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Original Article

Implementation of Machine Learning to Mitigate the Deficit of Health Personnel and Optimize Healthcare

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Abstract *- The health system in Peru over the years has presented various deficiencies that intensified during the pandemic; one of these problems continues to be the lack of health personnel. The country has a high deficit of human resources for the current demand for care in the different health centers nationwide. The present investigation proposes developing a web system that predicts the need for care in the different medical specialties using a field of artificial intelligence known as machine learning to analyse data in the format of electronic medical records. The results obtained show that efficient planning allows optimizing the organization of health personnel to cover the demand for the different health care services, in addition to reducing the administrative workload that is often assigned to care personnel, and that through the automation and rapid response offered by a system that uses artificial intelligence means more time is available to improve patient flow and provide prompt and timely care.*

Keywords *- Artificial intelligence, Electronic medical records, Health center, Machine learning, Medical care.*

1. Introduction

Poor administration and management of expenses lead to problems in various sectors of a society or country; according to the Inter-American Development Bank (IDB), there was an average increase in public spending in Latin America and the Caribbean of 7% during the last 2 decades. However, this is not reflected in the same way in an increase in physical and human capital and lasting social benefits for its citizens, thus demonstrating a huge problem for countries to achieve good management and efficiency in their public spending. [1].

Peru is no stranger to this problem, the health sector being one of the most affected and that during the first years of the pandemic, revealed a terribly abandoned system with a reduced budget where only approximately 6% of GDP is allocated, which causes various deficiencies such as poor infrastructure, shortages of inputs and human resources [2].

Given the worrying reality of the Peruvian health system, technology can offer an alternative solution by improving the efficiency of specific processes. Among the various technological tools, artificial intelligence (AI) stands out, which competes with abilities that are believed to be exclusive to the human being, as well as having the ability to process a wide variety of information in various formats and the short term. [3].

In research work [4], the authors propose a system to prevent non-attendance at scheduled medical appointments in order to avoid interruptions in clinical management and losses in resources for a health center. Through a branch of AI known as machine learning, it is possible to predict the rate of cases by specialty; these contributions are significant for achieving optimal programming and for other operational aspects of medical care.

The authors of the research work [5] develop a system that predicts patients' punctuality in their medical appointments to avoid interrupting the hours of care and increasing waiting time for other patients. The system manages to predict the risk of a patient arriving late using machine learning models, thus serving as a decision-making support tool, integrating itself into a medical appointment system and mitigating late arrivals.

On the other hand, the research work [6] where the authors make a system that can predict patient absenteeism, thus avoiding losses in service resources, queues and excessive waiting times that can impact user satisfaction. As in the works mentioned above, the authors resort to machine learning to achieve the system's functionality by accessing the profiles of missing patients and trying to discover the reasons for their absence from consultation and to know if the patient will attend the scheduled appointment or not.

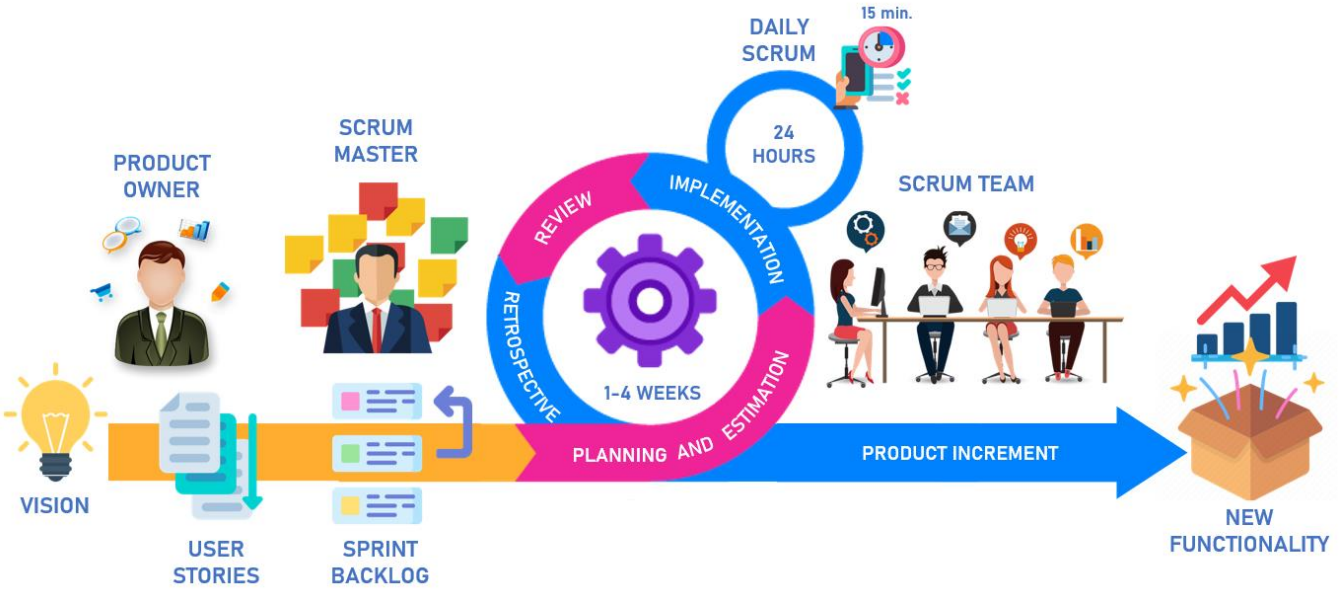

Fig. 1 Scrum methodology flow

The objective of this work is to develop a web system that allows knowing which specialties in a health center will be more requested or concurred, thus allowing better programming of the personnel to cover the demand for care and achieving more efficient results in favor of timely service for patients.

To carry out this project, various technological tools are applied that allow the creation of the desired functions. In addition, the SCRUM framework is used for the agile development of the system with the ease of managing changes as many times as necessary until the desired results are obtained. The implementation of artificial intelligence will help predict the information necessary for better programming of health personnel using data based on medical records and triage.

2. Methodology

2.1. Scrum

It is a methodology, also known as a framework, that allows the development of projects in a dynamic, personalized, agile and flexible way, thus achieving rapid results in a certain time [24]. Agreements are established to deliver the project's progress incrementally, that is, to make periodic work deliveries. In Figure 1 shows the different processes covered by the scrum methodology.

2.1.1. Start

The initial phase of the process is where the roles and functions of the team members are identified and assigned. Roles are defined according to the skills and contributions of each member. In this phase, the team organizes itself to start with the project's development and define its way of working.

