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

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

Abstract
Amidst the backdrop of the continual evolution of digital medicine in the increasingly interconnected world, where data convergence and the safeguarding of information are paramount, the concept of "Brain Map" has emerged, which is a web framework that is specifically designed to improve the management and visualization of brain tumors using medical images. This framework directly addresses the problem with fragmented legacy systems, which limit the efficient management, analysis, and transfer of medical images. The methodology employed in Brain Map integrates technological solutions for both the back-end and the front-end while also incorporating robust protocols that support the secure transfer of clinical data. This ultimately provides the system with its demonstrated ability to centralize and accurately visualize medical images while facilitating the harmonious integration of various complementary technologies. This development represents a breakthrough in the technological evolution of medical record management, thus overcoming the limitations of traditional methods. In doing so, it effectively addresses concerns about interoperability, privacy, and access to sensitive clinical information, and it is also expected to serve as a foundation for future research and clinical applications, thereby contributing to the continued advancement of healthcare modernization.

Category: Computer Graphics / Image Processing

Keywords: Healthcare technology; Microservices architecture; Integrative framework; Medical image segmentation; Transfer protocols

I. INTRODUCTION

The current era of technological transformation has led to substantial advancements in modern medicine through the integration and management of medical data as well as the digitization of medical images, specifically those obtained through magnetic resonance imaging and chest X-rays [1, 2]. However, the persistence of isolated legacy systems hinders their potential [3, 4]. The use of these systems, which are designed to operate independently, severely limits the interoperability and accessibility of essential diagnostic data [5, 6]. This has major consequences, as it restricts the integration and analysis of data on advanced technological platforms, including websites, virtual reality (VR), augmented reality (AR), environments, and other technologies [7, 8].

This limited accessibility poses a challenge to the efficient visualization and management of medical images in

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*Corresponding Author

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modern, decentralized environments, along with severe data privacy and security risks [9, 10]. Moreover, the manual transfer of images from machine to machine, through the use of 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]. Further, this way of managing and using legacy systems significantly impedes the development of artificial intelligence (AI) systems [13, 14]. Such systems are believed to have vast potential to transform disease diagnosis, treatment, and monitoring through the contributions they can make to advanced image analysis [15], but these technological barriers must be overcome before such systems can be implemented in practice.

With this background, the current study proposes a new approach, involving an integrating system based on a web microservices architecture. This solution facilitates the visualization as well as 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 lead to the establishment of new guidelines for research and development within digital medicine. This approach aims to address the current challenges involved in data privacy and security, with the ultimate intention of establishing a framework for effectively integrating emerging technologies that are focused on medical image analysis. The aim of implementing this pipeline is to overcome the technological obstacles that currently limit the potential of the imaging branch, thus marking a major step in the evolution of diagnostic medicine toward a more integrated and technologically advanced future.

II. RELATED WORKS

In this section, research that is relevant and similar to the existing work 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 ultimate goal is to enrich the system while improving its functionality and accessibility.

The first related work [16] uses a microservices architecture with Spring Boot to facilitate the management of public complaints through a backend application, and it has the ability to decompose the application's functionality into multiple services based on specific business processes. This structure promotes modularity and scalability, which ultimately facilitates efficient integration into cloud environments and offers simplified user access through web browsers.

On the other hand, another 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 technologies that are suitable for web system development through a comparative analysis, while ultimately concluding that Angular combined with NodeJS offers a practical solution due to its performance and scalability.

Another related study [18] implements a microservices-based web system to identify thoracic pathologies. This system uses the Angular framework in the front-end development, and Cornerstone.js is integrated for viewing and editing medical images in the browser. For the back-end, Flask, a Python microframework, is chosen to facilitate the inclusion and management of deep learning models that are suitable for analyzing X-ray images, and DenseNet-121 in particular. Hibernate and Postgre interact with the database, thus allowing for efficient information management. Moreover, 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.

The study [19] presents a system that achieves an improvement in the prediction of pathologies through medical images, thus highlighting the utility of deep learning techniques. This approach has allowed for the development of models with high sensitivity and specificity for detecting coronavirus disease 2019 (COVID-19) 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 have often omitted data security as a system requirement. The study's central proposal is to create a mobile application that is capable of detecting COVID-19 disease with 92% sensitivity and 90% specificity, but which also ensures the protection of all clinical data that is handled, ultimately demonstrating harmony between diagnostic efficacy and information security.

