# Expert Web System: Diagnosis of Visual Diseases

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**Abstract—**Sight is one of the senses that gives more support for daily life because the brain receives 80% of the information through the eyes. However, it is one of the most careless senses in Latin America, mainly in Peru. In this country, the sense of sight is related to the second disability with the highest percentage. Thus, 76% of the visually impaired population lost their sight due to lack of treatment or lack of early detection of any visual disease. For this reason, this research article seeks to design and implement an expert web system oriented to the welfare of the vulnerable population regarding visual issues and the care of the sense of sight. Therefore, we applied the Buchanan methodology in this project, which contains 5 phases in the development and planning. This methodology allowed the identification of viable requirements for the expert web system and the study of detailed solutions and design. Thus, it allowed the development of an expert web system that complies with the care of the sense of sight through early diagnosis. Finally, as a result of the present research work, it was obtained that the expert web system meets 88% of satisfaction, the value obtained through a questionnaire to a sample of 60 people, including patients and specialists of the company called MK Optical Center.

**Keywords—**Buchanan methodology, early diagnosis, expert web system, visual disease, visual impairment

## 1 Introduction

Since the origin of humanity, sight has been one of the senses that has contributed more to the development of our daily life because the brain receives 80% of information visually. Although the sense of sight is essential for our life, visual impairment and blindness continue to increase due to the delay in detecting these diseases. [1].

Similarly, in Latin America, eye diseases have become a matter of concern, and people can prevent most of these diseases by taking appropriate treatment to avoid complete loss of vision [2]. However, the World Health Organization (WHO) report estimated that 285 million people are visually impaired, 246 million of whom have low vision, and the remaining 39 million have lost their vision due to various diseases that attack the sense of sight [3]. That is why Latin America is the region with the most epidemiological studies on visual impairment and blindness, and the implementation of a prevention plan is necessary to help reduce the mortality rate.

Likewise, it happens in one of the countries in this region. In Peru, visual diseases are part of the cause of the second disability with the highest percentage of cases, according to data reported by the Ministry of Health (MINSA) and the WHO. As for the reasons for visual impairment increase, 76% result from lack of treatment or early detection of eye diseases that, in most cases, are treatable [4].

Therefore, early diagnosis plays a predominant role in guiding and encouraging people to seek appropriate eye care that can prevent the progression of eye disease or possible disability [5]. However, in low-resource countries such as Peru, there is little medical supply for early and timely diagnosis [1]. For this reason, the population is exposed to possible consequences such as dementia, depression, and anxiety, possibly leading to an increase in the mortality rate [6].

Thus, early diagnosis is essential to prevent diseases from irreversibly affecting the visual sense [7]. For this reason, ophthalmology specialists recommend annual eye evaluations, maintaining a healthy diet, taking care of eye hygiene, and protecting the visual organ from ultraviolet (UV) rays with special lenses that help prevent diseases that gradually deteriorate vision; since the damage produced generates a negative impact on the person, damaging the lifestyle they lead. Therefore, the early diagnosis of these diseases through regular examinations allows practically conducting a follow-up and monitoring, reducing at least 90% of blindness in new cases [8].

Therefore, this problem must focus on how vital it is to implement a system that supports doctors and patients to control the overflowing case of the second-highest percentage of disability in Peru, mainly because this country has certain rural areas without access to an ophthalmologist and basically to prevent the population from continuing to run the risk of losing their vision. Even more so, preservation and recognition of how fundamental sight is for our life can lead to avoiding these cases. [9]. Therefore, it is essential to determine viable strategies through technological advances to prevent a further increase in blindness in Peru.

Because of this, the present research work is born, which points to planning, designing, and developing an expert web system that provides an early diagnosis of visual diseases based on belief rules (BRB) to avoid the advance over the years. There are two causes for the percentage of blindness: treatable eye diseases and delay in diagnosis. For this reason, this research work focuses on preserving and improving the quality of social life, benefiting and promoting the importance of sight for human beings.

The current research work consists of different sections: The second section presents the literature review. The third section develops the methodology. The fourth section establishes the results and discussions, and the fifth section shows the conclusion and future work.

## 2 Literature review

This section focuses on two divisions: the first analyzes the theoretical basis of expert systems and visual diseases. Likewise, the second focuses on the study of works related to the topic of the present research work.

### 2.1 Theoretical basis

1) Expert Systems: Expert systems consist of the simulation of a set of solution processes on the most complex problems in a specific subject, these types of systems have the purpose of fulfilling the function of transporting and distributing knowledge and information, which is provided by experts on topics related to various scientific areas, fulfilling a behavior of support and backup for those who do not know the specific information provided [10]. Also, most expert systems are focused on rules that study external factors. Some of these expert systems replace human decision-makers while other expert systems function as support for problem-solving [11]. It depends on the type of expert system being used and developed.

   Most expert systems oriented to medicine are born out of the need to assist physicians in the diagnosis of diseases and patients in their treatment. These types of expert systems are classified into three different categories. One of the first categories is the Fuzzy expert system, which works under a mathematical logic receiving continual numbers as input data and performing a process that provides a translation of linguistic terminology [12].

   On the other hand, as a second category, we have medical expert systems that need constant updates by extending or changing the set of rules through their information. In this way, feedback between doctors and patients is made through the history of symptoms and diseases, shaping or forming new evaluative rules for the expert system. Finally, we have the category of portable expert systems, which has the working method of the second category. In contrast, these expert systems can be used on mobile devices due to the constant evaluation over long periods [13].

2) Visual illnesses: Nowadays, diseases produced in the visual organ have become one of the main problems with a predominant impact on our society. Sight is the most predominant sense of the human being; therefore, it is necessary to maintain adequate health [14]. Due to this problem, early detection and appropriate treatment of the different diseases that cause vision loss is essential [15].

   Eyesight is prone to suffer from different diseases such as cataracts, diabetic retinopathy, myopia, and glaucoma, among others, and as time goes by, these diseases become more and more complex, causing vision to diminish gradually [16]. Early detection of such diseases would prevent the person from losing total sight. Nowadays, several methods allow us to keep track of the eye condition, allowing experts to examine and evaluate patients. Therefore, it is necessary to have technological tools or systems that can help diagnose eye diseases.

### 2.2 Related work

Due to the increase in sanitation problems, different solutions have been created to prevent and diagnose them through intelligent technologies. However, not all technological tools are adequate for a viable solution. For this reason, a feedback study was carried out for the development of this research work. Thus, the purpose is to collect different perspectives to contribute to the decision-making process before implementing an expert system.