2.1.2. Planning and Estimation

In this second phase, the user stories are proposed and selected according to the end user's requirements. The product backlog is also carried out, taking into account an estimation process to be able to organize the stories. With the requirements ordered, the creation of the sprint backlog continues; the latter is selected by priority, going through a development and testing process that can last approximately between 1 to 4 weeks, resulting in an increase in the product.

2.1.3. Implementation

It is the third phase of the scrum, where the purpose is to deliver each sprint of the organized product without errors and potentially operational. In this phase, generally, at the beginning of the day, a brief meeting known as daily scrum is held, which can last a maximum of 15 minutes. In this meeting, the progress of the day before is communicated, and at the same time, it is exposed to what impediments may be arising for the project's progress.

2.1.4. Reviews and Retrospectives

It is the last phase where the sprint review is carried out, and the product owner is shown the increase in the operational product, demonstrating its functionalities. If the product owner requires it, possible new requirements are sometimes adapted. Once the review is completed, the retrospective is finally carried out, where the team analyzes the work and then proposes strategies and improvements during the project's development.

2.2. Technological Tools

For the present research work, specialized programs and applications are used in the development of this type of

project in order to have an adequate work environment and ensure that the proposed system can be implemented correctly.

2.2.1. Visual Studio

It is a development environment that allows you to create websites or applications using the .NET framework. This platform is compatible with various programming languages, making it easy to use and allowing cross-platform projects.

2.2.2. SQL Server

It is a database manager that uses the Transact-SQL development language; it allows you to store all the information needed to be used in various processes. In addition, it takes advantage of a wide set of functionalities to power artificial intelligence processes on a diverse scale of data.

2.2.3. Python

It is a programming language that allows the processing of all types of data, whether numerical or text. It is open-source, accessible and multiplatform software; it has an advantage due to its extensive library of resources, variety of frameworks and simplicity in its syntax when programming.

2.2.4. Artificial Intelligence

This technology aims to provide a machine or software with the ability to learn based on data and use algorithms and various methods to perform tasks similar to humans [8]. This is how AI makes it possible to automate activities in the learning process, decision making and problem-solving. Figure 2 shows a summary of how the fields of artificial intelligence are classified.

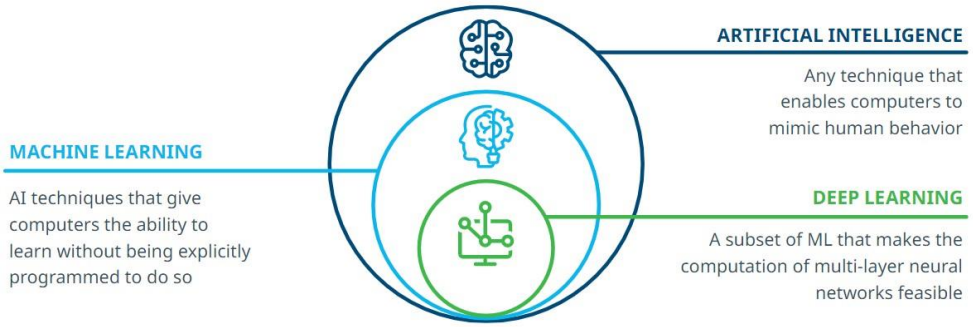

Fig. 2 Types of artificial intelligence [9]

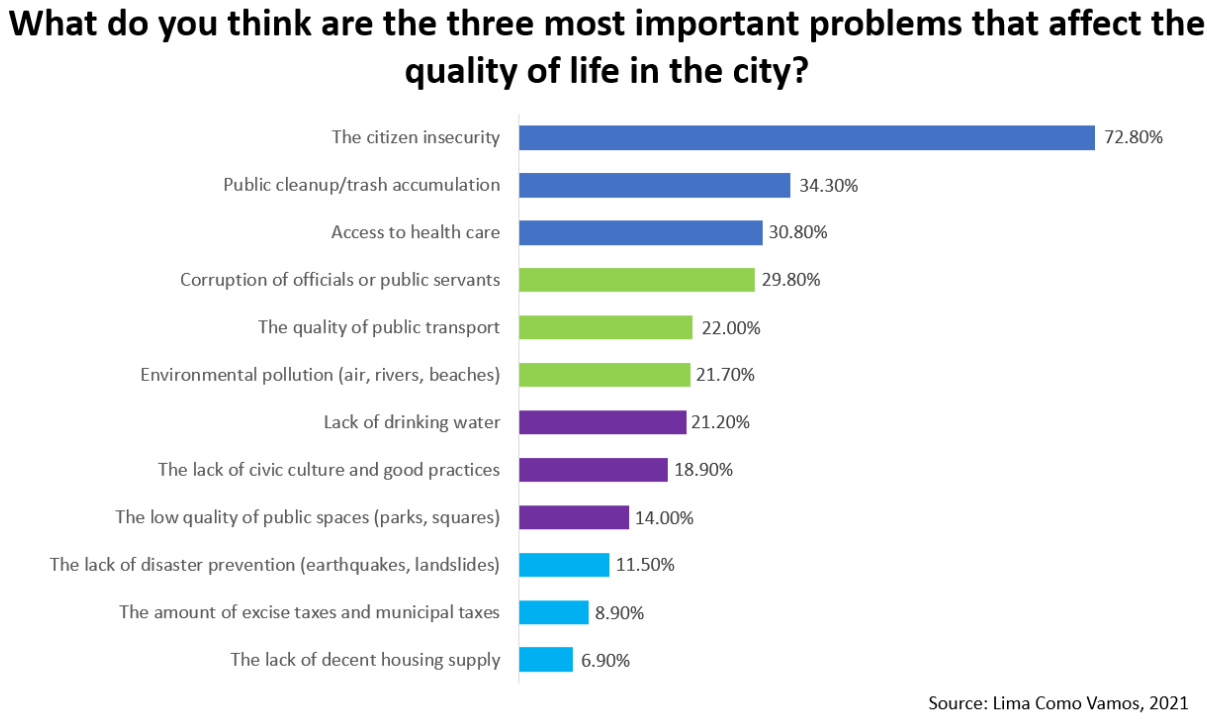

Fig. 3 Satisfaction survey in Lima and Callao 2021 with a sample of 1,100 people

3. Case of Study

3.1. Planning and Requirements

Once the roles have been duly defined and assigned, proceed to identify and select the requirements and functions that the web system will have, which must be completed within a certain time.