Meanwhile, the study [20] focuses on the use of convolutional neural networks and data augmentation techniques to detect pathologies in chest X-ray images. Although that article does not report specifics regarding the use of database technologies or authentication, these types of techniques are expected to 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 enable the handling of extensive medical data. At the same time, authentication technologies like OAuth 2.0 and JWT (JSON Web Tokens) would ensure secure access to information, ultimately protecting the privacy and integrity of patient data. These technological components are fundamental in ensuring efficient and secure information handling in automated medical diagnostic systems.

Moreover, in the field of medical image management and transfer, the authors of [21] propose a method for sharing medical images using a smartphone application while implementing an algorithm that uses matrix product and exclusive sum, and this system uses the file transfer protocol (FTP) and the short message service (SMS) for the exchange of images, where the sender creates an FTP server and sends an encrypted SMS containing the key for image retrieval. The previously mentioned review of various works [16-21] underscores the significance of strategic technology selection in the development of web systems. For the back end, some studies [19, 20] are particularly 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, thus promoting greater scalability and interoperability. This approach facilitates secure information management and efficient service integration. Moreover, another study [21] introduces the use of the FTP protocol for the safe transfer of medical images, thereby reinforcing the importance of robust protocols in handling sensitive data. In front-end development, [19] highlights the use of Angular and Cornerstone.js, ultimately providing a solid framework for visualizing medical images, such as MRI scans. This technological selection is distinguished from [17] by its specific focus and its ability to facilitate interaction with complex medical images, thus enhancing the end-user experience.

III. METHODS

This paper has developed a web system for the visualization and secure transfer of medical images that integrates various technological and methodological components. This section describes the system's structure and capabilities while addressing fundamental aspects such as imaging technology, data transfer protocols, microservices architecture, and user interface design. Each component is essential for the effective performance and overall effectiveness of the system. 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, which is a robust framework that is designed for web application development. It is characterized by its focus on modular components, which integrate TypeScript logic, HTML templates, and CSS styles. This integration makes it possible to quickly develop dynamic and visually appealing user interfaces. 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].

