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Original Article

Expert Systems and Epidemiological Surveillance for Tuberculosis: Innovative Tools for Disease Prevention and Control

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Abstract *- Expert systems have been automating several tasks in various social spheres as the years have passed. Health-related fields have made it possible to accept a lot of information that is used to inform decisions and train these systems about the most dangerous diseases on a global scale. As a result, the research aims to put in place an expert online system that would allow for epidemiological surveillance of Tuberculosis. Innovative tools like web-based systems and specialized programming languages like Swi-Prolog were used to diagnose Tuberculosis. For this reason, several sources of information in other authors' research were consulted in order to learn how Tuberculosis maintains a connection with expert systems. The Buchanan methodology was used, which consists of 4 phases; finally, for the validation and acceptance of the system by the customers, a questionnaire of 15 questions separated by 3 dimensions was carried out, applying an acceptance rate of 85% of the surveyed users. Finally, the conclusion reached is that the system developed will help many people to prevent and inform them about the danger of Tuberculosis and its consequences.*

Keywords *- Buchanan methodology, Expert systems, Epidemiological surveillance, Health-related, Tuberculosis.*

1. Introduction

The use of information technology (TIC) has had a significant impact on our society, and the use of computer programs has been crucial in providing remedies for diseases that have manifested in particular areas of health. In more specific terms, the disease of Tuberculosis is a significant global health issue, according to the Pan American Health Organization (OPS). The results showed that 10.6 million people had this illness, while 1.6 million died, and lastly, 187.000 had infections related to the human immunodeficiency virus (VIH) [1]. Due to the high number of deaths it causes over the course of years, Tuberculosis is one of the most prevalent diseases on a global scale. Mycobacterium is the type of bacteria that causes this disease. The seriousness of this illness stems from the fact that it not only affects the lungs but also other parts of the body like the brain and the ribs.Additionally, the study included in this investigation refers to the number of cases that were reported in 2021, reaching approximately 450.00 cases globally and increasing by 3.1% from 2020, when it is estimated that there will be around 437.00 confirmed cases of this illness [2]. A problem with this illness is adherence to treatment, which helps us understand how stopping the doctor's recommended course of treatment can have unfavourable effects and put the patient with Tuberculosis at risk for developing persistent drug resistance. To this end, possible approaches that make it possible to pinpoint the patient's reasons for this adherence are being researched [3]. It's important to keep in mind that Tuberculosis is classified as an infectious disease because it is typically discovered through contact with other people. However, prior contact with a patient has the characteristic of reducing the risk of the disease progressing. At the same time, current tests cannot identify the type of infection that a patient is suffering from because the patient's immune system does not recognize the infection [4]. According to the guidelines set forth by the World Health Organization (OMS), tests related to patient sputum have been established in order to conduct tests on the disease overall in individuals with a high percentage likelihood of being able to resist Tuberculosis (TB) active pulmonary. In this regard, the study using patient biomarkers has produced encouraging findings for the prevention of active Tuberculosis. To find improvements in the progression of this illness, however, certain investigations related to this affliction are deemed necessary [5]. According to studies conducted by the United Nations Joint Programme on the

VIH/SIDA (ONUSIDA), the mortality rate of Tuberculosis VIH continues to rise, and it is predicted that by 2030, specific global tasks will have been completed to eradicate the virus through preventative measures. However, the use of the IA has lessened the high risks associated with this type of infection that targets the lungs or, in the worst cases, other bodily organs. By using algorithms based on automatic learning to interpret predicted results, it has become possible to make a precise detection of the percentage of risk associated with this disease [6].

According to estimates, the cause of Tuberculosis, a disease that affects the lungs, is certain disorganizations in a person's daily life, such as smoking, which is a major contributor to the disease if a person is dependent on these drugs, as well as other factors like contaminated air or, at the time, the coronavirus 2019 (COVID-19). For this reason, artificial intelligence has the function of classifying using certain predictions using these technologies used in X-ray, computerized tomography, and magnetic resonance imaging images while taking into account the study models of automatic, deep, and transferable learning to suggest which algorithm is more practical to use [7].

On the other hand, algorithms based on automatic learning (ML) prescribed by IA have as their research task predicting bacterial resistance to drugs prescribed by doctors who are experts in treating the disease. Rifampin, isoniazid, pyrazinamide, and fluoroquinolones are drugs used to treat disease. However, their structural characteristics depend on just one idea: the nucleotides that indicate the impact of mutations on the cellular protein encoded by a gene [8].

The development of information technologies has been linked to a number of social problems. Certain technological principles that allow conceptualizing information according to the needs of the problem have been implemented in the health sector, and AI-based Expert Systems have been seen as a viable option to develop solutions for patients with various diseases [9].

Therefore, the contribution of this scientific research is focused on the presentation of several cases that were previously mentioned in previous paragraphs and that give us an idea of how information technologies help in the search for cures for some deadly diseases that claim the lives of many people.

2. Literature Review

2.1. Theoretical Basis

2.1.1. Expert Systems

An expert system refers to a technical model of artificial intelligence that carries out certain tasks to address various knowledge-related problems. The necessary information is gathered so that the SE can locate significant findings made using the foundation of knowledge [10].

These so-called artificial intelligence technologies are examined using mathematical algorithms that enable making predictions in accordance with the data input into the system. Algorithms such as statistical learning and knowledge-based models of representation carry out various tasks according to the desired implementation for their analysis [11], as shown in Figure 1, naming the components involved in the structure of an expert system.

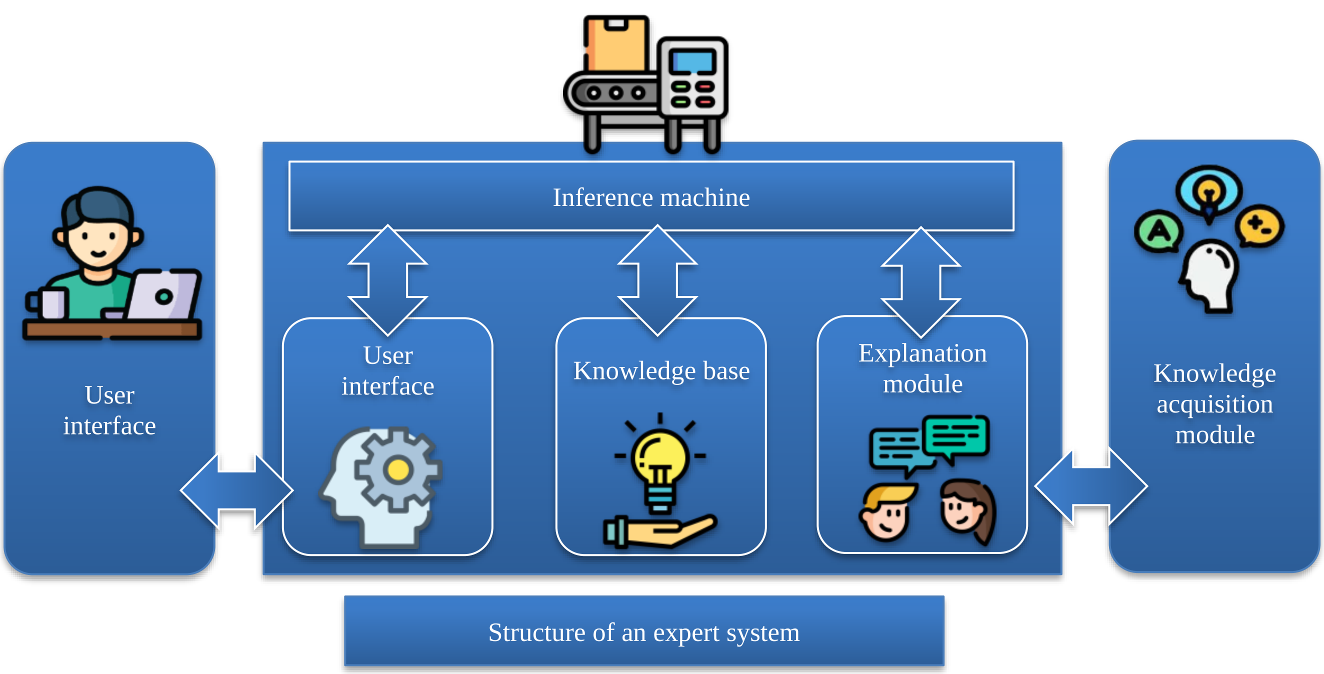

Fig. 1 Architecture of an expert system

2.1.2. Expert Systems

Expert systems are computer programs that mimic the ability of a human expert to make decisions or solve problems in a specific domain. Likewise, they consist of different components within the same in order to perform the corresponding tasks of each one. It was proposed to mention the components that interact to achieve an accurate prediction according to the problem posed [12], which will be mentioned below:

