application capable of detecting COVID-19 disease with 92 percent sensitivity and 90 percent specificity, but also ensures the protection of the clinical data handled, demonstrating a harmonization between diagnostic efficacy and information security.

The study "Detection of Pathologies in X-Ray Chest Images using a Deep Convolutional Neural Network with Appropriate Data Augmentation Techniques" [20] focuses on using Convolutional Neural Networks and data augmentation techniques to detect pathologies in chest X-ray images. Although the article does not specify the use of database technologies or authentication, these would play a crucial role in the secure storage and management of the analyzed data. The practical implementation of databases such as PostgreSQL or MongoDB would allow the handling of extensive medical data. At the same time, authentication technologies like OAuth2 and JWT would ensure secure access to information, protecting the privacy and integrity of patient data. These technological components are fundamental for the efficient and secure information handling in automated medical diagnostic systems.

Additionally, in the field of medical image management and transfer, "Smartphone application for medical images secured exchange based on

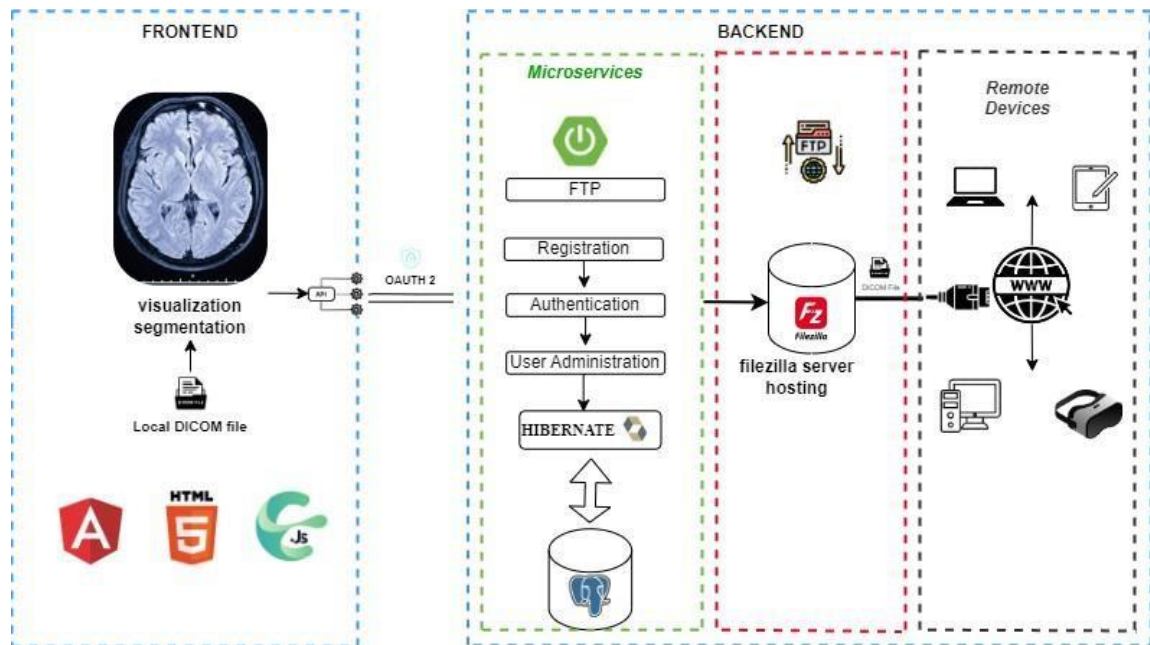


Fig. 1. Architecture: front-end in the left frame, back-end in the right frame

encryption" [21] which proposes a method for sharing medical images using a smartphone application, implementing an algorithm that uses matrix product and exclusive sum, this system uses the File Transfer Protocol (FTP) and the Short Message Service (SMS) for the exchange of images, in which the sender creates an FTP server and sends an encrypted SMS containing the key for image retrieval. Based on the review of various authors previously mentioned [16, 17, 18, 19, 20, 21] underscore the significance of strategic technology selection for the development of web systems. For the backend, studies [20, 19] are noteworthy for demonstrating the adoption of a microservices architecture alongside databases such as PostgreSQL and authentication mechanisms like OAuth 2.0 and JWT. These technologies enhance user security and management, promoting greater scalability and interoperability. This approach facilitates secure information management and efficient service integration. Additionally, the study [21] introduces the use of the FTP protocol for the safe transfer of medical images, reinforcing the importance of robust protocols in handling sensitive data. In frontend development, [19] highlights using Angular and Cornerstonejs, providing a solid framework for visualizing medical images, such as MRI scans. This technological selection is distinguished from [17] by its specific focus and ability to facilitate interaction with complex medical images, enhancing the end-user experience.