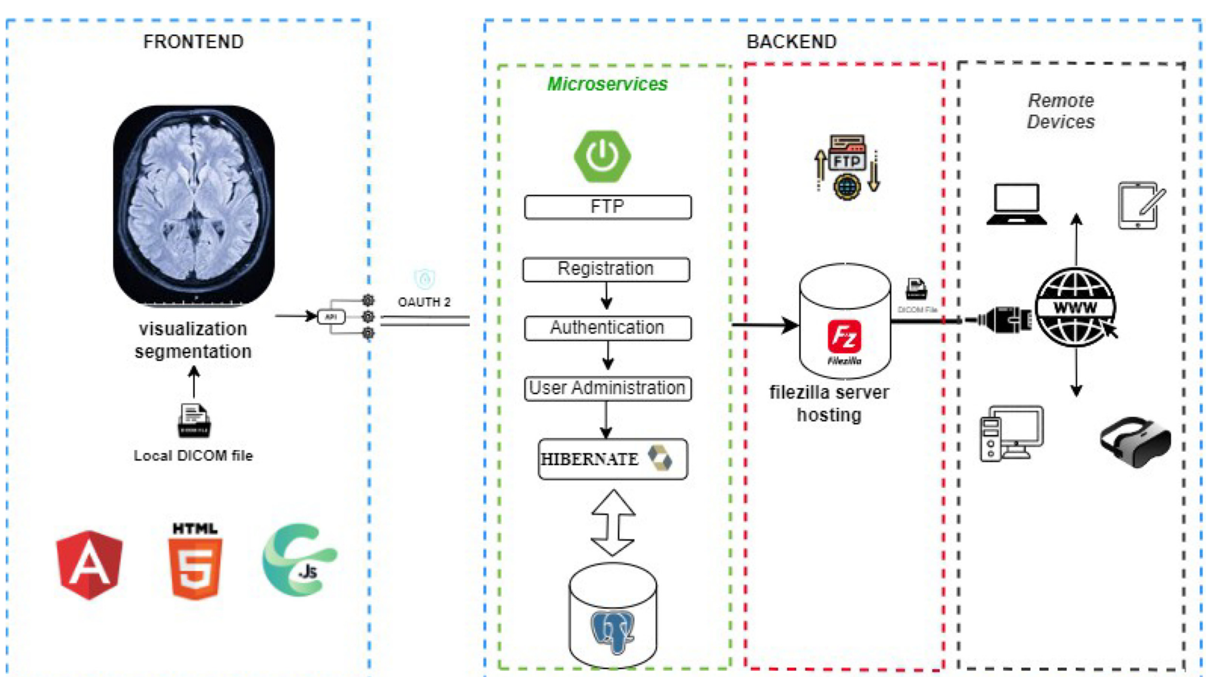

Fig. 1. Architecture: front-end in the left frame, back-end in the right frame.

2) Medical Image UI

A fundamental aspect in the front-end is the implementation of Cornerstone.js, which is an open-source JavaScript library that is focused on the medical sector and which is 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 the use of 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, methods integrating multiplanar reconstruction (MPR) techniques with crosshair functionality constitute a significant advance for the precise localization of anatomical structures and anomalies across multiple planes. MPR enables the visualization of images in the axial, sagittal, and coronal planes from cranial magnetic resonance imaging, and the crosshairs facilitate the exact spatial correlation between these different planes. This synergy provides medical professionals with an enhanced ability to interpret the spatial relationship of structures within the human body, optimizing both diagnosis and therapeutic planning [23].

The system also 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 the use of an HTTP client to establish secure communications with the back-end, a vital aspect for efficient data retrieval and submission management. It also utilizes OAuth 2.0 to improve the process, which enhances security through control over the authentication and authorization of application programming interface (API) access. During user authentication, OAuth 2.0 issues access tokens that are essential for validating and approving API requests. These tokens are integrated into the HTTP request headers, thus ensuring data transmission encryption and limiting access to authorized users only. The system also 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, thereby ensuring that the application is accessible and easy to use across various devices and screen sizes. This adaptability is essential for medical professionals who are 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 that are 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. Table 1 presents a detailed view of each microservice and its objectives.

This section details the capabilities involved in developing the back-end, which is designed to support the advanced functions that are necessary for effectively processing and analyzing medical images.

1) Microservice Architecture

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

Table 1. 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, and their storage on an FTP server

2) Security Implementation

• Authentication and Authorization: By implementing OAuth 2.0, the system provides secure and effective authentication and access to management procedures, and it also ensures the protection of sensitive medical data and personal information of users [24].

• Data Encryption: To enhance protection, sensitive information is encrypted, thus protecting 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, which is an object-relational mapping (ORM) solution intended to facilitate interaction with the database in an agile and efficient manner. The adoption of this methodology allows for information to be modeled in an object-oriented way, significantly simplifying data management. The system also uses a Postgres database, which has previously 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, it is highly necessary 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.

To meet this need, the FTP file transfer protocol was implemented. This mechanism enables the efficient reception of images in DICOM format. This 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 that is 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, and 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. Ultimately, 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 is shown in Fig. 2, where it can be seen that the system offers a set of functionalities that are designed to optimize clinical analysis. The DICOM MRI image viewer integrates the crosshairs function and MPR to facilitate detailed visualization of the brain through axial, sagittal, and coronal slices. The image manipulation toolbar also provides an arsenal of specific tools for manipulating and annotating medical images, thus enriching the imaging staff's interaction with MRI scans. In particular, by including a dedicated button, which is observable in the red rectangle, for secure image transfer to the server, this integrated approach highlights the intention to improve