Expert systems have had a crucial impact on decision-making in the healthcare sector. In addition, computer systems have contributed to generating accurate results, which require professionals. Nowadays, the support of technological tools in the medical area has resulted in a positive impact. Therefore, expert systems are required to help diagnose diseases in the various sections of a medical center. Author Hossain et al. [17], present an investigation of how to perform a diagnosis on a web-based expert system using a BRB-based methodology and generate reliable results.

Similarly, the ophthalmology area considers it necessary to implement expert systems because of the shortage of medical personnel. For this reason, the author's Mutawa and Alzuwawi [18] conducted a study in which a rule-based expert system was designed and built to diagnose uveitis. The research of these authors aims to help general ophthalmologists have an accurate diagnosis evaluated in a short time and with minimum effort. Also, they used a proprietary methodology in their research, which consisted of four phases: knowledge acquisition, knowledge analysis, system design, and system verification and validation. Finally, this study yielded promising results with the multilayer design, which was capable of generating a diagnosis based on the available information.

Similarly, the authors, Ahmed et al. [19] mentioned that one of the best alternatives for solving and speeding up disease detection is an expert system based on BRB. In their research, they proposed the development of an expert system using as support the BRB methodological model together with the combination of elements for clinical decision support systems. It allowed the development of an expert system that can predict the severity of coronary artery disease depending on the patient. As a result of their research, it became known that the developed expert system does not have a high margin of error, thanks to the division by classes or levels to reduce the errors in the predictions, obtaining that the results generated by the system are more accurate.

On the other hand, the main objective of the BRB-based expert systems development is to properly diagnose the disease and its correct and appropriate treatments. In addition, to grant the appropriate method for viable treatment through different pieces of advice regarding the disease and how to treat it [20]. In this research, an expert system that was based on diagnosing and producing immediate results for COVID-19 was developed through a heuristic approach, so that the expert system can be restructured under the experience of patients and doctors infected with COVID-19. Obtaining an expert system that allows for generating more accurate results, compared to conventional medical diagnosis, causes the reduction of time and adequate treatment for the patient sooner.

Similarly, in another study done by Safdar et al. [21], it is mentioned that controlling the state of health on people is one of the main priorities in any social environment. The purpose is to provide control of possibly dangerous diseases. That is why, in his research, an expert system that allows identifying the risk levels of gastric cancer was proposed. For this reason, MATLAB software was used as the main support tool for the development of the expert system. Applying the Mandani inference study method allows the simulation of expert reasoning through the determination of 67 regulations, providing an expert system that manages and controls the information of the reports on medical diagnoses to take over the risk of each one. Thus, demonstrating that it is possible to develop an expert system that identifies the medical risk of each patient with concern for their symptoms.

In summary, the authors were able to contribute to the advancement of expert systems through their research and development, obtaining better optimization of the normal processes performed for medical diagnosis. However, the expert systems created lack innovation and more viable management for a better assertive diagnosis. In addition, one of the main problems has not been covered feasible yet, such as visual diseases, so it should be restructured more appropriately through study processes that contain innovation and feasibility for better medical diagnoses. Thus, contributing to an advance of the expert systems efficiently and effectively, providing a better quality of life for society.

# 3 Methodology

## 3.1 Buchanan methodology

For the development and implementation of this research work, the Buchanan methodology was selected, since it is based on a cascade life cycle, which is composed of five phases: identification, conceptualization, formalization, implementation, and validation. This methodology focuses on the acquisition of knowledge [22]. It is also characterized by the constant relationship between the engineer and the area expert. On the other hand, the advantages of using this methodology are, that thanks to the suggestions made by the experts, it allows the project to have improvements and adequate control of the operation of the system. In addition, it presents adequate documentation of the processes that are carried out within the development of the expert system [23].

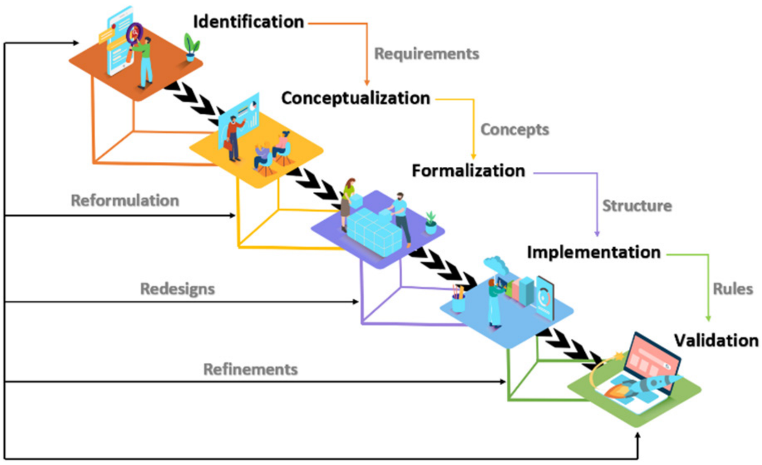


**Fig. 1.** Buchanan methodology

The Buchanan methodology is composed of 5 construction phases as shown in Figure 1. First, there is the identification stage where the focus is on knowing the problem and the domain. The second stage is conceptualization, where the type of expert system to be developed is defined according to the concepts provided by the area specialist. The third stage is formalization, where the aim is to build the inference model based on rules to obtain simple and compound conclusions for the development of the system [24]. Next is the implementation phase the fourth stage of this methodology, which is responsible for the specification of the use cases and the selection of the development tool facilitating the construction of the expert system. And to culminate with the life cycle of this methodology, we have the validation phase, in this process must comply with the performance evaluation of the developed prototype [25].

### 3.2 Development tools

1) Adobe XD Mockup: Adobe Experience Design is an application for the creation of wireframes oriented to the web and mobile environment. It is one of the tools with greater optimization and ease of prototyping through a drag-and-drop environment of components under a detailed design [26]. In addition, allow simulating the interaction of a user with the prototyped application [27], simultaneously allowing designers to work under error reduction at the graphic level.
2) JavaScript: It is a programming language, to provide interactivity to web pages. In addition, this language can be developed for client and server activities [28]. On the other hand, this language establishes the possibility for designers to create dynamic special effects, which has made this programming language one of the most widely used today.
3) Nodejs: It is a technological tool developed based on JavaScript for the Web server environment. It also contains an architecture that focuses on event processing to manage requests from users [29]. Moreover, this tool provides the advantage of long-term maintenance and support
4) MySQL: It is a multi-platform and multi-user database management system that works under SQL, which is an open-source structured query language, oriented to relational databases [30]. In addition, this database satisfies business requirements by providing high performance, easy usability, and portability. Likewise, it provides advantages through its speed and security features making it optimal for the use of large amounts of data.
5) Visual Studio Code: It is an open-source editor oriented to the development and compilation of applications, both in the cloud and on the web [31]. In addition, Visual Studio Code takes care of pleasing developers with different keyboard shortcuts, which optimize their work [32]. On the other hand, one of the greatest benefits provided by this code editor is the continuous daily integrated update functionality. In addition, it supports a wide list of programming languages and database managers.