Knowledge Base

A knowledge base is an efficient method of collecting, storing and retrieving data and knowledge for later use. Both humans and machines can benefit from its use in decision-making and problem-solving. This component extracts the expert's knowledge on the subject to be investigated and records all these concepts in a knowledge base based on established rules that build certain descriptions of the objects and the relationships that exist between them.

Factual Basis

It is the information widely accepted by the Knowledge Engineers and scholars in the task domain. Also, the ability to clearly and accurately explain what happened in a particular scenario is crucial in many legal and conflict resolution contexts, and this factual basis is often necessary for it.

Interference Engine or Rule Interpreter

It is a crucial component of expert systems, which are computer programs that use artificial intelligence to mimic the reasoning and problem-solving capabilities of human experts. The inference engine is the part of the expert system that uses the rules and data provided to it to conclude.

The interpretive rules-related inference engine focuses mostly on deducing new facts when the knowledge base and the factual foundation are working together. It involves new operations based on searching for and selecting rules for the reasoning process in order to arrive at concise conclusions about the issue.

Explanation Subsystem

In an expert system, it is an essential part that provides information on how a certain conclusion or recommendation is reached. Basically, it tries to explain to the user the rules and knowledge used to solve the given problem. Through the explanation subsystem module, the expert system can explain to the user why the question was asked and how the conclusion was reached.

User Interface

The user interface of an expert system is crucial for its human users to interact and understand the system's options and suggestions. This represents the means of communication with the user. The user interface is usually not a generic part of the Expert System technology, and was not given much attention in the early years of the development of Expert Systems.

Knowledge Acquisition Module

In order for the system to be able to draw conclusions and make judgments, this component must first collect and store information from human specialists. This assists the expert by allowing him or her to quickly build a knowledge base and providing tools to update the knowledge base as needed. The knowledge collection module creates a central database or a system independent of the knowledge base and database, as well as the software tools needed to create knowledge-based systems.

Communications Module

The communications module of an expert system is crucial because it allows the expert system to communicate with other systems and users. This component is essential for the successful rollout and operation of the system as a whole. The knowledge-based communication system does not exist in isolation but rather interacts with other information systems, allowing them to engage not only with an expert but also with these systems to gather information or search databases.

2.1.3. Tuberculosis

Tuberculosis, or TB, is named after a type of bacteria known as Mycobacterium, which attacks the respiratory tract. In this sense, the transmission of this disease occurs primarily through person-to-person contact because the disease spreads through airborne germs to the person who is infected. When infected, a person maintains a germ-breathing cycle without being aware of the disease in the air [13]. Figure 2 shows an image of the Mycobacterium bacteria that attacks the respiratory system under the name of TB tuberculosis.

Causes of Tuberculosis

One of the most common causes of tuberculosis infection is in patients who have been intubated for an extended period of time for various reasons in the intensive care unit of hospitals. Other causes include malignant neoplasia and trauma.

On the other hand, it is crucial to note that person-to-person interaction is very common among patients suffering from these symptoms, as various forms of communication between people amplify the contact.

For example, in one study, a chiropractic repair was performed on a 32-year-old male with Tuberculosis pulmonary multirresistente, and it was discovered that the disease was not malignant or that there was trauma as a result of which the patient developed spontaneous FTE, most likely due to necrosis of the linfátic mediastnic ganglios [14].

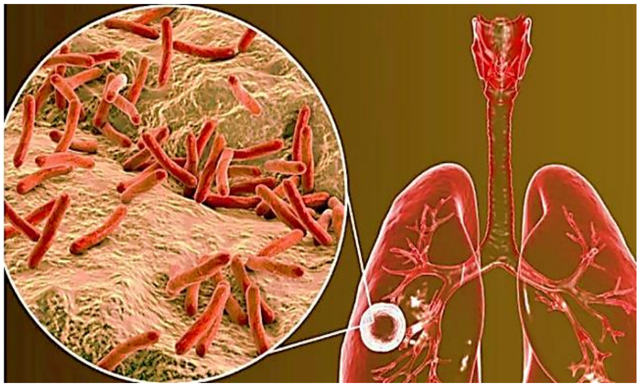

Fig. 2 Tuberculosis bacterium mycobacterium

2.2. Related Work

In this study, the goal is to create an expert application programming interface (API) whose job is to apply direct encadement algorithms and a quality factor for the early detection of Tuberculosis. This was accomplished by testing strategies and in-depth interviews with medical experts, and as a consequence, satisfactory results were obtained for the completion of this scientific study [15]. In Indonesia, there is a high level of vulnerability to pulmonary diseases such as Tuberculosis, which has claimed the lives of many people who have contracted the disease. The city of Tasikmalaya, in particular, suffers from a shortage of medical professionals who specialize in lung diseases. In many cases, the demand for certain pulmonary diseases exceeds the supply, making the development of an expert system based on artificial intelligence a viable option for the diagnosis and prevention of these fatal diseases. Implementing recovery algorithms from nearby neighbors will classify a doctor's knowledge for diagnosing these diseases in relation to 25 primary symptoms of health problems that affect the population [16].

An investigation of pulmonary diseases presented in the year 2018 in Indonesia finds a prevalence of 4.0% and 0.4% for pulmonary pneumonia and Tuberculosis, respectively. In this regard, there is a scarcity of experts in the field for treating pulmonary infections. It is estimated that between 600 and 700 specialists have the tools needed to treat this disease; hence, the use of ANFIS to present a precise diagnosis of the disease is growing. To that end, the implementation of an expert-directed ANFIS process determines the early or progressive detection of symptoms associated with pulmonary diseases such as Tuberculosis. The integration of classification and grouping of data will allow training on algorithmic models that obtain an efficient result compared to other proposed models [17]. According to other authors, research conducted in Vietnam, which is mainly one of the countries most affected by tuberculosis disease, the mortality rate is increasing every year. For this, an expert system was implemented to realize a tool to help medical experts, especially in rural areas where the increase of the disease has a degree of danger. In order to determine to decongest the high demand in public hospitals, which receive many cases per day of Tuberculosis. The development of a medical expert system related to the idea of conceptualizing the information with rules associated with fuzzy logic has been carried out in order to offer an accurate diagnosis and treatment concerning Tuberculosis [18].