For the present research work, the requirements are considered based on the citizens' dissatisfaction regarding the health services in Lima and Callao. In Figure 3 shows part of the results of the report prepared by the DATUM pollster [10], where access to health care with 30.8% ranks third among the three most important problems that affect the quality of life in the city.

One factor determining user dissatisfaction is the lack of medical personnel, in addition to the evidence of an excess of administrative personnel in the health sector. In Peru, for every 3 administrative workers, there is 1 doctor, while in other Latin American countries, this relationship is inverse [11].

Once the requirements for the project have been identified, the user stories are made, which detail the system's characteristics. For the present research work, a total of 7 user stories were defined. In Table, I, the description of each story is observed for a better understanding of the operation of the web system.

Table 1. User Stories

Nro	Description of stories
H1	As a user, I want a web system with an intuitive, friendly, easy-to-use interface.
H2	As a user, I want to define the system's workflow once I enter the clinical history and triage data.
H3	As a user, I want to implement the Machine Learning algorithm with the best performance for predictions.
H4	As a user, I want to be notified when the data analysis has finished, and the results are ready.
H5	As a user, I want the results to be shown in report format.
H6	As a user, I want to send the results of the analysis and receive the schedule planned by the administrative staff.
H7	As a user, I want to be able to register to have a unique username and password.

3.2. Implementation and Development

In this stage, the procedures carried out in the advances of the user stories are explained, as well as the technologies implemented.

3.2.1. Pattern Model View Controller

The proposed web system is developed using the Model View Controller (MVC), which separates an application's data, the user interface and the control logic into 3 layers or levels that together make up the software architecture. This type of pattern over the years has continued to be valid, demonstrating its validity by being able to be applied in various types of projects, programming languages and development platforms [12].

Figure 4 shows the 3 components that make up the MVC and how they interact with each other when executing an operation by the user.

3.2.2. Data Set

It is necessary to have a set of data to carry out the research work that can be used for training and testing the functions to be implemented in the web system.

The data is extracted from the clinical history and triage information belonging to the same health center because the vast majority of these documents are physically registered; on paper, they must be transferred to a digital format for application in the proposed system. Currently, this procedure is possible, as shown by [14] in this work, where the process's feasibility for converting documents and information recorded on paper to a set of digital data is confirmed.

Figure 5 details the steps for the document digitization process in which AI also plays an important role, and that is that through this technology, the digital transformation procedure is not only limited to importing the documents but also being able to classify them and recognize text with the intention of extracting or editing the information and obtain a better result in the creation of an Electronic Medical Record (EMR).

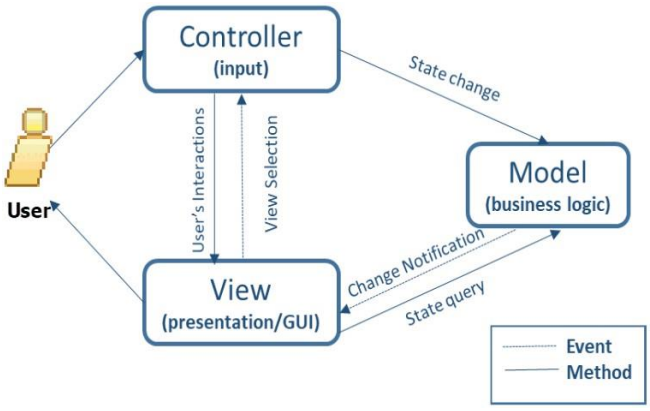

Fig. 4 MVC workflow [13]

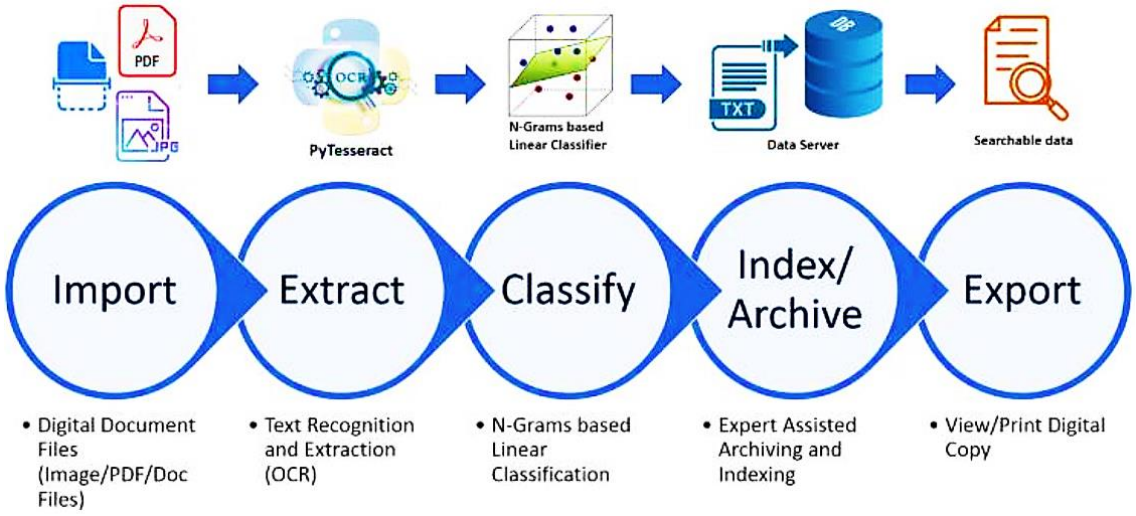

Fig. 5 Flow of the document digitization process [15]