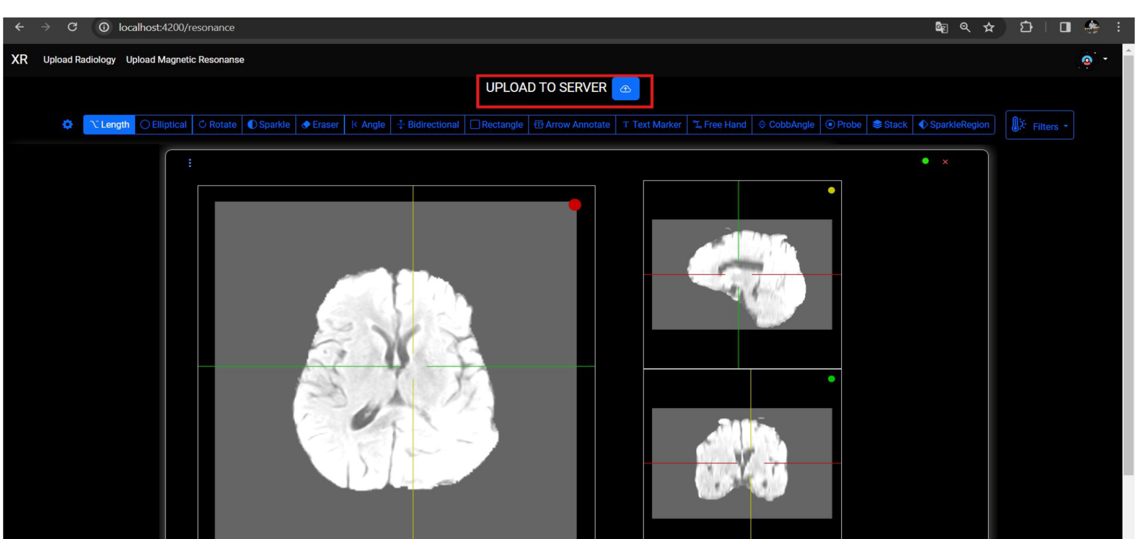

Fig. 2. Magnetic resonance imaging management and visualization interface.

clinical decision-making by providing intuitive and advanced visual tools.

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 where new users can create their accounts. As shown in Fig. 3, data integrity checks are integrated to ensure that 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 OAuth 2.0 and JWT, to efficiently verify user credentials, and user credentials are entered into a login form as shown in Fig. 4. This ensures that only authenticated users can access their accounts and sensitive information related to patients and their medical images.

A user administration system also 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, which ultimately allows for 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. It also demonstrates the flexibility and effectiveness of microservices in solving complex user management problems in medical software environments.

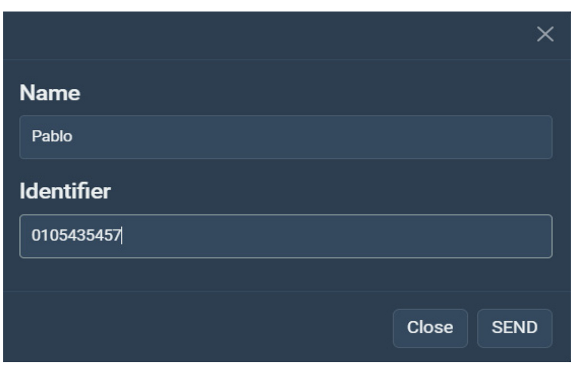

Fig. 3. Patient information form.

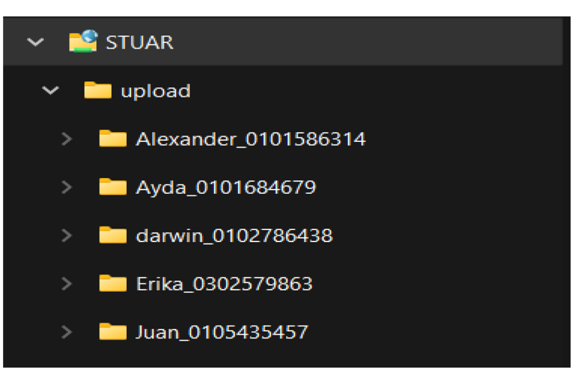

Fig. 4. Folder creation with patient's credentials.

B. System Integration

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

A notable aspect of this system is its 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, which enhances the analysis and interpretation of clinical data. This approach not only improves the accessibility and interoperability of medical data but also highlights its commitment to technological innovation in the continuous improvement of health services and medical research. All of this can be seen in Figs. 3-6.

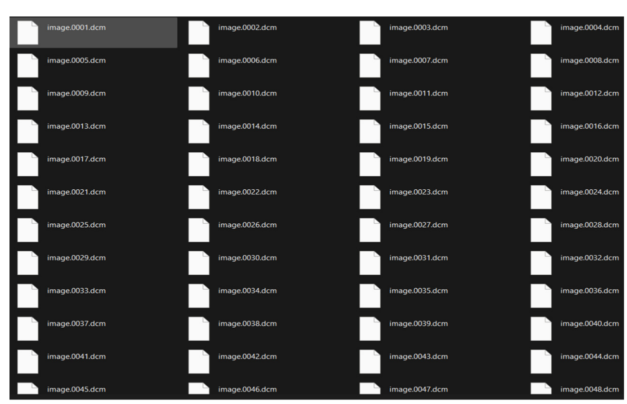

Fig. 5. DICOM files stored in the folders.