The current study discusses the mortality rate of Tuberculosis; in this regard, the number of physicians specializing in tuberculosis detection is limited. To address this issue, information technology is being developed, which will allow for the diagnosis of Tuberculosis as well as the prediction of the disease through a distributed expert system. To complete this task, enter symptoms related to Tuberculosis as entry data to predetermine the process via fuzzy logic. The information after data entry is presented in a graphical web interface to show the result, which is the disease diagnosis based on disease rules prescribed by experts in the field of external sources of information to medical knowledge. On the other hand, the importance of ambiguous logic in predicting this disease is determined, with a 90% precision in the conclusion obtained by the expert online system [19]. This study focuses on Tuberculosis, which is defined as an infection caused by a group of viruses known as Mycobacterium. According to experts, any type of mortality should be diagnosed as soon as possible. According to this information, a professional system has been designed and implemented to provide a positive solution to this situation. The goal of the research is to predict the disease based on the symptoms that the user exhibits from Tuberculosis TBC. According to this implementation, the logic of an expert system, such as the development of the knowledge base in which the information from the Paradox database is stored, is consulted with the Dempster-Shafer rule method and Bayes theory, which are algorithms used for prediction [20].

3. Methodology

3.1. Definition of the Buchanan Methodology

The significance of the Buchanan method stems from the consolidation of knowledge using various sources of information and the interaction of the knowledge engineer with the expert who will provide his knowledge so that the system can process that information and identify significant patterns that will allow the problem to be solved using an expert system [21]. In addition, Buchanan methodology is defined as the application of the life cycle in cascade conceptualized with Engineer knowledge related to information systems. To consolidate an expert system using this method, a continuous review of each developed process is performed. Its main advantage is that it is simple to redefine previously established concepts in order to supplement or correct errors in the expert system that has been implemented [22]. Figure 3 shows the stages of the Buchanan methodology in a figure arranged according to each process, showing the identification, conceptualization, formalization, implementation and testing stages.

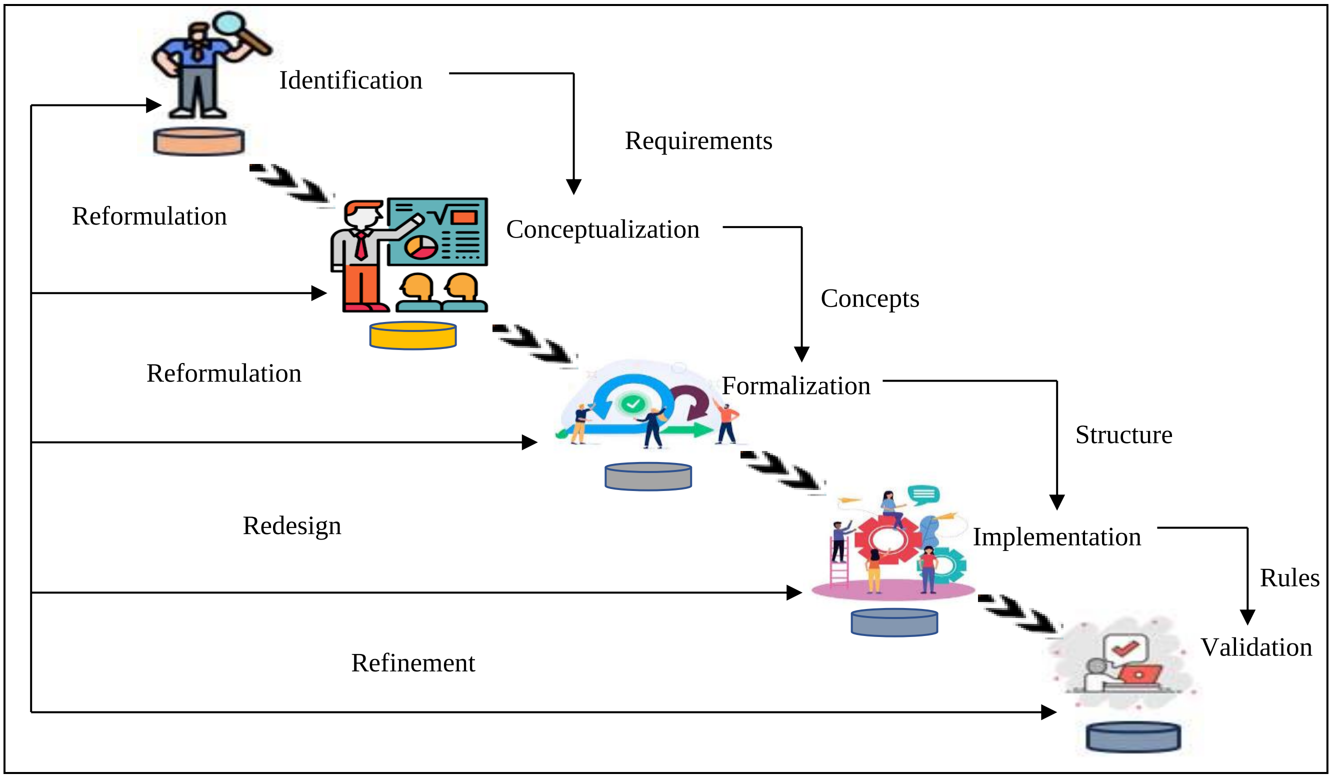

Fig. 3 Buchanan methodology

3.1.1. Identification

During this stage, different important aspects of the problem to be studied are conceptualized. Such as the people who carry out the system, such as the domain expert, the knowledge engineer, or future users, or the characteristics of the problem to be carried out (type, subtasks), terminologies that will be used, and other fundamental aspects. In addition, there are resources available as sources of information, knowledge, development time, and funding.

3.1.2. Identification of the Problem

In several parts of the city, there is a significant shortage of specialist physicians capable of diagnosing respiratory diseases such as Tuberculosis (TB). In addition, one of the main problems is the high demand for hospitals that treat respiratory diseases; hospitals are becoming increasingly overcrowded due to the high volume of patients.

There is a serious public health risk associated with the city's scarcity of doctors trained to diagnose respiratory infections like Tuberculosis (TB). Hospital overcrowding is a contributing factor because of the increasing number of people seeking care for respiratory illnesses.

3.1.3. Solution about the Problem

In order to solve the problem, we intend to consolidate an expert system using the programming language SWI - PROLOG oriented to a web system where it can also be opened in mobile devices that are most used by patients.

Developing an expert system for the identification of respiratory diseases can be a useful means of expanding access to medical treatment in underserved communities. When designing a healthcare system, it's crucial to get input from both medical professionals and patients.

3.1.4. Familiarization with the Domain

In order to perform a correct interpretation with the familiarization with the domain. Constant meetings were held with the expert pulmonologist who is in charge of providing us with the necessary information about the disease to be investigated. In order to do so, we also relied on classified information located in research carried out by other authors and to contribute to the Expert System to be carried out.

3.1.5. Expert System Task

- To gain access to the system, the user must first register with the system.
- The user will gain access to the system by entering their username and password.
- The symptoms will be allowed to be entered immediately in order to establish the severity of the disease.
- The system will do disease diagnosis based on the causes or consequences of the disease, as well as monitoring and epidemiology.
- Realize the addition of a new knowledge base that is dependent on the initial knowledge base.
- Realize the updating of previously stored and entered knowledge by the user.

Table 1. Symptoms primary pulmonary tuberculosis

Symptoms	Frequency of patients (%)
Cough	78
Weight loss	74
Fatigue	68
Fever	60
Night sweats	55
Hemoptysis	37

Table 2. Symptoms miliary tuberculosis

Symptoms	Frequency of patients (%)
Anorexia	88
Fever	88
Weight loss	85
Asthenia	78
Cough	59
Dyspnea	35
Abdominal pain	13
Headache	17
Hemoptysis	11
Nausea	9

Table 3. Intestinal tuberculosis symptoms

Symptoms	Frequency of patients (%)
Abdominal pain	60
Weight loss	59
Fever	47
Asthenia	45
Nauseas	44
Anorexia	38
Vomiting	38
Strain	24
Constipation	21
Diarrhea	18

3.2. Conceptualization

For this stage, the acquisition of knowledge for the expert system will be performed; for this section, the information provided by the expert will be obtained and also consulted from articles or scientific journals based on the topic to be investigated. Table 1 presents a description of the most common symptoms in patients with primary pulmonary Tuberculosis and their impact on the percentage affected according to each symptom. Table 2 shows the following symptoms and the degree of percentage that affect patients related to Miliary Tuberculosis, showing that the diseases with the highest percentage are Anorexia, Fever, Weight loss, Asthenia and Cough. Table 3 shows the symptoms and the percentage of patients who contract these symptoms according to Intestinal Tuberculosis, for which these data are mentioned in the table that is displayed.