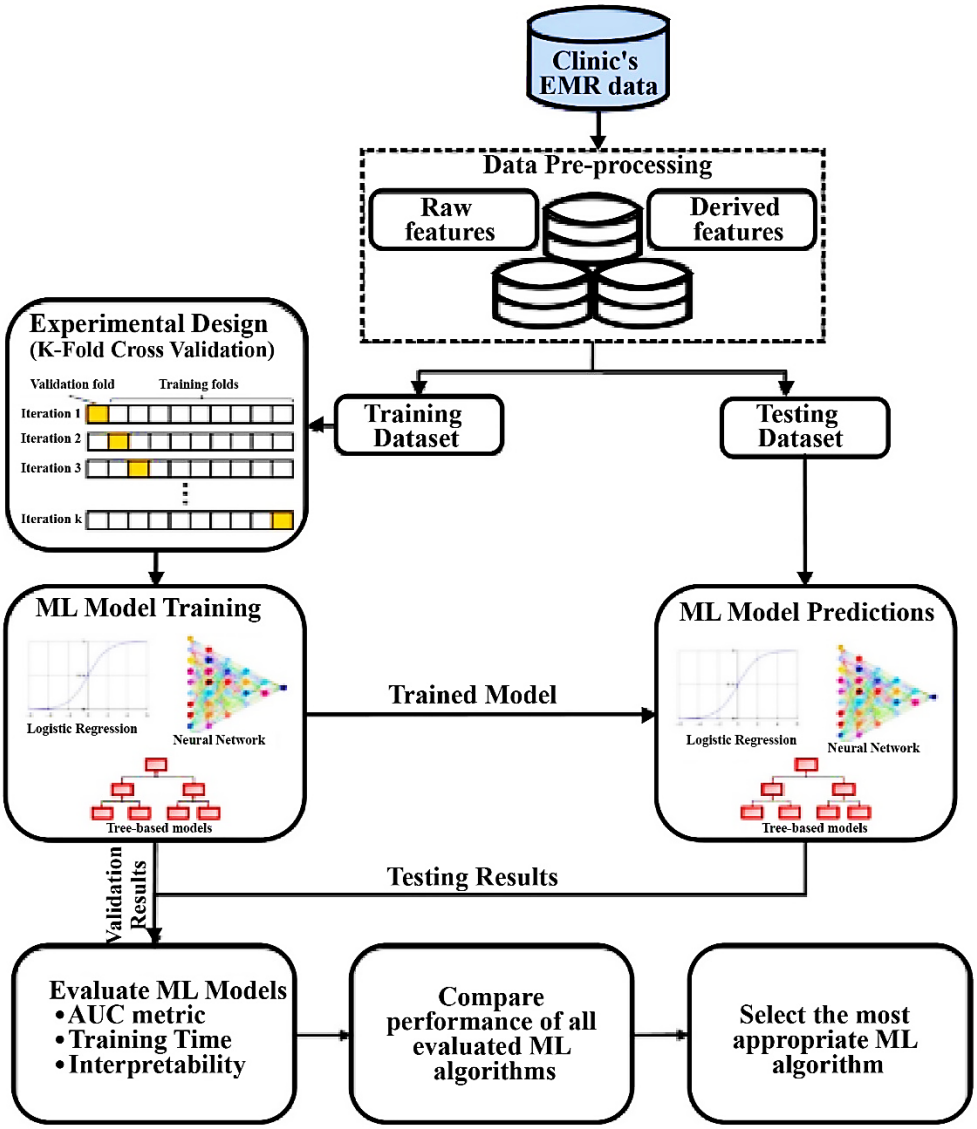

Fig. 6 Flowchart of the modeling process used by Machine Learning [5].

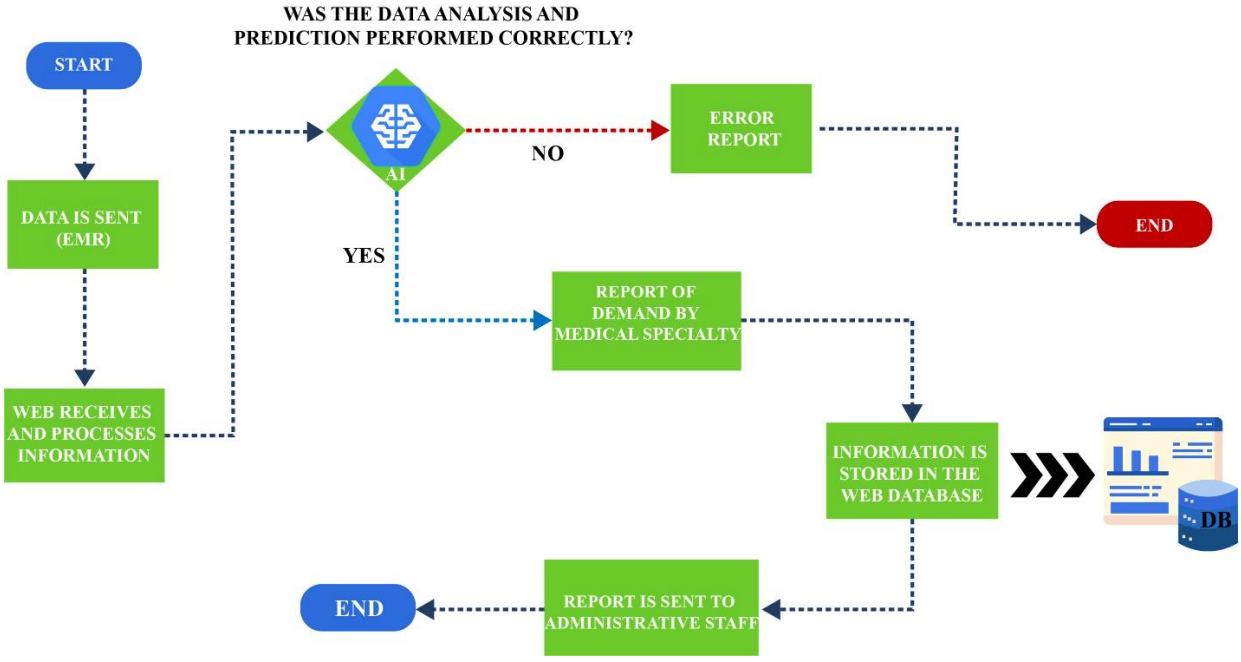

Fig. 7 Web System Flowchart

3.2.3. Machine Learning

It is a field of artificial intelligence that develops systems that learn automatically. A machine learning system performs learning through data to identify complex patterns among a large amount of information that would be impossible for a human being to analyze [16].

Through an algorithm, it reviews a large set of data and is capable of predicting future behavior automatically, that is, without the need for constant supervision, since these systems improve over time and independently.

The present work uses machine learning with the use of EMR to predict the most requested specialties in the health center; in Figure 6 the graph shows us the procedure that all machine learning software performs for its learning process dividing into 2 groups of previously digitized data, one for testing and the other for training, determining their efficiency based on a percentage of successes and errors, resulting in modeling with a high rate of accuracy.

3.2.4. System Operation

Once all the previous requirements have been completed, and the necessary tests have been carried out to evaluate its performance and performance, the operating web system is obtained, fulfilling the specified functions.