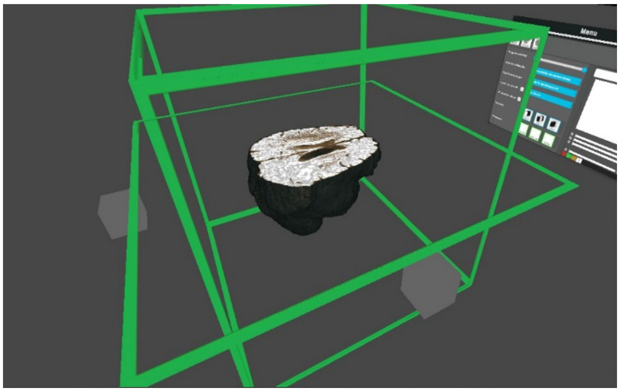

Fig. 6. Virtual reality file access.

C. Evaluation of User Experience using SUS

User evaluation is an essential aspect of optimizing usability, as it ensures alignment with specific user needs as well as flaw detection. In this case, the System Usability Scale (SUS) was used, which is a tool that was developed by Brooke [25] in 1996 to evaluate systems from the user's perspective.

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 recruited 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.

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 potential of the system's adoption and application in clinical and research settings.

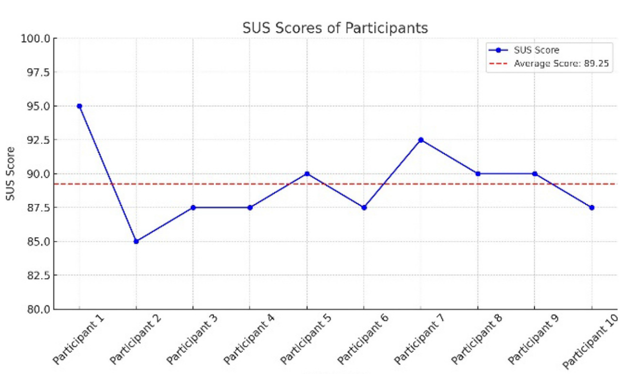

Fig. 7. The System Usability Scale (SUS) results.

D. Code Availability

The code generated for this experiment can be found at https://github.com/PePeWee07/chest-xr-system-front-end.git.

V. CONCLUSION

This study has succeeded in establishing a framework that can be used for effectively integrating emerging technologies in medical image visualization and management. By devising a detailed methodology and interdisciplinary collaboration with experts in AI and VR, 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, thereby promoting a more efficient and secure management of this type of file in the medical context. Detailed segmentation and efficient management of brain tumors has also been facilitated by magnetic resonance imaging, which has led to improvements in diagnostic and therapeutic capabilities in neurology. Protecting sensitive information has been a fundamental pillar in this process, ensuring technological advances comply with current privacy and data security regulations.

VI. FUTURE WORK

Future work in this area might identify three main areas of interest for the evolution of the present system. First, integrating artificial intelligence (AI), which would be mainly dedicated to magnetic resonance image segmentation, might be contemplated. This incorporation could aim to optimize accuracy and efficiency in identifying and delineating specific features of the dataset.

Second, the development and implementation of advanced visualization systems are proposed. These systems are expected to 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 that offers 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 link clinical evaluations and related diagnoses.

Conflict of Interest

The authors have declared that no competing interests exist.

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Juan Pablo Orellana https://orcid.org/0009-0001-7813-5293

Juan Pablo Orellana is a student at the Faculty of Informatics, Computer Science, and Technological Innovation (ICCIT) at Universidad Católica de Cuenca. During his academic training, he has demonstrated a strong commitment to research and innovation in informatics and computer science.

Sebastián Quevedo https://orcid.org/0000-0001-5585-0270

Sebastián Quevedo is a Ph.D. candidate in Computer Science at the Escuela Superior Politécnica del Litoral, Ecuador. Since 2012, he has been a tenured professor in the Software Engineering program at the Universidad Católica de Cuenca. Additionally, he has been a guest lecturer in the Master's program in Cybersecurity since 2022. His research interests include deep learning applied to computer vision tasks and natural language processing.