3.2.1. Definition of types of tuberculosis

As mentioned in previous chapters, Tuberculosis is an infectious disease caused by bacteria at a chronic level; experts in the field mention that it is produced by 4 microorganisms of the Mycobacterium tuberculosis family of microbacteria [23]. Rapid TB diagnosis and treatment are crucial for stopping the disease and its consequences in their tracks. Drug susceptibility testing results for drug-resistant TB cases also factor into treatment decisions and how long they should last. Multiple antibiotics, spread out over a period of months, are the standard treatment for Tuberculosis.

3.2.2. Pulmonary Tuberculosis

Pulmonary Tuberculosis remains a significant global health concern, particularly in regions with high TB prevalence. Effective diagnosis, treatment, and prevention strategies are essential to combat this infectious disease and reduce its impact on public health. For the localization of this type of Tuberculosis, the manifestations are frequently presented by means of dry cough at the beginning of the symptoms of the disease and then with mucopurulent expectoration sometimes tinged with blood or, in rare occasions, the expulsion of blood or hemoptysis.

3.2.3. Extrapulmonary Tuberculosis

In this type of symptom, the extrapulmonary organs present infection immediately after primary infection, when the infection spreads to the lymph nodes and bloodstream may be located in the upper part of the lungs. Table 4 shows the classification of TB tuberculosis as Pulmonary Tuberculosis and Extrapulmonary Tuberculosis and their main characteristics.

Table 5 shows different characteristics of the drugs administered by patients over 15 years of age, the dose, maximum daily dose, dose, and maximum per dose. Table 6 shows different characteristics of the drugs administered by patients under 15 years of age, the dose, maximum daily dose, dose and maximum per dose.

3.3. Formalization

During the formalization phase, the necessary information about the type of expert system that will be used will be obtained. In the project, we will present the System Expert Model based on Swi-Prolog, which is a programming language used to create expert systems that can be combined with other programming languages.

Swi-Prolog is a type of programming language aimed at declarative expert systems. Its main feature is that it is based on abstract formalisms. Prolog maintains a high level of logic, and Lisp, another declarative programming language, and lambda calculus [24].

3.3.1. SLD (Selective Linear Defined) Algorithm

This algorithm presents fundamentally the capacity of logic programming; that is to say, it allows us to make queries and find solutions through the unification and resolution of clauses.

Table 4. Types of TB Tuberculosis

Types of Tuberculosis	
Disease	**Features**
Pulmonary Tuberculosis	The disease is always contagious, especially when 5 millimeters of a sneeze or tossing are transmitted.
	One of the most common symptoms is tossing and turning for more than 15 days.
	The disease is diagnosed using molecular tests and Tórax's Rayos X.
	This type of Tuberculosis is treated for free if the patient is sensitive or standardized.
	Aerosol isolation is required for pulmonary Tuberculosis.
Extrapulmonary Tuberculosis	For pulmonary Tuberculosis, aerosol isolation is essential.
	Affects any region of the body, particularly the menstrual, renal, and osteomuscular systems.
	Standardized treatment depends on the organ affected.
	Patients with VIH coinfections, immunocompromised individuals, and children are more vulnerable to Tuberculosis.

Table 5. Anti-tuberculosis drugs for patients over 15 years of age

Medications	First daily phase		Second Phase: Three times per week	
	Dose (mg/Kg)	**Maximum daily dose**	**Dose (mg/Kg)**	**Maximum dose per dose**
Isoniazid	5 (4-6)	300 mg	10 (8 -12)	900 mg
Rifampicin	10 (8-12)	600 mg	10 (8-12)	600 mg
Pirazinamida	25 (20-30)	2000 mg		
Ethambutol	20 (15-25)	1600 mg		

Table 6. Anti-tuberculosis drugs for patients under 15 years of age

Medications	First daily phase		Second Phase: Three times per week	
	Dose (mg/Kg)	**Maximum daily dose**	**Dose (mg/Kg)**	**Maximum dose per dose**
Isoniazid	10 (10-15)	300 mg	10 (10 -20)	900 mg
Rifampicin	15 (10-20)	600 mg	10 (10-20)	800 mg
Pirazinamida	35 (30-40)	1500 mg		
Ethambutol	20 (15-25)	1200 mg		

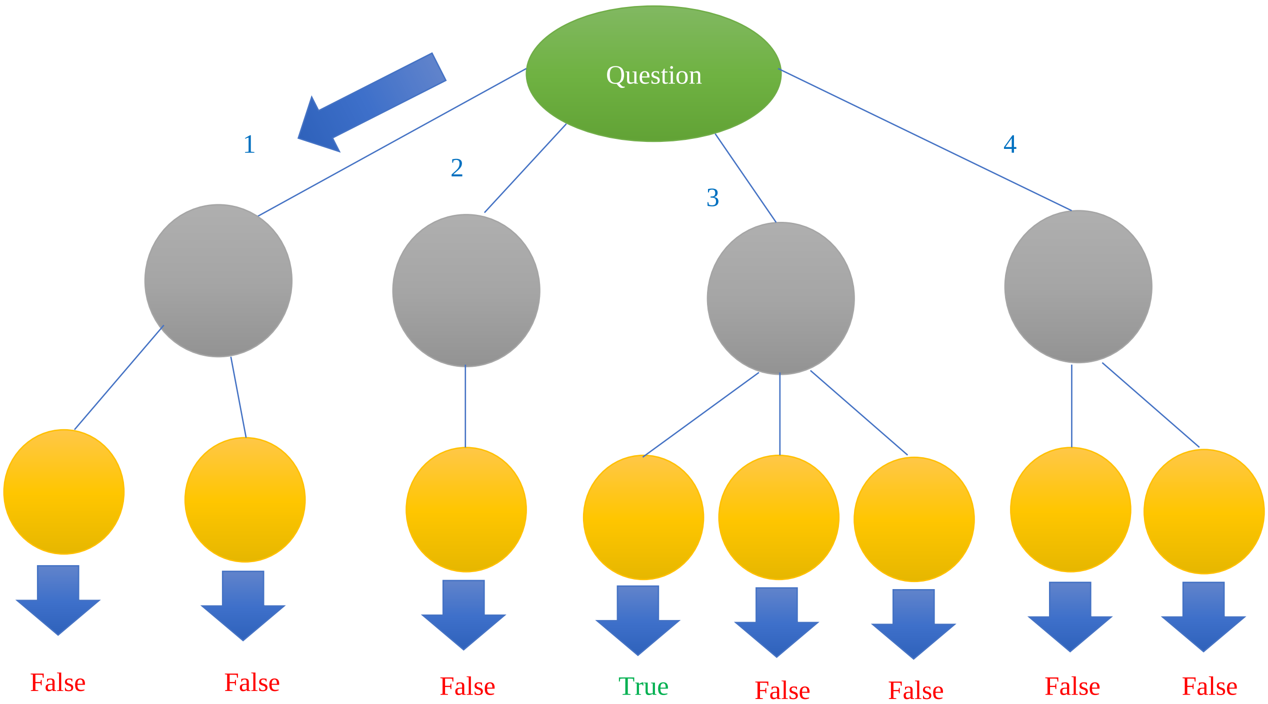

Fig. 4 SLD algorithm (Selective Linear Defined)

Prolog programming based on the SLD (Selective Linear Definite) algorithm is defined as logic programs performed by Horn clauses according to fact and business rules, in which the algorithm is oriented to traverse a search tree up and down, from left to right until a possible solution is found for the given query or until a cut-off condition is reached as shown in Figure 4.