In Figure 7, once the user has been registered, observe the flow carried out by the web system where, to begin with, the data must be uploaded in EMR format so that they can be analyzed. If the AI processes the data set successfully, a report is created with the information on the demand for care based on medical specialties; this information will first be stored in the internal memory of the device where the web system is executed. Then the information is saved in the platform's database, and finally, the user must send the report for later review and response by the administrative staff of the health center.

4. Results and Discussions

4.1. Design and Prototypes

At this stage of the development process, the prototypes of the different interfaces that the web system has and their respective functionalities are explained and shown.

4.1.1. Login

Figure 8 shows the first interface with which you interact. To enter, you must have a unique username and password; once you go through this validation, you can start using the web system; there is also an option to register if you do not have a user yet.

4.1.2. Main Menu

After validating the username and password, entry is allowed by going to the main interface of the web system, as shown in Figure 9. Whenever the session starts, a window will be shown informing us of important changes due to new features or updates implemented in the web system.

4.1.3. Loading Screen

In order for the data to be loaded and later used in the analysis and prediction process of the system, the user must use the enabled button located in the left column. Figure 10 shows the screen that appears after performing the previous steps. A notice notifies the user that the data is being uploaded to the system.

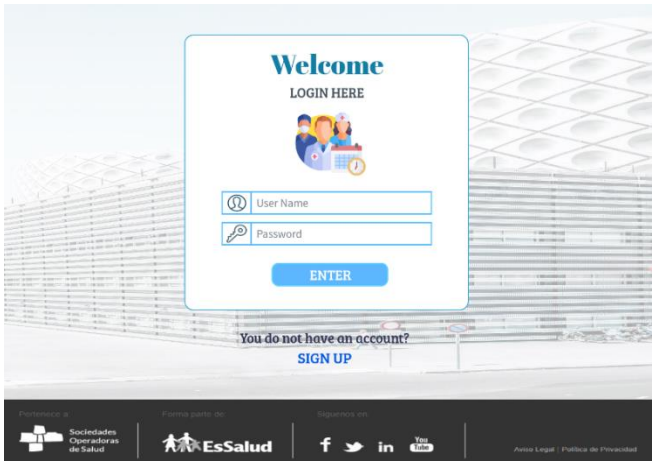

Fig. 8 Interface for the user to enter

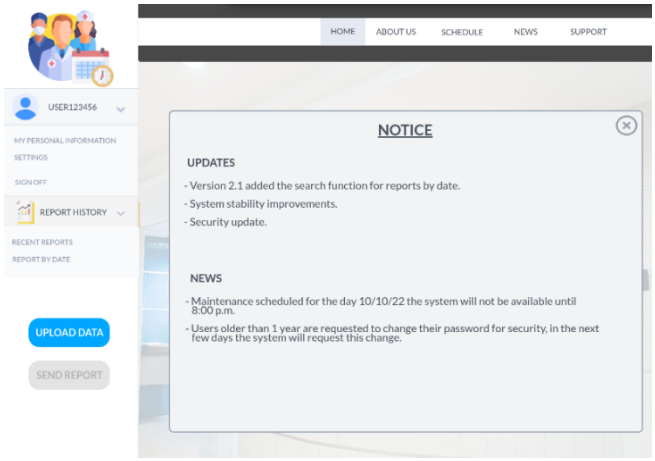

Fig. 9 A notice appears on the main screen notifying the user of the most recent system changes

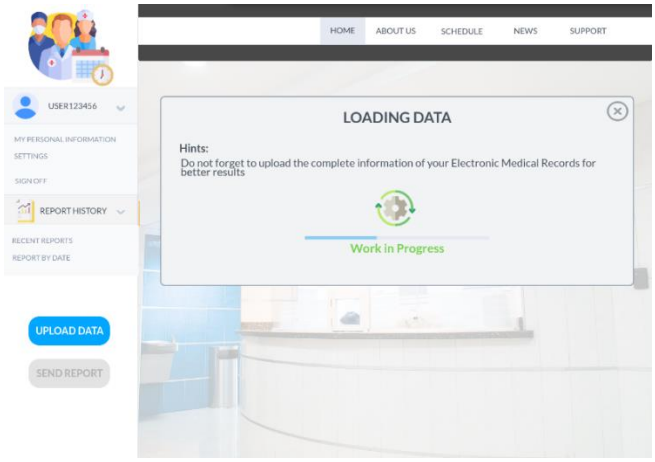

Fig. 10 During the data upload, brief recommendations for the user appear on the screen

4.1.4. Confirmation Screen

Figure 11 shows the screen that confirms that the data has been uploaded to the web system and allows the user to choose if they want to continue and start the analysis process or if they want to discard the operation by cancelling the current progress. If the user decides to continue, the AI generates a report with the data so it can be later sent to the administrative staff in charge of the health center.

4.1.5. Reports Menu

It is the interface where the user can review all the reports that have been generated, sent and accepted through the web system. For a report to be sent, it must first be selected by marking a check, as shown in Figure 12. After the report has been chosen, it can be deleted or sent; if this last action is carried out, the data arrives with the administrative staff in charge of planning the schedules of the health personnel, who later send the schedule to the head doctor of the establishment.

4.2. Algorithm

For the proposed system, it was determined that the XGBoost algorithm is the most suitable for its performance and precision in similar projects. This prediction algorithm is distinguished by its performance and speed when working with large datasets. It achieves quick results during training, even when working in parallel on a single machine.

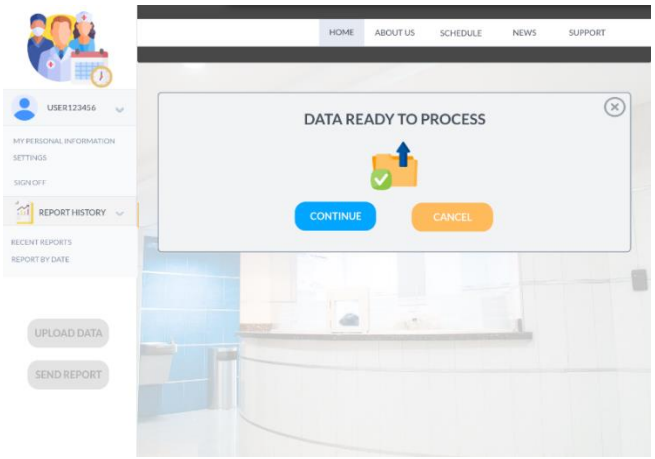

Fig. 11 Two alternatives are offered to the user to continue or cancel the progress made