### 3.3 Methodology development

*Identification:* As the first stage of the Buchanan methodology in this research work, both the problem and the solution will be presented, the familiarization with the domain will be explained and finally, the tasks that the expert system will develop will be determined.

**Problem:** Shortage of professionals and resources in the area of ophthalmology in Peru. This generates slowness in medical attention for the diagnosis of visual diseases. For this reason, it is essential to have technological tools that help specialists to detect and diagnose early and prevent vision loss.

**Solution:** Implement an expert system capable of

- evaluating, monitoring, and assisting in the process of early diagnosis for both patients and specialists in the area of ophthalmology.
- **Sources of Knowledge:** The main sources of knowledge for the development of the expert system of the present research work come from books, scientific articles, eye disease specialists, and informative videos.
- **System Activities:**
  a) Allow the user to select the symptoms to obtain the diagnosis of eye disease.
  b) Provide a diagnosis based on the results provided by the user.
  c) Make recommendations to the user regarding the diagnosis generated.

*Conceptualization:* In the next stage of the Buchanan methodology, the acquisition of the knowledge used for the development of the expert system was carried out. Therefore, three specialists in the area of ophthalmology at the MK optical center were interviewed. They provided the main symptoms of the most common visual diseases in Peru such as conjunctivitis, trachoma, and cataracts, among other diseases that affect the ocular area, as an example of the results obtained can be visualized in Table 1 oriented to the symptoms of cataracts. On the other hand, through the interview, the specialists recommended and observed the viability of the expert system when oriented to the diagnosis of these visual diseases.

**Table 1.** Symptoms of cataracts

| N° | Symptom |
|---|---|
| 01 | Cloudy vision |
| 02 | Susceptibility to light |
| 03 | Double vision in one eye |
| 04 | Difficulty reading |
| 05 | Difficulty seeing at night |
| 06 | See bright colors in yellowish tones |
| 07 | Loss of color intensity |
| 08 | Visualizing rings around the light |
| 09 | Changing reflections |
| 10 | Crystal Vision |
| 11 | Loss of vision |
| 12 | Color blindness |

*Formalization:* After having determined the identification and conceptualization phase, the formalization stage was carried out. This stage focused on creating knowledge and operation of the expert system. To achieve the objectives of this methodological stage, 3 fundamental points were determined, among them the architecture of the expert system, the system flow diagram, and finally the functionality simulation.

- **Expert System Architecture:** For the development and operation of the expert system it was necessary to establish four vital modules such as the user interface, the inference engine, the development engine, and the knowledge base as shown in Figure 2.

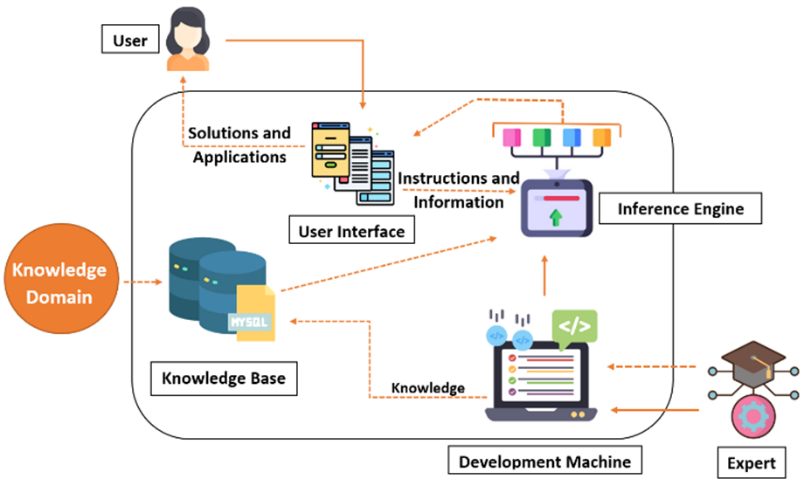


**Fig. 2.** Expert system architecture

These 4 modules have a unique raison d'être which is to provide together a proper diagnosis to the user. However, each one has a certain remarkable functionality. First, there is the development engine, which generates an interaction of receiving the expert's knowledge and sending the information to the knowledge base to store it. In addition, the development engine and the knowledge base in turn send the data to the reference engine which models the process based on human reasoning. Finally, the inference engine is integrated with the user interface allowing the functionality cycle to be completed when the user interacts with the expert system and receives the final process diagnosis.

System Process Modeling: For the development of the process modeling, the user interaction with the expert system was evaluated to register, design, and optimize the processes on a better scale, as shown in Figure 3, which is the final result of the process study for better management of functions. This made it possible to detail processes such as user registration and login as well as user interaction when performing the medical evaluation to obtain the diagnosis according to the symptoms selected in the system.

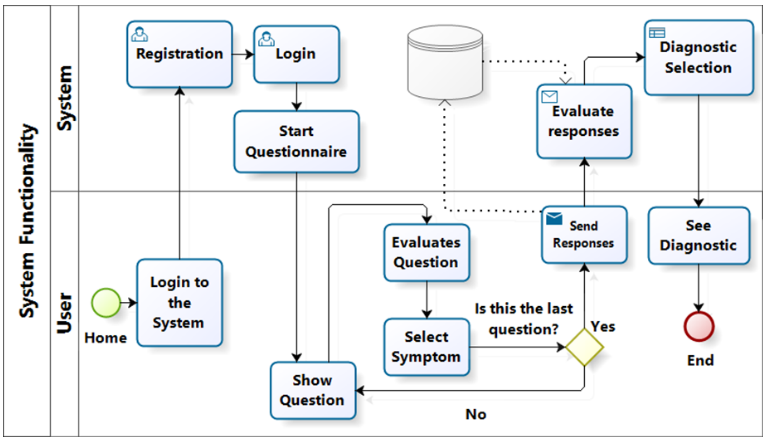


**Fig. 3.** System process modeling

*Implementation:* Immediately after having carried out the main stages of the Buchanan methodology with the knowledge, techniques, and tools acquired in the previous stages, we will proceed to develop the implementation stage of the expert system. In this phase, the design of the prototyping environment will be carried out using Adobe XD. Also, four use cases (CU) were made to describe the actions or activities of the processes within the system, which indicates the iteration that the actors (user) have when making use of the expert system.