3.3.2. Swi -Prolog Programming Code

% declaration of libraries for the interface
: -use module (library (pce)).
: -use module (library (pce_style_item)).
% main method to start the graphical interface, declaration of
% buttons, labels, and the position on the screen.

home: -
new (*Menu*, dialog (Project SDM version Alienigena 1.3'., size (1000,800))),
new (L, label (name, ‘MEDICAL DIAGNOSTIC ')),
new (A, label (name,'-- 2023 --')),
new (@text, label (name, ‘answers a brief questionnaire for diagnosis')),
new (@respl, label (name,'')),
new (Exit, button (EXIT, and (message (Menu, destroy), message (Menu, free)))),
new (@boton, button ('realizar test’, message (@prolog, butons))),
send (Menu, append(L)), new (@btncarrera, button('Dignosis?')),
send (Menu, display, L, point (100,20)),
send (Menu, display, A, point (50,650)),
send (Menu, display, @boton, point (20,150)),
send (Menu, display, @text, point (20,100)),
send (Menu, display, Exit, point (600,650)),
send (Menu, display, @respl, point (20,130)),
send (Menu, open_centered).
% disease presentation and treatment according to the rules of diagnosis

failures ('YOU ARE SUFFERING FROM TUBERCULOSIS PRIMOINFECTION):

The primary infection by the virus of human immunodeficiency is defined as the collection of immunological and viral symptoms that develop from the time an individual is infected by the virus until viremia and the accumulation of CD4 lymphocytes in peripheral blood become stable. The treatment consists of administering Isoniacida at a dose of 5 mg/kg, which provides excellent disease protection (more than 80%). The outcome of tuberculin testing on TB patients' contacts determines their treatment.

failures ('YOU HAVE POST-PRIMARY TUBERCULOSIS):

It is the most common form of infection in adults, and it occurs in those who have developed a delayed immune response to M. tuberculosis. The immune system can suppress the infection in the vast majority of people with latent Tuberculosis. They are drugs with a high level of efficacy combined with a low level of toxicity. They can treat the vast majority of patients successfully and are included in all first tuberculosis treatment plans. This class includes rifampin, pirazinamida, isoniazida, etambutol, and estreptomicin.

failures ('YOU HAVE MILIARY TUBERCULOSIS):

The symptoms of miliary Tuberculosis can be vague and difficult to identify. Weight loss, fever, chills, disability, malaise and respiratory distress are some of the symptoms. Antibiotic treatment is often administered for a period of 6 to 9 months, assuming that the meninges are not affected. In this case, antibiotics are administered for 9 to 12 months. Tuberculosis germs can easily develop resistance to antibiotic drugs, especially if people do not take the medications on a regular basis or for the recommended amount of time.

failures ('YOU SUFFER FROM TUBERCULOSIS OF THE BONE):

The disease can affect people of any age, but it is most common in children aged 2 to 5 years old. Then diminishes and then increases again between the ages of 18 and 25 years old in low-income environments and due to germ virulence. There is no sex predisposition. It can happen anywhere in the world.

3.3.3. Must be combined with

3.3.3.1 General Medical Treatment

Hygiene, rest, fresh air, balanced diet, vitamins, psychological support. Also, the local incredulous orthopedist Immobilization of the affected joint with plaster devices to rest the joint. And avoid deformation during treatment, possibly seeking ankylosis in those joints that have been destroyed.

3.3.3.2. Antibiotherapy

It lasts 1 year. The drugs used are
a) Isoniazid (INH): 5 mg/kg body weight per day tab. of 100 mg 3 per day.
b) Rifampicin (RFP): 10 mg/kg body weight per day tab. of 300 mg 2 per day (fasting).
c) Pyrazinamide (PZA): 25 mg/kg body weight per day tab. of 500 mg 3 per day.
d) Ethambutol (ETB): 20 mg/kg of weight per day tab. of 400 mg 3 per day.

3.3.3.3. Surgery

Treatment of fistulas and abscesses that do not resolve with medication, even if they are the cause of compressive symptoms, such as póttic abscess. Arthrodesis is used to stabilize a damaged, painful joint. To move into dangerous positions.

The operation is performed after the invading period when the immunological state is favorable, eritrosedimentation in franco descent, and with good medication support.

failures ('YOU ARE SUFFERING FROM GENITORURINARY TUBERCULOSIS):

Tuberculosis genitourinaria, also known as Tuberculosis urogenital, is an infection caused by Mycobacterium tuberculosis that affects the genitourinary system, which includes the kidneys, urinary tract, bladder, reproductive organs, and suprarenal glands. It accounts for around 15-20% of extrapulmonary tuberculosis cases and is the second most common kind of extrapulmonary Tuberculosis after ganglion tuberculosis. The treatment of genitourinary Tuberculosis is based on an antituberculous medication regimen that includes isoniazid, rifampicina, pirazinamida, and etambutol. The treatment usually lasts six to twelve months, but it might be extended if the patient develops resistance to the medications or has complications. In severe cases, surgery may be required to remove tuberculous lesions, drain abscesses, or, in extreme cases, remove severely damaged organs.

failures ('YOU HAVE MENINGEAL TUBERCULOSIS):

Meningitis tuberculosa (MTB) is a severe form of extrapulmonary Tuberculosis that affects the meninges. Following a pulmonary tuberculosis infection, children and young adults are more likely to develop hematologic disease. To make a diagnosis, the following tests must be performed: - PPD: a negative result does not rule out a diagnosis. In cases of TBC, the PPD sensitivity ranges between 50 and 60%. - IGRA: will be performed if there is high suspicion and a negative PPD (especially in malnourished or immunocompromised patients). Similarly, his negativity does not rule out a clinical diagnosis. - LCR analysis (request studies and routine findings): - Biochemistry: low glucose concentration (45 mg/dl) with high protein concentrations (100 to 500 mg/dl). Citoquimia is caused by pleocitosis linfocitaria (100-500 células/microL). The predominance of polymorphonuclear (PMN) can be detected in the early stages. - ADA. According to several articles, three levels of ADA value can be considered: 1. An ADA value of 4 UI/L is associated with a 93% sensitivity and 80% specificity for the diagnosis of Tuberculosis. 2. Values between 4 and 8 UI/L do not allow for the exclusion or diagnosis of meningitis. 3. An ADA value greater than 8 UI/L suggests a TB diagnosis. It must be said that your sensibility is quite low.

failures (no results, you did not provide the necessary or sufficient information).
ERROR p560c4!').
% questions to direct you to the appropriate disease with its respective
% disease identifier
primoinfection: - tprimoinfection,
question (' Has a high fever?'),
question (' Has weight loss?'),
question (' Has anorexia?'),
question (' Has agitation?'),
question (' You have conjunctivitis?'),

postprimary: - tpostprimary,
question (' Counts with pain in the oral cords?'),
question (' You have throat discomfort?'),
question (' Itching of the vocal cords?'),
question (' Difficulty breathing?'),

miliar: - tmiliar,
question (' Maintains fever for 4 weeks or more?'),
question (' Excessive sweating during sleep?'),
question (' You have skin lesions?'),
question (' Their immune system is weakened?'),

cough: - tcough,
question (' You have pain in joints and muscles?'),
question (' Knee pain on flexion?'),
question (' Hip pains?'),
question (' Weakness when lifting the arms or legs.?'),

genitourinary: - tgenitourinary,
question (' You have pain when urinating?'),
question (' Constant urination?'),
question (' Pain in the part of the kidneys?'),
question (' Painful urination with bleeding?'),
question (' Account with fiere, asthenia or anorexia?'),
meningea: - tmeningea,
question (' You have a constant headache with neck stiffness?'),
question (' You have hypertension?'),
question (' Maintains sensitivity to light?'),
question (' You have neck stiffness?'),

% fault identifier directing to the corresponding questions
tprimoinfection: - question (' You have general malaise?')!
tpostprimary: - question (' Do you have lymph node discomfort?')!
tmiliar: - question (' Patient is under 4 years of age?')!
tcough: - question (' Muscle and bone discomfort?')!
tgenitourinary: - question (' Urinary system complaints?')!
tmeningea: - question (' You have spinal discomfort?')!
% If the user says yes, the next question of the same line of business will be asked.
% says that it does not move on to the question of the next line of business.