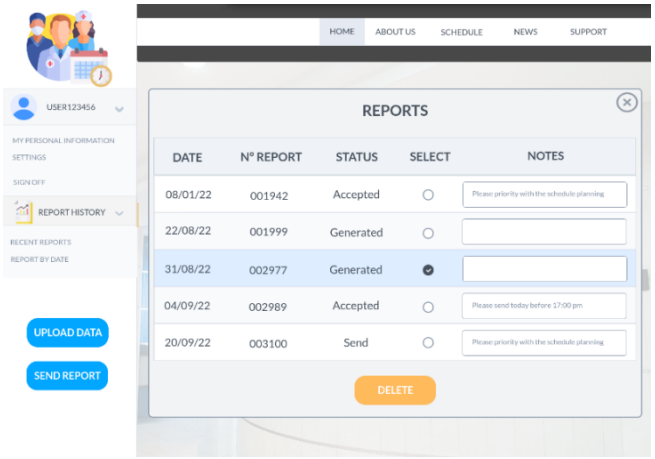

Fig. 12 Before making a shipment, you can add a note with observations regarding the report sent

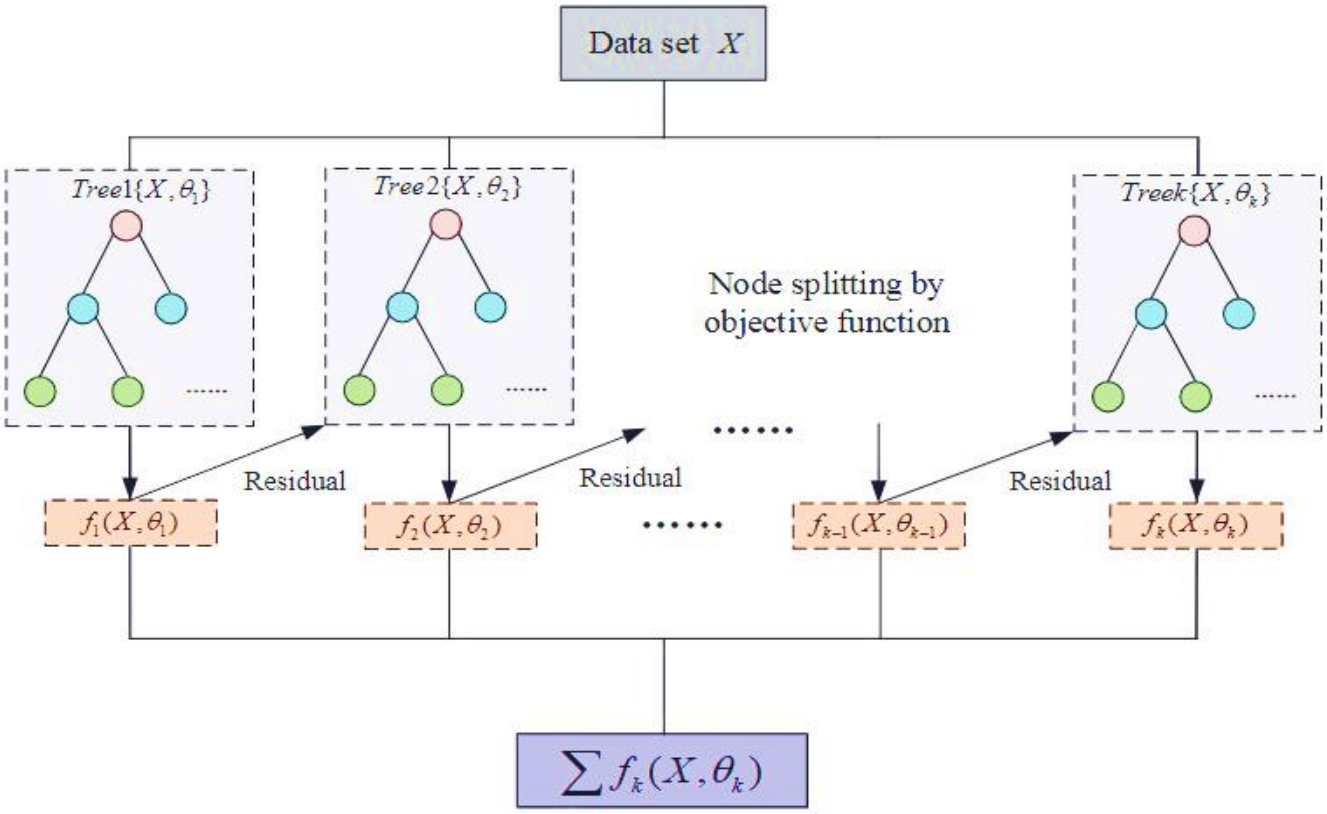

Fig. 13 Algorithm Xtreme Gradient Boost [17]

Figure 13 observed that the algorithm's operation consists of a sequential connection of decision trees to learn from the results of the previous trees to correct errors and make the algorithm improve with each iteration until there are no more corrections than realized.

This research work uses this algorithm's advantage to accurately anticipate the number of patients that should be treated in the coming days according to a medical specialty to schedule the available staff most efficiently. It is shown in research [25] favorable results applying this algorithm to predict patient demand through the use of EMRs that contain clinical history and triage information, achieving 0.93% efficiency in the AUC test, as shown in Figure 14.

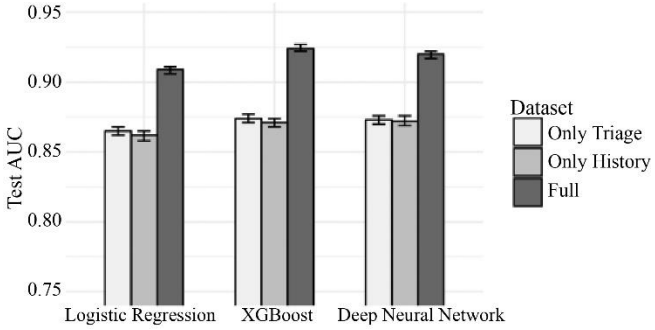

Fig. 14 Comparison between different algorithms confirming that XGBoost has better performance [25]

4.3. Perception of Health Services in Peru

According to the report [10] on citizen perception in Lima and Callao 2021, it is confirmed that 6 out of 10 Peruvians are dissatisfied with the current health services in the city. This dissatisfaction on the part of the citizenry is not something recent since, in 2016, a survey carried out on a total of 25,753 people by the National Health Superintendence (SUSALUD) [19] showed unfavorable results in several aspects of this sector. Among these results, the response of 47.4% of the interviewees who recommend that there should be more medical specialists in health centers stands out.