- **Use Cases Login:** The first use case allows all users to access the expert system, to corroborate the identity of each user. Therefore, a table was created to determine the functionality of the expert system, as shown in Table 2.

**Table 2.** Cu01 – Login

| **Use Case** | Login |
|---|---|
| **Code** | CU01 |
| **Target** | Allow the user to validate his identity in the expert system. By which, a window is displayed where the user can enter the username and password to enter the system. |
| **Preconditions** | The user must be registered in the database. |
| **Post conditions** | The program allows access to the expert system |
| **Actors** | User |
| **Main flow** | Enter the corresponding user. |
| | Enter the corresponding password. |
| | The system validates if the information entered exists in the database. |
| | The system authorizes user access. |

Therefore, the prototype was developed under the description of the functionalities of the expert system, where the user and password must be entered, as shown in Figure 4.

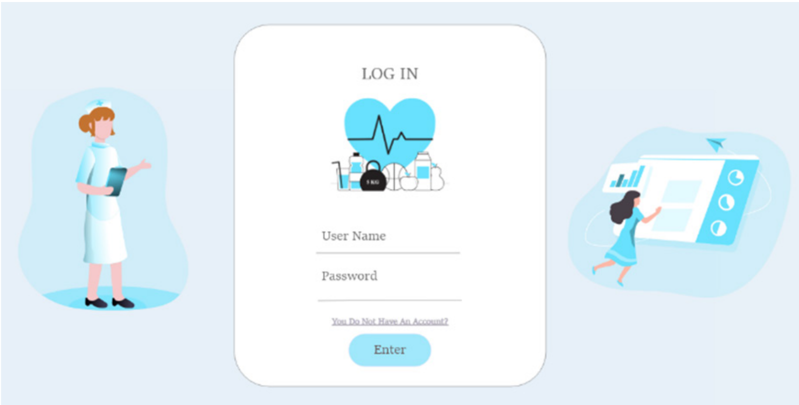


**Fig. 4.** Use case prototype 1

Use Cases Register User: Next, the second use case was developed, where the user can register his information to generate an account with access to the system. As can be seen, Table 3, describes the flow of the system to ensure proper registration.

**Table 3.** Cu02 – register user

| | |
|---|---|
| **Use Case** | Register User |
| **Code** | CU02 |
| **Objective** | Allows registering the user's data so that he/she can access the expert system. |
| **Preconditions** | The user must not be registered in the database |
| **Post Conditions** | User information is recorded in the database |
| **Actors** | Users |
| **Main Flow** | Enter name |
| | Enter the last name. |
| | Enter age |
| | Enter password |
| | Enter phone number |
| | Enter email address |
| | Select genre |
| | Click on the register button |
| | The system saves the data entered by the user. |

Similarly, the second prototype was developed under the description of the functionalities of the second use case, which shows a form where the user must enter the required information to create an access account, as shown in Figure 5.

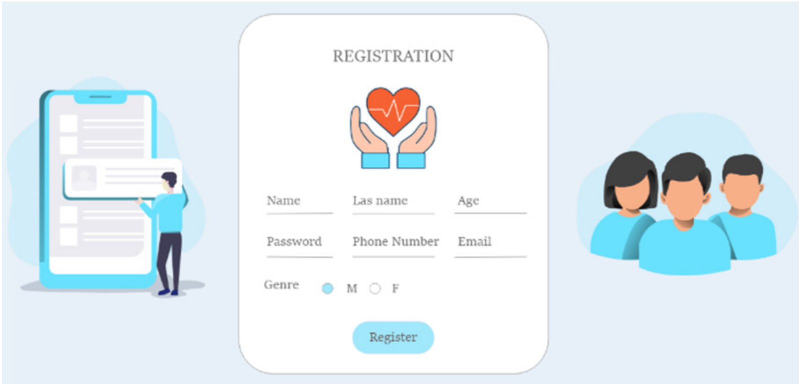


**Fig. 5.** Use case prototype 2

Symptom Evaluation Use Cases: In the third use case, the user's interaction with the system was detailed as a functionality, around the development of a medical evaluation to know his diagnosis. Through questions that contain as selection alternatives symptoms of multiple visual diseases, as shown in Table 4.

**Table 4.** Symptom assessment

| | |
|---|---|
| **Use Case** | Symptom Assessment |
| **Code** | CU03 |
| **Objective** | Allows the user to select symptoms according to a series of questions to see what state of health they are in. |
| **Conditions** | The user must be logged in. |
| **Post Conditions** | Not Applicable |
| **Actors** | Users |
| **Main Flow** | The system displays symptom options according to question |
| | The user chooses the option according to the presenting symptoms |
| | The system sends evaluation results |

In the same way, a prototype was designed in which the user must choose to obtain a diagnosis in the next stage. As shown in Figure 6.

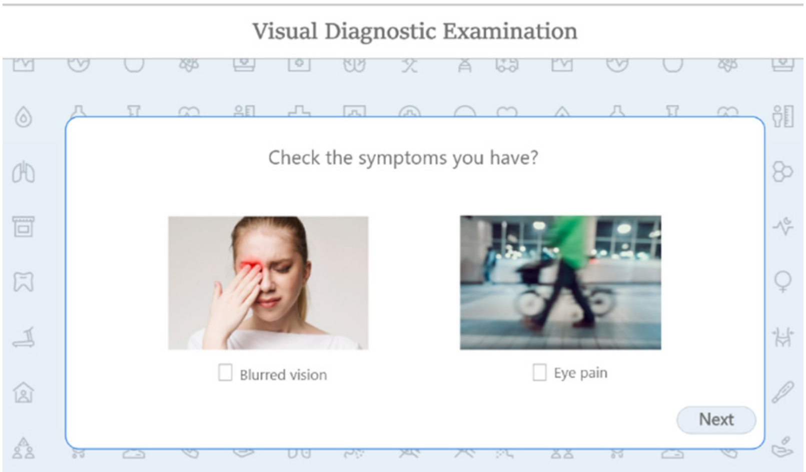


**Fig. 6.** Use case prototype 3

Use cases Obtain diagnostics: Finally, as a fourth use case, the user will be able to obtain an accurate diagnosis of the state of his eyesight. Therefore, the user must choose the options with the utmost sincerity so that the diagnosis is correct to the patient's condition, so this use case was determined to ensure the full effectiveness of the expert system, as shown in Table 5.