III. METHODS

A web system is developed for the visualization and secure transfer of medical images, integrating various

technological and methodological components. The Methods section describes the system's structure and capabilities, addressing fundamental aspects such as imaging technology, data transfer protocols, microservices architecture, and user interface design. Each component is essential for effective performance and overall effectiveness of the system, and it is described in more detail in its respective sections. Each section focuses on a particular system element, as illustrated in Fig. 1.

A. Front-End Development

1) Framework and Technologies:

The front-end interface leverages Angular, a robust framework designed for web application development, is used. It is characterized by its focus on modular components, which integrate TypeScript logic, HTML templates, and CSS styles. This integration allows dynamic and visually appealing user interfaces to be quickly developed. This combination makes it easy for programmers to efficiently create reactive and complex web applications. This choice guarantees a scalable and maintainable user interface in the long term [22].

2) Medical Image UI:

A fundamental aspect in the front-end is the implementation of Cornerstonejs, an open-source JavaScript library focused on the medical sector, dedicated to facilitating the processing and visualization of medical images in web applications. This essential tool allows the visualization in the browser of various types of medical images, including X-rays and magnetic resonance images, without additional software.

It provides a series of essential functionalities, such as the ability to render images in the DICOM format [23].

3) *Medical Imaging Interaction:*

In medical imaging, integrating Multiplanar Reconstruction (MPR) techniques with crosshair functionality constitutes a significant advance for the precise localization of anatomical structures and anomalies across multiple planes. While MPR allows

the visualization of images in the axial, sagittal, and coronal planes from cranial magnetic resonance imaging, the crosshairs facilitate the exact spatial correlation between these different planes. This synergy enhances the ability of medical professionals to interpret the spatial relationship of structures within the human body, optimizing both diagnosis and therapeutic planning [23].

Additionally, the system offers users other possibilities for working with medical images, providing features such as:

- Enlargement and reduction for a thorough analysis.
- Modification of color gradients to increase image sharpness.
- Creation of annotations to highlight areas of interest or concern.

4) *API Calls:*

Another critical point for front-end development is using an HTTP client to establish secure communications with the back-end, a vital aspect for efficient data retrieval and submission management. Moreover, it utilizes OAuth 2.0 to improve the process, which enhances security through control over authentication and authorization of API access. During user authentication, OAuth 2.0 issues access tokens essential for validating and approving API requests. These tokens are integrated into the HTTP request headers, ensuring data transmission encryption and limiting access to authorized users only. Furthermore, the system employs robust strategies for the secure storage and handling of these tokens during the client's session, thus ensuring session security and protecting sensitive medical information and user data [24].

5) *Responsive Design:*

The interface is responsive, thus ensuring that the application is accessible and easy to use across various devices and screen sizes. This adaptability is essential for medical professionals accessing the system from different devices.

B. Back-end Development

The core of the Back-end system incorporates a set of advanced development tools and functionalities

Table I. Microservices Objectives

Microservice	Objective
Registration	Optimizes the user registration process by facilitating the efficient entry of personal data
Authentication	Provides a secure mechanism for verifying user identity
Role Management	Manages access levels and permissions assigned to each user
User Data Management	Facilitates the secure and efficient handling of users' personal information
FTP Protocol	Enables file transfer between systems connected to a network, storing them on an FTP server

specifically designed to ensure scalability and operational efficiency while maintaining the highest standards of security. This careful integration allows for a remarkable specialization in executing each task, ensuring that all operations, from data management to user authentication and secure transfer of medical images, are carried out with maximum efficiency and precision. For a detailed view of each microservice and its objectives, see Table I.

This section details the capabilities of developing the backend, designed to support the advanced functions necessary for effectively processing and analyzing medical images.

1) *Microservice Architecture:*

System architecture is organized through a microservices structure, which is an advantage for easy scalability, maintenance, and autonomous updating of multiple of its functionalities, oriented towards specific tasks, each microservice exhibits a remarkable specialization and efficiency in its operations. Communication between these microservices is realized through clearly established application programming interfaces (APIs), thus facilitating seamless data exchange and harmonious integration of the various system components. [18, 16].