: - dynamic yes/1, no/1.
preguntar (*Problem*): - **new** (Di, dialog (' Medical diagnosis')),
new (L2, label (text, 'Answer the following questions')),
new (La, label (prob, Problem)),
new (B1, button (yes, and (message (Di, return, yes)))),
new (B2, button (no, and (message (Di, return, no)))),

send (Di, append (L2)),
send (Di, append (La)),
send (Di, append (B1)),
send (Di, append (B2)),
send (Di, default_button, yes),
send (Di, open_centered), get (Di, confirm, Answer),
write (Answer), send (Di, destroy),
((Answer==yes)->assert (yes (Problem));
assert (no (Problem)), fail).
% each time a question is answered, the screen is cleared for
% ask again

question(S):-(yes(S)->true; (no(S)->fail; question(S))).
clean: - retract (yes (_)), fail.
clean: - retract (no (_)), fail.
clean.
% selection process according to the diagnosis based on the following questions

botones: - lim,
send (@button, free),
send (@btnrace, free),
Fail (*Fail*),
send (@text, selection (' ')),
send (@respl, selection (*Falla*)),
new (@button, button ('initiates mechanical procedure', message (@prolog, buttons))),
send (Menu, display, @ button, point (40,50)),
send (Menu, display, @btncarrera, point (20,50)),
clean.
lim: - send (@respl, selection (' ')).

3.3.4. Implementation

In the implementation phase, the analysis of the system will be carried out to gather the requirements, consolidate the information obtained in previous phases, and also construct the graphic interfaces of the system with all the classified information. Figure 5 shows the activity diagram that allows us to understand each process that takes place when the patient-user interacts with the system components. Figure 6 shows the case diagram of the system, where we can see the processes developed by each character interacting with the system. Also, Table 7 describes the main problem in the state health centers, where demand exceeds supply and, therefore, there is a collapse of the medical centers in the area of pneumology. Table 8 refers to the entities - objects and the requirements of each object that the object must manage in order to interact with the system. Table 9 presents the functional requirements consisting of the functions that the different objects named in the table will be able to perform. This section shows the class diagram where the classes interact with each other to perform different tasks within the system, as shown in Figure 7. Table 10 shows the description of the functional requirements of the system, which evaluates different criteria in the system and the use of technological tools for the development of the project.

Table 7. Identification of the problem

Nº	Problem	Business requirements
RN1	Medical care in the specialty of pneumology	Expert web System

Table 8. User requirements

Nº	Entity - Object	User Requirements
RU1	Patient	Manage profile
RU2	Symptoms	Symptom management
RU3	Disease	Disease management
RU4	Recommendation	Manage recommendation
RU5	Treatment	Manage treatment
RU6	Diagnosis	Manage diagnostics
RU7	Result	Manage results

Table 9. Functional requirements

Nº	Entity - Object	User Requirements
RF1	Manage profile	Enter data
		User login
		Password entry
RF2	Symptom management	Place symptoms
		Add symptom
RF3	Disease management	Predict disease
		Show disease
RF4	Manage recommendation	Predict recommendation
		Show recommendation
RF5	Manage treatment	Predict treatment
		Show treatment
RF6	Manage diagnostics	Predict diagnosis
		Show diagnosis
RF7	Manage results	Consult expert
		Show result
		Add history