**Table 5.** CU04 – Obtain diagnostics

| | |
|---|---|
| **Use Case** | Obtain Diagnostics |
| **Code** | CU04 |
| **Objective** | It allows the user to obtain a diagnosis by choosing the symptoms that the user presents. |
| **Preconditions** | The user must be logged in |
| | The user must select the options from the questions |
| **Post Conditions** | Not Applicable |
| **Actors** | Users |
| **Main Flow** | The system displays a series of questions with different options. |
| | The user chooses the option according to the presenting symptom. |
| | The system displays the diagnosis ob-trained according to the evaluation. |

The last prototype designed is the determination of the diagnosis according to the symptoms entered by the user, as shown in Figure 7. The prototype shows the diagnosis generated and the recommendation provided by the expert system according to the diagnosed disease.

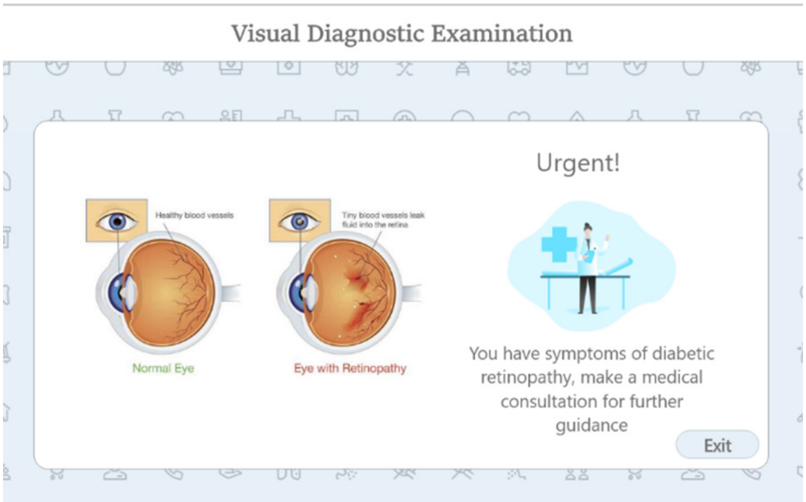


**Fig. 7.** Prototype use case 4

# 4 Results and discussion

## 4.1 About the prototype survey

In this stage of the present research work, the prototypes and the scope of the project were evaluated using a questionnaire addressed to the ophthalmology organization called MK Optical Center. Likewise, this questionnaire was addressed to both patients and specialists, obtaining a total sample of 60 people. This questionnaire was structured through 5 options as can be seen in Figuer 8, the five options established were “Very Satisfactory”, “Satisfactory”, “Undecided”, “Unsatisfactory” and “Very Unsatisfactory”. In Figure 8, the (y) axis shows the percentage of satisfaction, while the (x) axis shows the levels of satisfaction. This diagram shows that the requirements and objectives of this research work obtained high percentages of satisfaction on the part of the specialists and patients.

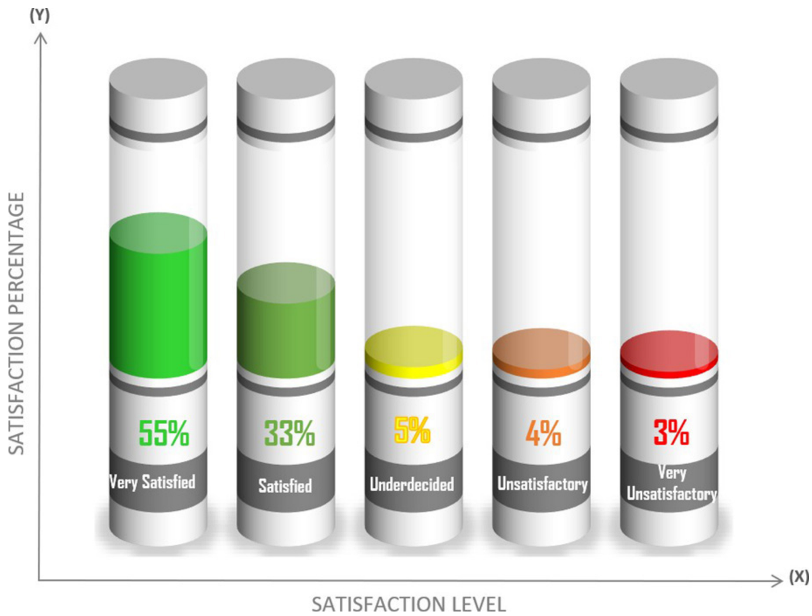


**Fig. 8.** Satisfaction graph

### 4.2 About the methodology

There are a large number of methodologies for expert systems, but among the best known are the IDEAL methodology and the Buchanan methodology. On the one hand, when developing the Buchanan methodology in this research work, we found several benefits that guaranteed the well-structured development of the expert system through 6 fundamental stages, since one of the main characteristics of this methodology is the constant relationship between the knowledge engineer and the field expert [33]. On the other hand, the IDEAL Methodology has the fundamental characteristic of being based on rapid prototyping, allowing the system to be improved and made more optimal through the development of its 5 methodological stages [34, 35]. Therefore, it was necessary to make a comparison between the two best methodologies for the development of an expert system, to select the most appropriate one according to the requirements of this project.

This comparison between both methodologies can be seen in Table 6, where the evaluation criteria selected were the bibliographic information (E1), the availability of feasible and detailed data (E2), the percentage of the methodology's approach to design and implementation (E3), and finally the level of adaptability of the processes to the objectives and time of the present research project (E4). Likewise, the evaluation method was through three categories where 1 means low, 2 means intermediate, and 3 means high.

**Table 6.** Methodological comparison table

| | Evaluation Criteria | | | | |
|---|---|---|---|---|---|
| | E1 | E2 | E3 | E4 | Total |
| **IDEAL** | 2 | 2 | 2 | 1 | 7 |
| **Buchanan** | 1 | 3 | 3 | 2 | 9 |

Finally, through the evaluation criteria given for the comparison study between the two methodologies, an evaluation of productivity was developed to detail the level of productivity for the needs of this project. As can be seen in Table 6, 4 evaluation criteria were used for the analysis of Figure 9. Likewise, a value of 8.3% was given for each point corresponding to each evaluation criterion. In case the evaluated criterion is rated with 3 points, the percentage would be 25.0%. Therefore, Figure 9 shows that the Buchanan methodology was the most appropriate for the present project with 74.7% compared to the 58.1\% productivity of the IDEAL methodology.