2) *Security Implementation:*

- **Authentication and Authorization:** By implementing OAuth 2.0, the system provides secure and effective authentication, accessing management procedures, and ensuring the protection of sensitive medical data and personal information of users [24].
- **Data Encryption:** To enhance protection, sensitive information is encrypted, thus protecting

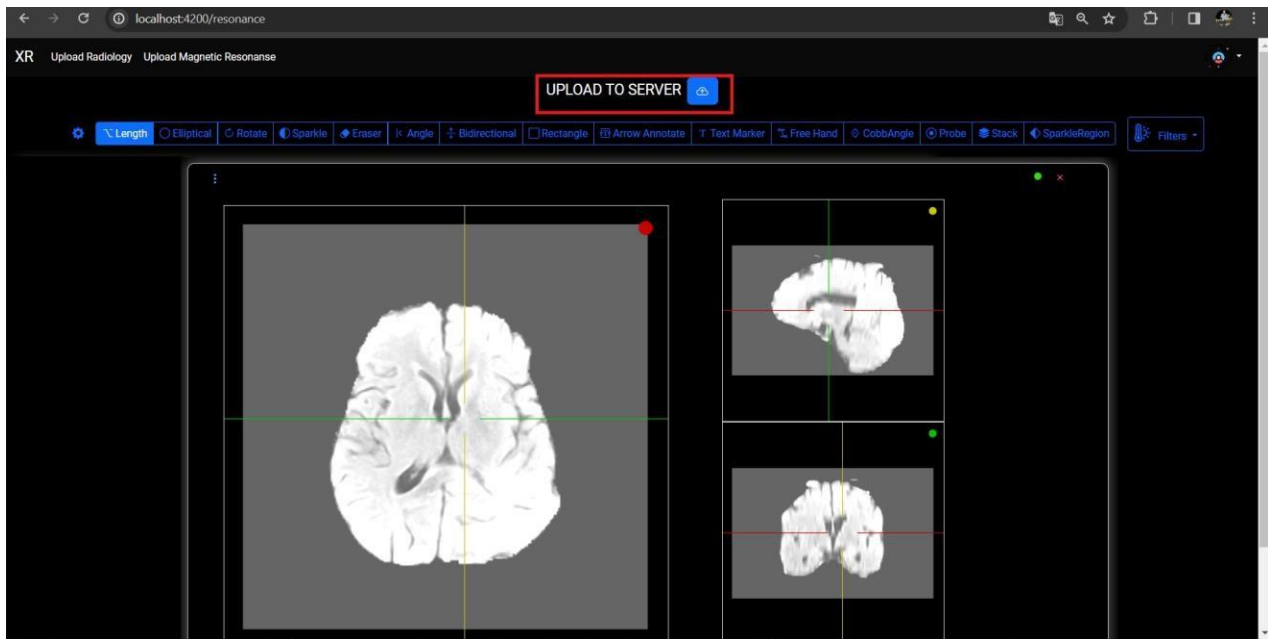


Fig. 2. MRI management and visualization interface

important data and ensuring the confidentiality and integrity of patient and diagnostic information.

3) Data Management::

The back-end architecture of the system is based on Hibernate, an Object-Relational Mapping (ORM) solution to facilitate interaction with the database in an agile and efficient way. The adoption of this methodology allows modeling information in an object-oriented way, significantly simplifying data management. In addition, the system uses a Postgres database, which has been noted for its robustness and good integration with ORM tools.

C. Secure FTP Medical Image Transfer

Within the process of transferring magnetic resonance imaging (MRI) medical images, the efficiency and security of the data transfer process have been prioritized. In this context, the need to implement a back-end solution that allows the optimal manipulation and transfer of these images once they have been appropriately visualized and segmented through the front-end interface stands out.

To meet this need, the FTP file transfer protocol was implemented. This mechanism enables the efficient reception of images in DICOM format. It ensures the correct identification of each data set by including the patient's name and identification number in the controller.

Once received, this data is processed to connect to the microservice. The files are transferred securely and efficiently to a server configured with Filezilla. The server automatically creates a personalized folder

for each patient, identified by name and ID number, where the corresponding DICOM files are stored.

This approach facilitates the secure organization and storage of files. It also allows users from various devices versatile access to images, regardless of whether they are on the same local network or require a remote connection. This significantly expands the possibilities for viewing and analysis in different clinical or research environments. This methodology demonstrates a commitment to the accessibility and interoperability of medical data, which are fundamental pillars in the continuous improvement of healthcare services and medical research.

IV. RESULTS

The main screen of the developed system can be seen in Fig. 2, offering a set of functionalities designed to optimize clinical analysis. The DICOM MRI image viewer integrates the crosshairs function and Multiplanar Reconstruction (MPR) to facilitate detailed visualization of the brain through axial, sagittal, and coronal slices. In addition, the image manipulation toolbar provides an arsenal of specific tools for manipulating and annotating medical images, enriching the imaging staff's interaction with MRI scans. In particular, by including a dedicated button, observable in the red rectangle, for secure image transfer to the server, this integrated approach highlights the intention to improve clinical decision-making by providing intuitive and advanced visual tools.