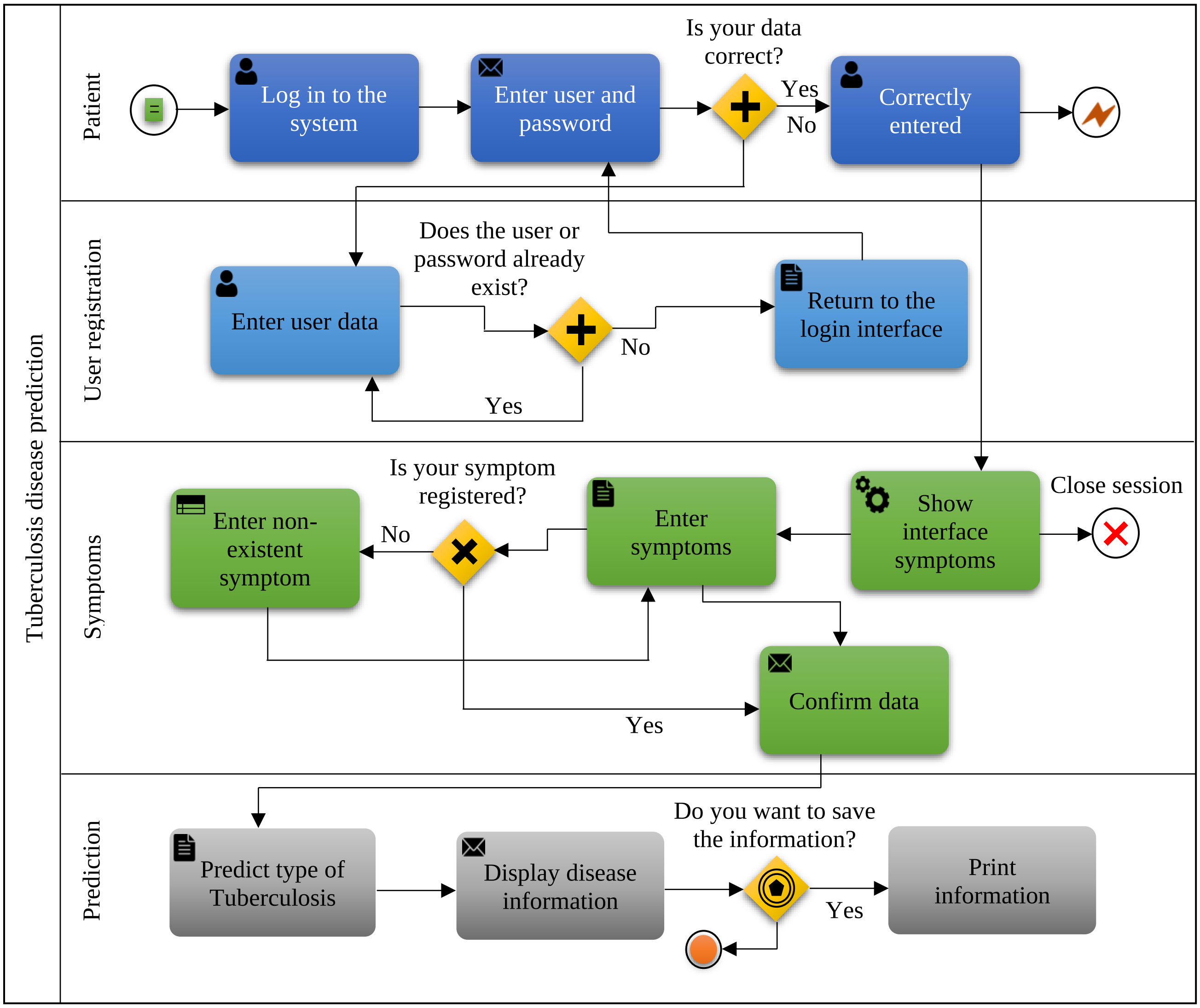

Fig 5. Diagram of activities

Table 10. Non-functional requirements

No.	Attributes Quality	Non-functional requirements
RNF1	Hardware	Client/Server Technology.
RNF2	Software	HTML, CSS, JavaScript, PHP, G - Prolog, MY SQL (XAMP).
RNF3	Security	Queries with markers to protect data in PHP, regular expressions, and use of security methods in PHP.
RNF4	Security	Protection against possible Malware attacks and vigilance against possible security vulnerabilities.
RNF5	Confidentiality	Transactions at 95% confidentiality.
RNF6	Confidentiality	Fault tolerance of 5% of transactions
RNF7	Availability	24 hours a day.
RNF8	Scalability	Easy to make changes in different components (version upgrades).
RNF9	Reusability	Ease of reuse of system components.
RNF10	Integration	It can be easily integrated with other components.