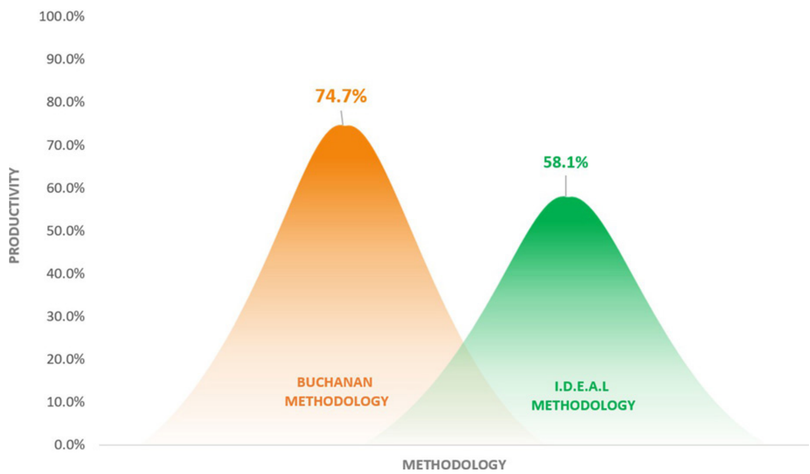


**Fig. 9.** Productivity graph

### 4.3 About system functionality simulation

Functionality simulation is one of the fundamental points for the internal knowledge of the system. For this purpose, 5 visual diseases were determined for the planning stage within the formalization, to analyze and detail the functionality or information management within the expert system as shown in Table 7. not all the symptoms can indeed be detailed within these diseases, they are enough for the simulation of the system, using these symptoms as example values.

**Table 7.** Visual diseases

| Diagnosis | Symptoms | Symbology |
|---|---|---|
| Cataract | Double vision in one eye | VDO |
| | Light intolerance | IL |
| | Halos around lights | HADL |
| | Increased difficulty seeing at night | DNA |
| | Blurry vision | VB |
| Tracoma | Itching and irritation of the eyes and eyelids | PILP |
| | Ocular discharge | SC |
| | Eyelid swelling | HLP |
| | Loss of vision | PDV |
| | Eye pain | DO |
| Uveitis | Redness of the eyes | EO |
| | Eye pain | DO |
| | Blurred vision | VB |
| | Intolerance to light | IL |
| | Inflammation in sight | IAV |
| Glaucoma | Nausea and vomiting | NV |
| | Redness of the eyes | EO |
| | Blurred vision | VB |
| | Headache | DC |
| | Halos around the lights | HADL |
| Presbyopia | Ocular Fatigue | CAO |
| | Headache | DC |
| | Blurred vision | VB |
| | Difficulty focusing on objects | DPO |
| | Increased difficulty in seeing at night | ADN |

According to the 5 visual diseases detailed in Table 7 and their symbology, the simulation of the system was carried out utilizing a decision tree as shown in Figure 10. While the blue color refers to the data not selected by the user. Likewise, this tracking allows the system to detail an approximation of the disease that the user suffers, when the system has found the approximate disease begins to ask questions with the following remaining symptoms on the evaluation. In the case of Figure 10, the user made the selection of 3 symptoms (VB, EO, IAV) before the system derives the approximation of the disease suffered by the user (UVEITIS), and then asks if the user has the other remaining symptoms (DO, IL).

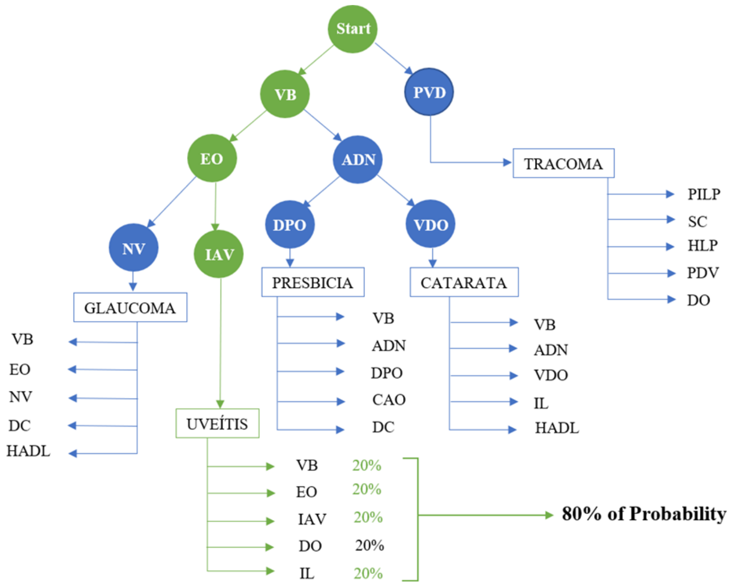


**Fig. 10.** System functionality simulation

Likewise, in Figure 10, the biased percentage for each symptom is observed, the green percentages are those that the user marked as a symptom that they suffer from. While the black color is the one that the user has not selected, giving the result that the user has an 80% probability of suffering the resulting disease. Referring to this result, equation 1 was used to calculate the probability, where the number of symptoms stored within a disease was multiplied by the symptoms selected by the user, and finally, the result was divided by 100.

Equation 1

$$P = \frac{(Symptoms\,Disease) * (Selection\,Symptom)}{100}$$

## 5 Conclusion and future work

Finally, an expert system was developed capable of evaluating, controlling and assisting in the early diagnosis process aimed at patients with visual diseases to prevent vision loss. Likewise, it is concluded that the use of the Buchanan methodology in the development of expert systems achieves 74.7% productivity because this methodology is characterized by the constant iteration between the knowledge engineer and the field expert allowing them to develop an effective and quality project. Thus, the expert system will bring different benefits both for the professionals who will facilitate their work when providing an early diagnosis and for the patients, allowing them to prevent and improve their lifestyle. That is why this research work should be taken as a basis for creating more technological tools that help human beings to improve their quality of life. In such a way that this expert system could be implemented in the different health posts as well as in the companies oriented in the commercialization of custom-made lenses. To conclude with the present work, we want to encourage more professionals to create this type of technology that helps society.