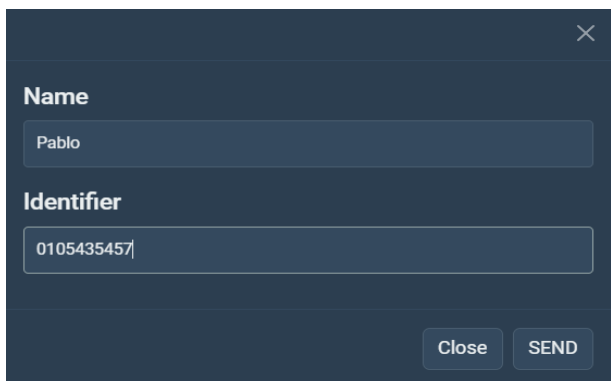


Fig. 3. Patient information form

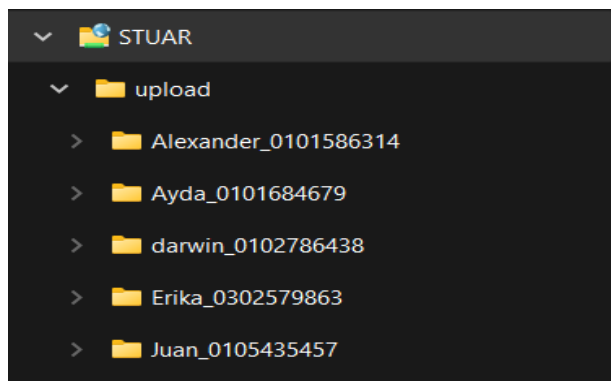


Fig. 4. folder creation with patient's credentials

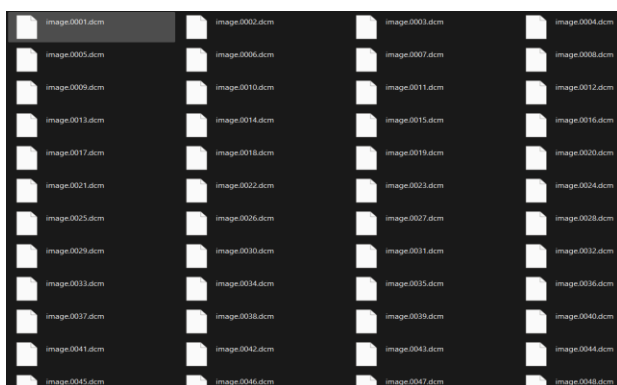


Fig. 5. Dicom files stored in the folders

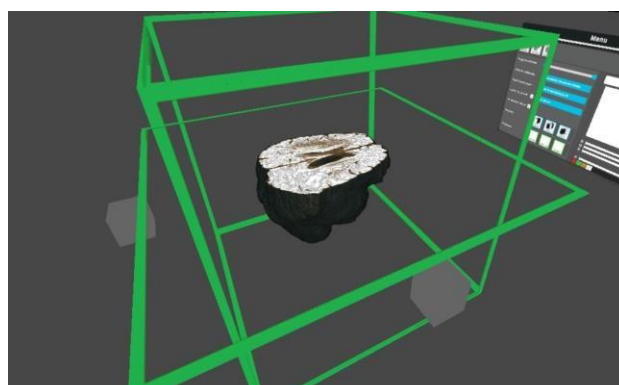


Fig. 6. VR File Access

A. Registration, Authentication and User Management through Microservices

This subsection presents how adopting a microservices-based architecture facilitates the creation of an efficient system for managing users within the platform. This modular approach allows for simplified integration and maintenance while ensuring the system's security and scalability.

First, the registration microservice provides a secure interface for new users to create their accounts as shown in Fig. 3, integrating data integrity checks and ensuring user information is handled confidentially and securely. This process includes security measures such as email validation and password creation to prevent unauthorized access.

User authentication is managed through a dedicated microservice that employs standard security protocols, such as OAuth2 and JWT (JSON Web Tokens), to verify user credentials efficiently, and user credentials are entered into a login form as shown in Figure 4. Ensuring that only authenticated users can access their accounts and sensitive information related to patients and their medical images.

In addition, a user administration system allows system administrators to manage user accounts, assign specific roles and permissions, and monitor

activity within the platform. This system is crucial to maintaining the operational integrity and security of the system, allowing effective management of access and functionality available to different users.