4.3.1. Distribution and Planning of Health Personnel

Figure 15 observed the data obtained according to the Ministry of Health in 2020 in Peru, showing that there are 14 doctors for every 10,000 inhabitants approximately [20] a figure below recommended by the World Health Organization (WHO) and the Organization for Economic Cooperation and Development (OECD) [21] which indicate that there should be at least between 23 to 35 doctors for every 10,000 inhabitants to ensure adequate care, coverage and quality of health service. As previously mentioned, citizens perceive this personnel deficit and, in addition, an inadequate distribution of medical personnel in the country with much lower numbers in certain regions. A number of doctors below what is recommended make it even more

difficult to intervene promptly and respond to the health demands of the population.

Faced with this problem, the present work offers an alternative solution by implementing the proposed web system, automating the process of analyzing the demand for care and managing to predict the most requested medical specialties through the machine learning model. Using the XGBoost algorithm, the data obtained from the history information and care of recurrent patients at the health center are used. The results provided by the web system are intended to be used to improve availability and carry out better. More precise planning of the hours assigned to health personnel according to the needs and requirements of the different medical care services, allowing savings in administrative costs and optimizing the limited human resources available, which, as evidenced, are currently below what is recommended.

4.3.2. Health Centers and Analysis of the Demand for Medical Care

In Peru, there are a total of 7431 health establishments distributed among the different departments around the country; of the total of these establishments, 80.1% are health posts, and only 2% are hospitals [22]. These figures indicate that the majority of citizens attend health posts, the vast majority of which do not usually have the basic conditions to care for a person. In Figure16 observed an increase in the number of insured since 2004; in addition, there is evidence of a significant increase at the beginning and during the pandemic in 2020; however, the latter did not occur in the same way with hospital resources to deal with the high demand for care.

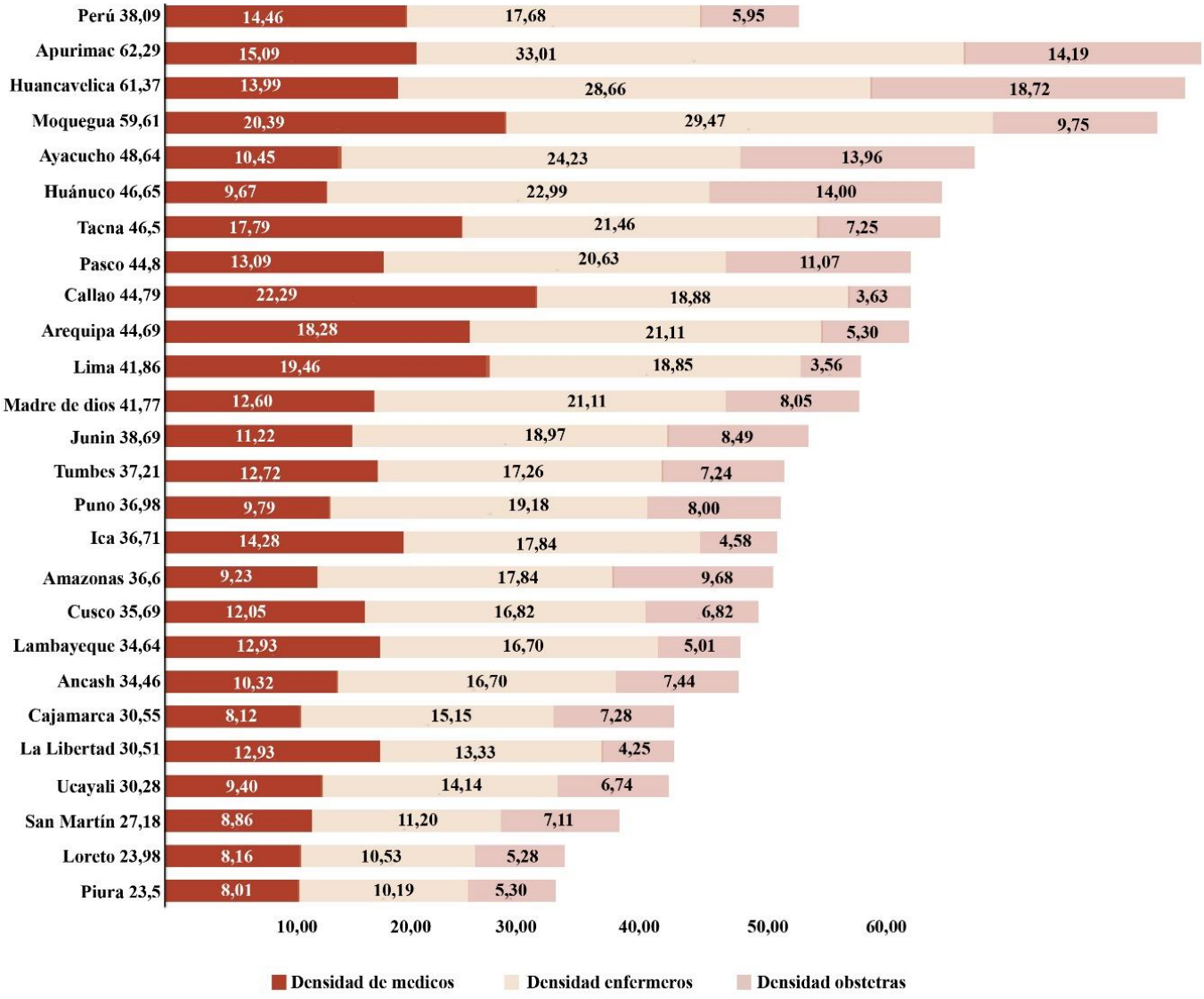

Fig. 15 Human Resources Data in the Health Sector during the COVID-2019 Pandemic in Peru