## 6 References

[1] A. Naim, M. F. Khan, M. R. Hussain, and N. Khan, "'Virtual Doctor' Management Technique in the Diagnosis of ENT Diseases," International Journal of Online and Biomedical Engineering (iJOE), vol. 15, no. 09, pp. 134–140, Jun. 2019, https://doi.org/10.3991/ijoe.v15i09.10665

[2] T. Reis, V. Lansingh, J. Ramke, J. C. Silva, S. Resnikoff, and J. M. Furtado, "Cataract as a Cause of Blindness and Vision Impairment in Latin America: Progress Made and Challenges Beyond 2020," American Journal of Ophthalmology, vol. 225, pp. 1–10, 2021. [Online]. Available: https://doi.org/10.1016/j.ajo.2020.12.022

[3] J. L. Leasher, T. Braithwaite, J. M. Furtado, S. R. Flaxman, V. C. Lansingh, J. C. Silva, S. Resnikoff, H. R. Taylor, and R. R. Bourne, "Prevalence and Causes of Vision Loss in Latin America and the Caribbean in 2015: Magnitude, Temporal Trends and Projections," British Journal of Ophthalmology, vol. 103, no. 7, pp. 885–893, 2019. [Online]. Available: https://doi.org/10.1136/bjophthalmol-2017-311746

[4] A. K. Jilani Saudagar, "Biomedical Image Compression Techniques for Clinical Image Processing," International Journal of Online and Biomedical Engineering (iJOE), vol. 16, no. 12, pp. 133–154, Oct. 2020, https://doi.org/10.3991/ijoe.v16i12.17019

[5] N. Nasrin, M. Asaduzzaman, D. Sharmin, N. S. Tithi, and S. M. N. Hudda, "A Survey-Based Study on Awareness of Eye Diseases Among Population of Bangladesh," Asian Journal of Medical and Biological Research, vol. 5, no. 4, pp. 292–296, 2020. [Online]. Available: https://doi.org/10.3329/ajmbr.v5i4.45267

[6] N. E. Maghawry and S. Ghoniemy, "A Proposed Internet of Everything Framework for Disease Prediction," International Journal of Online and Biomedical Engineering (iJOE), vol. 15, no. 04, pp. 20–27, Feb. 2019, https://doi.org/10.3991/ijoe.v15i04.9834

[7] E. K. Nida, L. Geurts, and V. V. Abeele, "Paradoxes in Eye Health Care in Low-Income Countries and Design Strategies for Mobile Health Technology to Overcome Them," EAI Endorsed Transactions on Pervasive Health and Technology, vol. 5, no. 17, pp. 1–11, 2019. [Online]. Available: https://doi.org/10.4108/eai.30-10-2018.161366

[8] N. A. Kumar and M. S. Anuradha, "Research Review Perspective on Retinal Clinical Features Diagnosis Automation of Non-Proliferative Diabetic Retinopathy (NPDR)," Madridge Journal of Bioinformatics and Systems Biology, vol. 1, no. 1, pp. 27–30, 2019. [Online]. Available: https://doi.org/10.18689/mjbsb-1000105

[9] J. Boyle, M. Vukicevic, K. Koklanis, C. Itsiopoulos, and G. Rees, "Experiences of Patients Undergoing Repeated Intravitreal Anti-Vascular Endothelial Growth Factor Injections for Neovascular Age-Related Macular Degeneration," Psychology, Health and Medicine, vol. 23, no. 2, pp. 127–140, 2018. [Online]. Available: https://doi.org/10.1080/13548506.2016.1274040

[10] B. Subaeki, S. G. Lovelina, H. H. Solihin, S. Pitara, A. Munandar, and M. Sulaksmi, "Expert System: Vertigo Disease Diagnosis with Backward Chaining Method," in 2020 14th International Conference on Telecommunication Systems, Services, and Applications (TSSA, pp. 1–5, 2020. [Online]. Available: https://doi.org/10.1109/TSSA51342.2020.9310820