Using these microservices improves the user experience when interacting with the platform and strengthens the security framework, which is essential for handling sensitive medical data. Furthermore, it demonstrates the flexibility and effectiveness of microservices in solving complex user management problems in medical software environments.

B. System Integration

Implementing the framework for managing DICOM magnetic resonances has proven effective in providing secure access to medical information. This process facilitates automatically creating custom directories on the server, labeled with the patient's name and identification, ensuring an intuitive and accessible data classification. In addition, including DICOM files within these custom directories contributes to orderly and coherent storage, simplifying the retrieval and management of the files.

A notable aspect of this system is the capability of remote access to the images, which is enabled through integration with technologies such as virtual

reality. This advance allows healthcare professionals to visualize DICOM images in an immersive and detailed manner, regardless of their physical location, enhancing the analysis and interpretation of clinical data. This approach not only improves the accessibility and interoperability of medical data but also highlights the commitment to technological innovation in the continuous improvement of health services and medical research. all of which can be seen in the Figs.3-6.

C. Evaluation of User Experience Using System Usability Scale (SUS)

User evaluation is essential to optimizing usability, ensuring alignment with specific user needs, and detecting flaws. In this case, the System Usability Scale (SUS) was used, a tool developed by John Brooke in 1996 to evaluate systems from the user's perspective [25].

For this specific case, to assess the usability of the "Brain Map" system, a survey using SUS was conducted with 10 participants. These participants were from the neuroscience laboratory belonging to the "Centro de Investigación, Innovación y Transferencia Tecnológica" (CIITT), the Faculty of Medicine and included general practitioners.

The results from the 10 participants, applying the SUS questions, are shown below in Fig. 7:

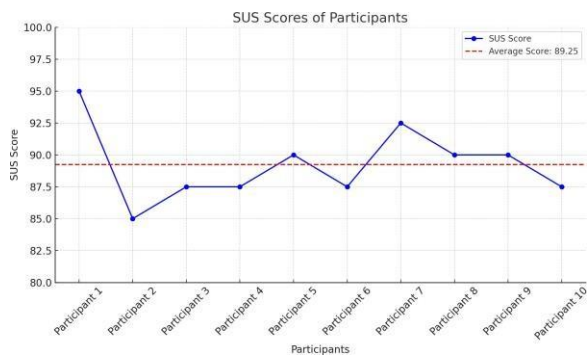


Fig. 7. SUS Results

The system's average SUS score was 89.65, indicating a good level of usability and user satisfaction. The SUS scores indicate that the "Brain Map" system is functional and suitable for managing and visualizing brain tumors in magnetic resonance imaging. This feedback from various participants supports the system's potential for adoption and application in clinical and research settings.

D. Code Availability

The code generated for the experiment can be found at <https://github.com/PePeWee07/chest-xr-system-frontend.git>.

V. CONCLUSION

The study succeeds in establishing a framework for effectively integrating emerging technologies in medical image visualization and management. Through a detailed methodology and interdisciplinary collaboration with experts in artificial intelligence and virtual reality, challenges related to the security and accessibility of sensitive data have been accurately addressed. This work stands out for its ability to facilitate the use of DICOM images, promoting a more efficient and secure management of this type of file in the medical context. In addition, it has been shown to enable detailed segmentation and efficient management of brain tumors by magnetic resonance imaging, improving diagnostic and therapeutic capabilities in neurology. Protecting sensitive information has been a fundamental pillar, ensuring technological advances comply with current privacy and data security regulations.

VI. FUTURE WORK

Future work that can be applied to this study identifies three main areas of interest for the evolution of the present system. First, integrating artificial intelligence (AI), mainly dedicated to magnetic resonance image segmentation, is contemplated. This incorporation aims to optimize accuracy and efficiency in identifying and delineating specific features of the dataset.

Secondly, the development and implementation of advanced visualization systems are proposed. These systems will enhance the ability to visualize various abnormalities in the brain and other body areas. The integration and comparison of medical images, which will be expanded to include other medical imaging modalities such as magnetic resonance imaging (MRI), computed tomography (CT), ultrasound, and functional magnetic resonance imaging (fMRI) of different body regions, will enrich the holistic and detailed understanding of patients' conditions. This innovation in visualization systems promises to be a turning point in medical diagnostics, offering more powerful and versatile tools for the detection and in-depth analysis of pathologies.

Finally, mechanisms are proposed for integrating diagnoses made by imaging professionals into the system. This development will enable the system to attach clinical evaluations and related diagnoses.

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ANEXOS

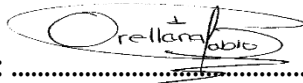


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F: 

Juan Pablo Orellana Guamán

C.I. 0105435457