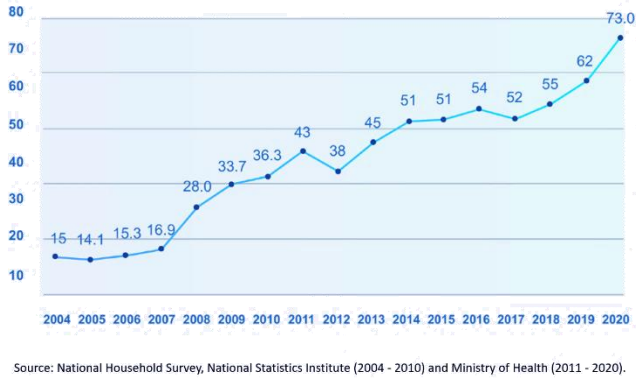

Fig. 16 Increase of the insured to the health service during the last 16 years [23]

Faced with this problem, the proposed system also proves to be an aid and support tool to deal with the increase in insured persons in the Peruvian health system, allowing information on patients assigned to the different medical specialties to be obtained quickly and systematically for timely decision-making decisions and better management. By not having the conditions for appropriate care, health posts must resort to entrusting administrative tasks to healthcare personnel, which translates into fewer human resources available for patient care. Using the web system reduces the administrative workload for health personnel, allowing them to plan, analyze and consult data more quickly and, in turn, reduce the possibility of human error.

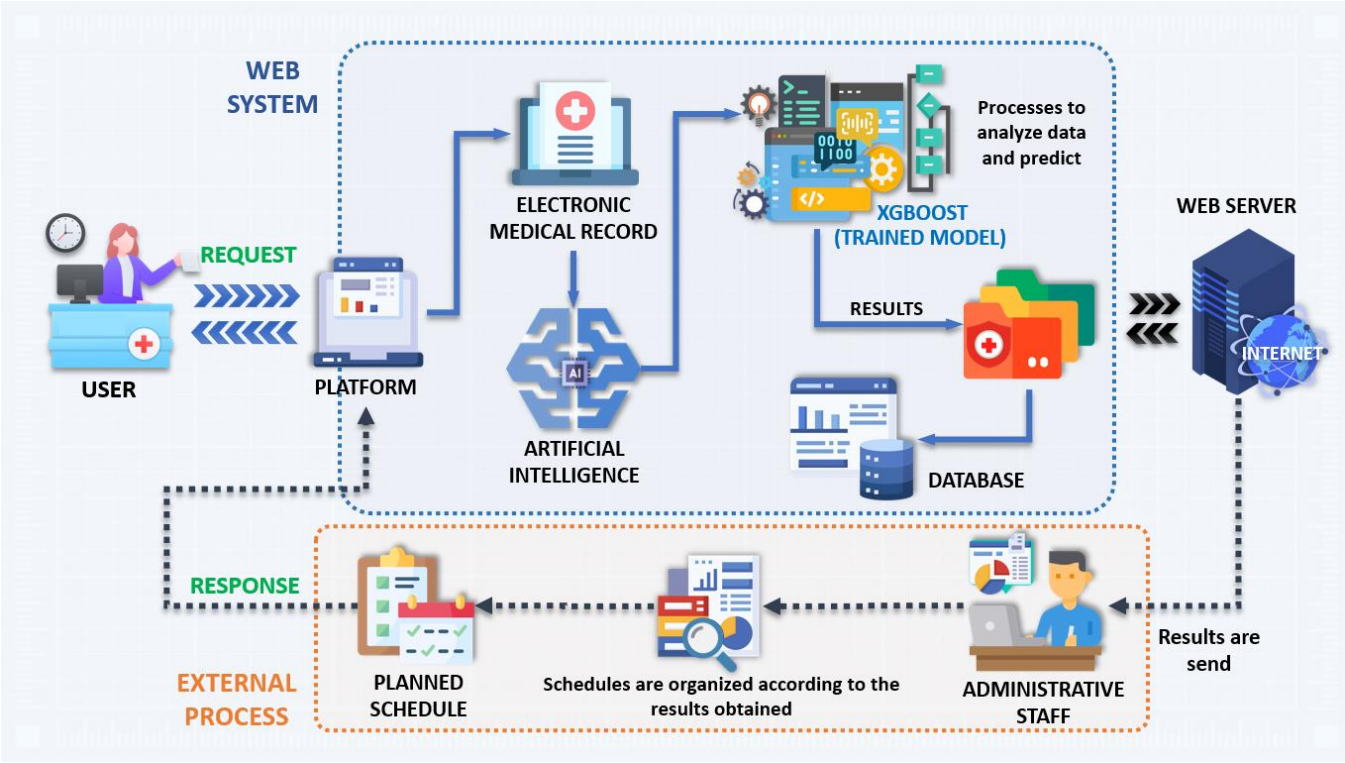

Fig. 17 Web architecture of the proposed system

This automation also generates time savings that are used to improve the flow of patients and early identification of those who may require urgent care at the health center.

4.4. System Architecture

Figure 17 shows graphically the processes and the interaction of the system to contribute to the better planning of schedules of the health personnel; the workflow begins with the user uploading the data of the electronic medical records to the system so that these can be uploaded and analyzed by the AI.

Once the analysis process has been validated, the information in a report format is stored in the internal memory of the device where the web system operates. Finally, the report is sent for later review by the personnel in charge of the schedule planning of the clinic.

5. Conclusion

The present research work manages to develop a web system capable of predicting the demand of patients in a certain medical specialty; this information, when organized in reports, contributes to the programming of schedules of health personnel more efficiently, thus achieving that patients receive timely care. The artificial intelligence implemented in the system also plays an important role in quickly analyzing a large amount of medical data, generating time savings that facilitate part of the administrative work that the health personnel themselves must sometimes carry out. The results of this work show

that the digital transformation significantly benefits the Peruvian health system by modernizing its processes and digitizing the way in which medical information is recorded; unlike the works mentioned in the literature review, it not only seeks to focus on the solution in a single health center or the absenteeism of patients but in the analysis of the demand for medical specialties, in this way it contributes to the optimization of the use of hospital resources, managing to improve the efficiency during the planning of the health personnel available for a better quality of care in health centers at the national level.

The research project presented offers a support tool that, unlike the works mentioned in the literature review, seeks not only to focus on a single health center or on the absenteeism of patients. But also to contribute to the efficiency and use of staff health available through the analysis of the demand of the different specialties in the health centers, thus contributing to the health of the population in the country.

As a recommendation, it is considered to be able to integrate functions into the system that allow prioritizing care cases according to the patient's symptoms for continuous improvement of processes and thus provide rapid care, early diagnosis and timely treatment. In addition, the algorithm must continue to be adjusted and modified to increase its efficiency and precision in the results, which also allows for anticipating other service needs.

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