[11] O. M. and Klyuchko, "Electronic Expert Systems for Biology and Medicine," Biotechnologia Acta, vol. 11, no. 6, pp. 5–28, 2018. [Online]. Available: https://doi.org/10.15407/biotech11.06.005
[12] M. Tavana and V. Hajipour, "A Practical Review and Taxonomy of Fuzzy Expert Systems: Methods and Applications," Benchmarking, vol. 27, no. 1, pp. 81–136, 2020. [Online]. Available: https://doi.org/10.1108/BIJ-04-2019-0178
[13] A. Saibene, M. Assale, and M. Giltri, "Expert Systems: Definitions, Advantages and Issues in Medical Field Applications," Expert Systems with Applications, vol. 177, p. 114900, 2021. [Online]. Available: https://doi.org/10.1016/j.eswa.2021.114900
[14] H. Andrianof, "Design and Built an Expert System Application Fir Diagnosing Human Eye Diseases by Using Forward Cahining Metodh Web-Based," Komtekinfo, vol. 8, no. 1, pp. 73–77, 2021. [Online]. Available: https://doi.org/10.35134/komtekinfo.v8i1.1397
[15] J. Hong, X. Liu, Y. Guo, H. Gu, L. Gu, J. Xu, Y. Lu, X. Sun, Z. Ye, J. Liu, B. A. Peters, and J. Chen, "A Novel Hierarchical Deep Learning Framework for Diagnosing Multiple Visual Impairment Diseases in the Clinical Environment," Frontiers in Medicine, vol. 8, pp. 1–16, 2021. [Online]. Available: https://doi.org/10.3389/fmed.2021.654696
[16] R. D. Badgujar and P. J. Deore, "Region Growing Based Segmentation Using Forstner Corner Detection Theory for Accurate Microaneurysms Detection in Retinal Fundus Images," Proceedings - 2018 4th International Conference on Computing, Communication Control and Automation, ICCUBEA 2018, pp. 1–5, 2018. [Online]. Available: https://doi.org/10.1109/ICCUBEA.2018.8697671
[17] M. S. Hossain, Fatema-Tuj-Johora, and K. Andersson, "A Belief Rule Based Expert System to Assess Hypertension Under Uncertainty," Journal of Internet Services and Information Security, vol. 9, no. 4, pp. 18–38, 2019. [Online]. Available: https://doi.org/10.22667/JISIS.2019.11.30.018
[18] A. M. Mutawa and M. A. Alzuwawi, "Multilayered Rule-Based Expert System for Diagnosing Uveitis," Artificial Intelligence in Medicine, vol. 99, p. 101691, 2019. [Online]. Available: https://doi.org/10.1016/j.artmed.2019.06.007
[19] F. Ahmed, Fatema-Tuj-Johora, R. J. Chakma, S. Hossain, and D. Sarma, "A Combined Belief Rule Based Expert System to Predict Coronary Artery Disease," Proceedings of the 5th International Conference on Inventive Computation Technologies, ICICT 2020, pp. 252–257, 2020. [Online]. Available: https://doi.org/10.1109/ICICT48043.2020.9112540
[20] S. D. S. Dass, F. Meskaran, and M. Saeedi, "Expert System for Early Diagnosis of Covid-19," International Journal of Current Research and Review, vol. 12, no. 22, pp. 162–165, 2020. [Online]. Available: https://doi.org/10.31782/IJCRR.2020.122227
[21] R. Safdari, H. K. Arpanahi, M. Langarizadeh, M. Ghazisaiedi, H. Dargahi, and K. Zendehdel, "Design a Fuzzy Rule-Based Expert System to Aid Earlier Diagnosis of Gastric Cancer," Acta Informatica Medica, vol. 26, no. 1, pp. 19–23, 2018. [Online]. Available: https://doi.org/10.5455/aim.2018.26.19-23
[22] E. J. G. Buitrón, D. C. Corrales, J. Avelino, J. A. Iglesias, and J. C. Corrales, "Rule-Based Expert System for Detection of Coffee Rust Warnings in Colombian Crops," Journal of Intelligent and Fuzzy Systems, vol. 36, no. 5, pp. 4765–4775, 2019. [Online]. Available: https://doi.org/10.3233/JIFS-179025
[23] M. O. S. Monardez and D. A. A. Pizarro, "Expert System for Assistance in Decision Making of Students in Practice of a Psychological Care Center in Clinical Cases of Suicidal Risk." Institute of Electrical and Electronics Engineers Inc., vol. 10, pp. 1–9, 2020. [Online]. Available: https://doi.org/10.1109/CLEI52000.2020.00006
[24] G. V. Torres, L. L. Aponte, and L. Andrade-Arenas, "Implementation of an Expert System for Automated Symptom Consultation in Peru," International Journal of Advanced Computer Science and Applications, vol. 12, no. 12, pp. 805–813, 2021. [Online]. Available: https://doi.org/10.14569/IJACSA.2021.0121298

[25] L. Delgado Montenegro, A. Cortez Vásquez, and E. Ibáñez Prentice, "Aplicación de metodología Buchanan para la construcción de un sistema experto con redes bayesianas para apoyo al diagnóstico de la tetralogía de Fallot en el Perú," Industrial Data, vol. 18, no. 1, p. 135, 2016. [Online]. Available: https://doi.org/10.15381/idata.v18i1.12076
[26] A. Delgado, J. Torrejónburgos, M. E. Section, and P. Universidad, "Design of a Web System for the Control of Anemia Patients under the Agile Scrum Methodology, Lima - Peru," International Journal of Advanced Trends in Computer Science and Engineering, vol. 9, no. 5, pp. 7980–7985, 2020. [Online]. Available: https://doi.org/10.30534/ijatcse/2020/153952020
[27] R. Arias-Marreros, K. Nalvarte-Dionisio, and L. Andrade-Arenas, "Design of a Web System to Optimize the Logistics and Costing Processes of a Chocolate Manufacturing Company," International Journal of Advanced Computer Science and Applications, vol. 12, no. 8, pp. 860–866, 2021. [Online]. Available: https://doi.org/10.14569/IJACSA.2021.0120897
[28] F. D. A. Farzat, M. D. O. Barros, and G. H. Travassos, "Evolving JavaScript Code to Reduce Load Time," IEEE Transactions on Software Engineering, vol. 47, no. 8, pp. 1544–1558, 2021. [Online]. Available: https://doi.org/10.1109/TSE.2019.2928293
[29] A. A. Prayogi, M. Niswar, Indrabayu, and M. Rijal, "Design and Implementation of REST API for Academic Information System," IOP Conference Series: Materials Science and Engineering, vol. 875, no. 1, 2020. [Online]. Available: https://doi.org/10.1088/1757-899X/875/1/012047
[30] L. Zhao, H. Gu, J. Xu, Y. Cui, and C. Shuai, "Research on Simufact Simulation Data Processing System Based on QT and MySQL," Applied Mathematics and Nonlinear Sciences, vol. 6, no. 2, pp. 291–298, 2021. [Online]. Available: https://doi.org/10.2478/amns.2021.2.00042
[31] S. bin Uzayr, "Introduction to Visual Studio Code," pp. 1–46, 2021. [Online]. Available: https://doi.org/10.1007/978-1-4842-7344-9
[32] A. D. Sole, "Customizing Visual Studio Code," Visual Studio Code Distilled, pp. 95–110, 2019. [Online]. Available: https://doi.org/10.1007/978-1-4842-4224-7
[33] M. Z. K. Patricia, V. Z. E. Santiago, and M. Y. F. Javier, "Expert System for the Pre-Diagnosis of Skin Diseases," International Journal of Machine Learning and Computing, vol. 10, no. 1, pp. 81–86, jan 2020. [Online]. Available: https://doi.org/10.18178/ijmlc.2020.10.1.902
[34] E. F. M. Peñafiel, B. V. Barahona, and I. M. Camejo, "Methodology of Building an Expert System Using Induction Rules with Structured Programming," KnE Engineering, vol. 3, no. 9, p. 235, dec 2018. [Online]. Available: https://doi.org/10.18502/keg.v3i9.3658
[35] D. Hernando, S. D. Sharma, M. Aliyari Ghasabeh, B. D. Alvis, S. S. Arora, G. Hamilton, L. Pan, J. M. Shaffer, K. Sofue, N. M. Szeverenyi, E. B. Welch, Q. Yuan, M. R. Bashir, I. R. Kamel, M. J. Rice, C. B. Sirlin, T. Yokoo, and S. B. Reeder, "Multisite, Multivendor Validation of the Accuracy and Reproducibility of Proton- Density Fat-Fraction Quantification at 1.5T and 3T Using a Fat–Water Phantom," Magnetic Resonance in Medicine, vol. 77, no. 4, pp. 1516–1524, 2018. [Online]. Available: https://doi.org/10.1002/mrm.26228

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