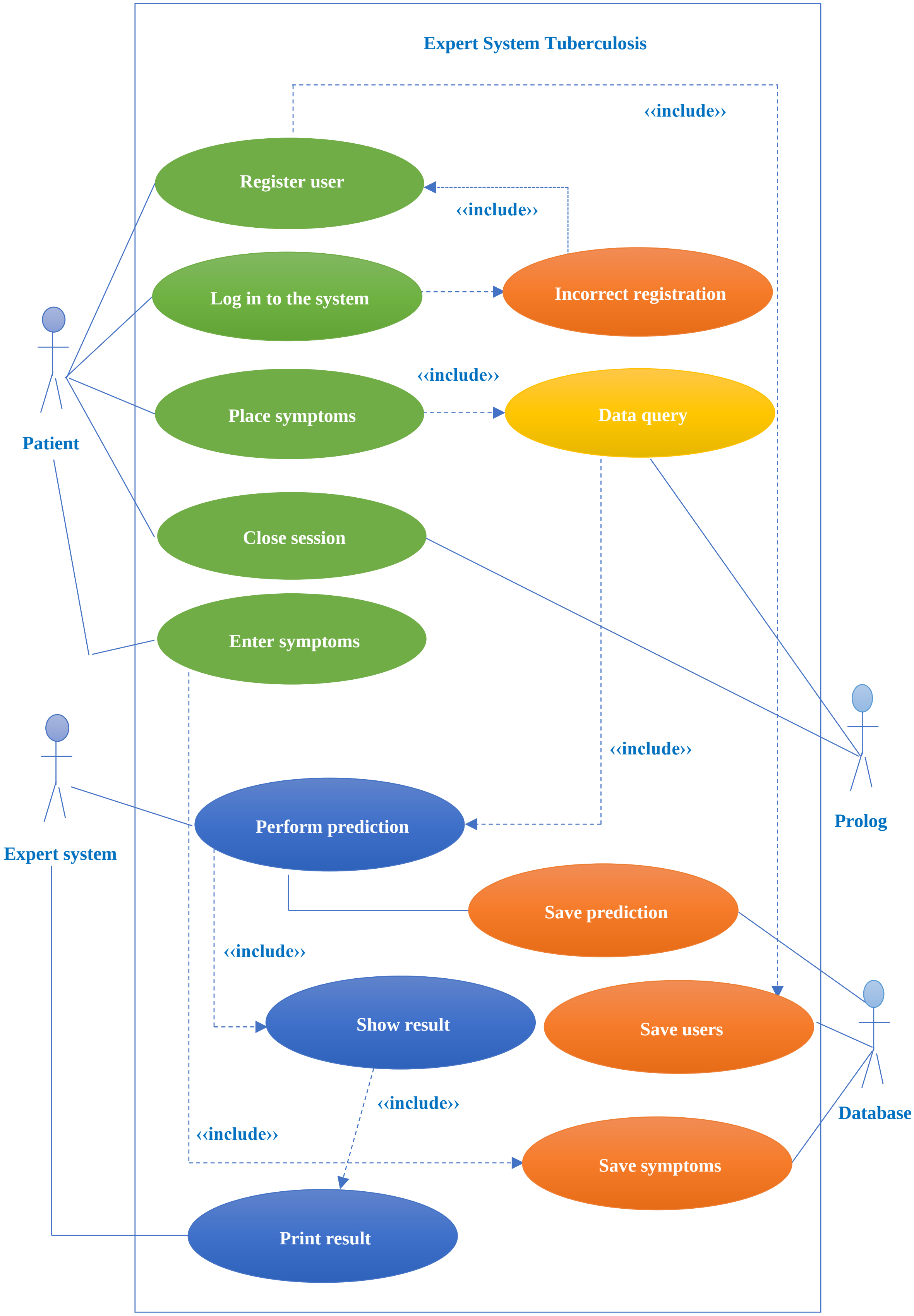

Fig. 6 Use case diagram

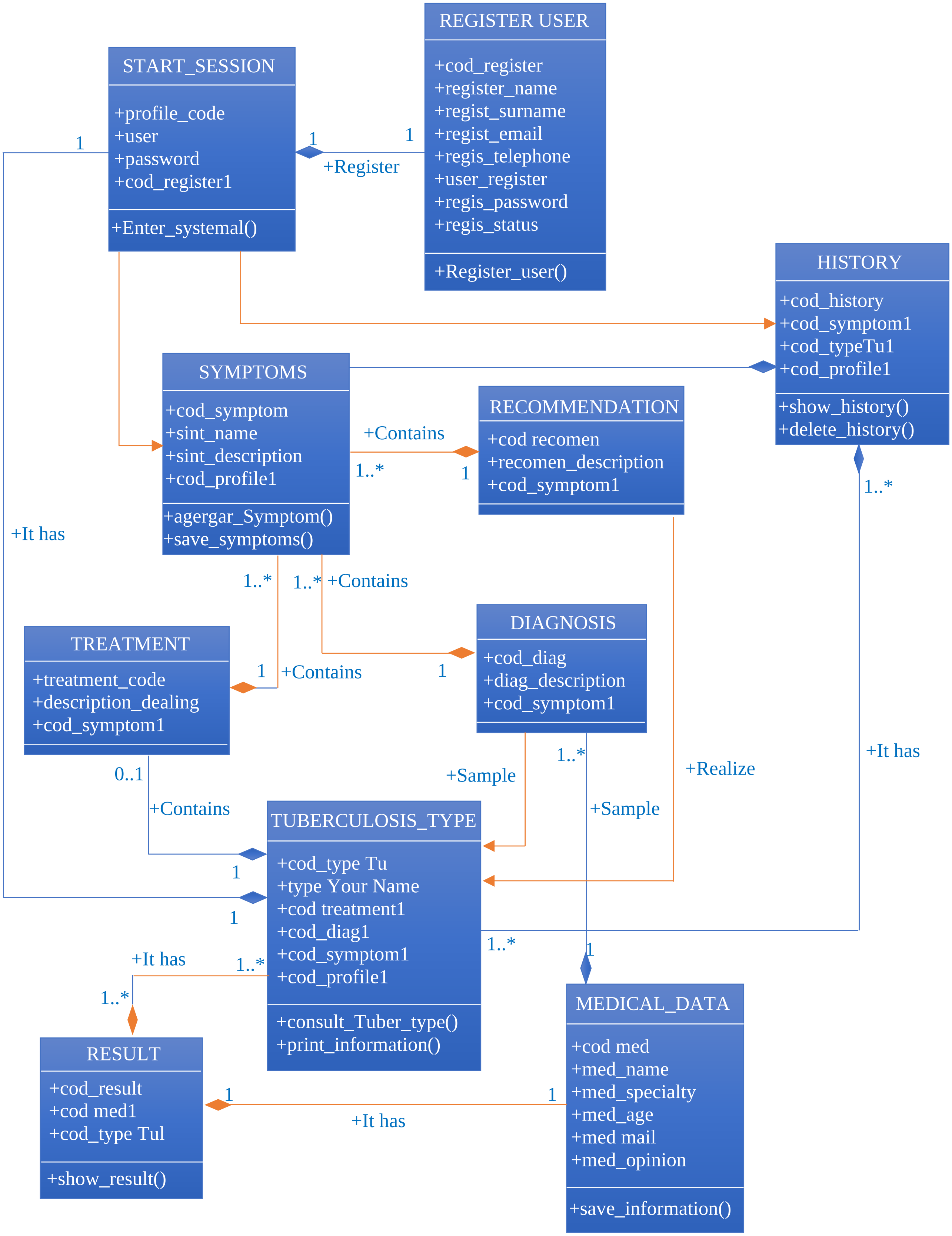

Fig. 7 Class diagram

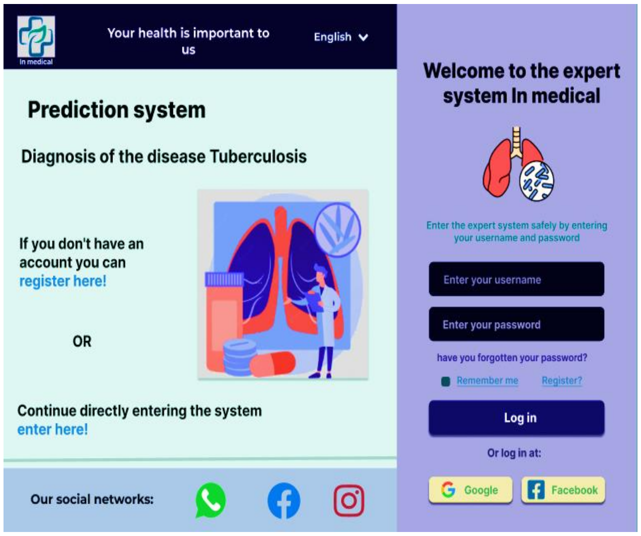

Fig. 8 Prototype login

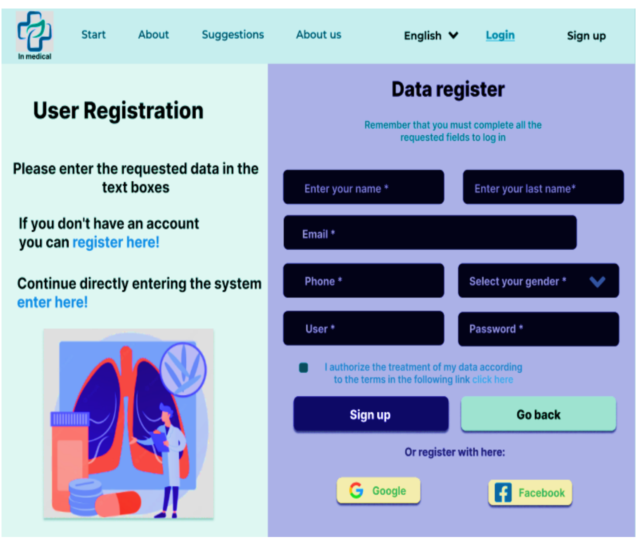

Fig. 9 Prototype user registration

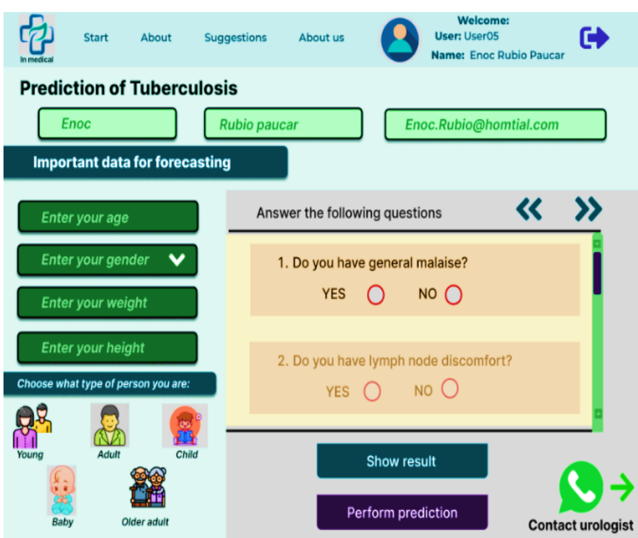

Fig. 10 Prototype prediction of tuberculosis type

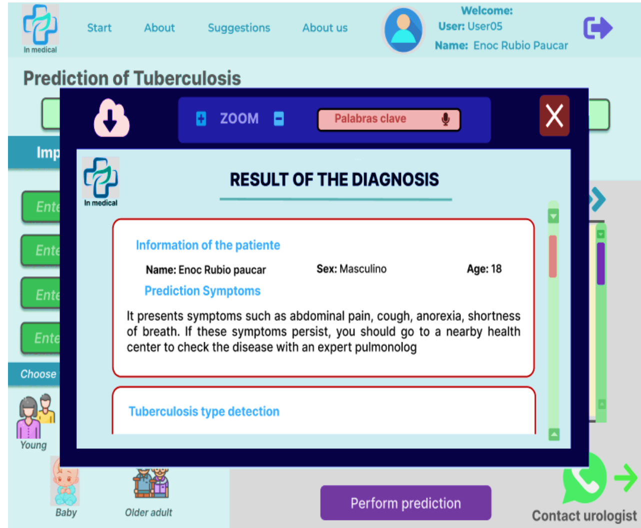

Fig. 11 The prototype shows the prediction result

4. Results and Discussion

4.1. *About the prototypes*

The login prototype allows us to enter a username or password to log in to the system, and you also have the option to log in with a Gmail or Facebook account, as shown in Figure 8. In the graphical user registration interface, the user's data will be entered in order to access the system. It will also be possible to register with Google and Facebook accounts, as shown in Figure 9. The prediction prototype aims to answer a questionnaire of questions to predict the type of Tuberculosis of a patient, as shown in Figure 10. Figure 11 shows the result of the prediction in relation to the type of Tuberculosis detected by means of the symptoms entered in the previous graphical interface.

4.2. *Test*

4.2.1. Security through Regular Expressions

In the login interface, the patient's username or password is entered, and a validation of the data is performed. In the user text box, regular expressions are used to determine that only letters and numbers are accepted by performing a validation in JavaScript. This method will prevent so-called hackers from entering malicious code, such as SQL injection, into the text boxes to steal sensitive information.

```
const usernameRegex = /^[a-zA-Z0-9_-]{3,10}$/;
const passwordRegex = /^(?=.*[a-z])(?=.*[A-Z])(?=.*\d)(?=.*[@$!%*?&])[A-Za-z\d@$!%*?&]{8,}$/;
```

Validation to check if the entered data matches the regular expressions stored in a variable.

```
if (!nameRegex.test(name)) {
    document.querySelector(".format").innerHTML = "Incorrect name format";
    setTimeout(() => {
        document.querySelector(".format
```

```
").innerHTML = "";
        }, 2000);
        return false;
    }
 if (!surnameRegex.test(surname)) {
        document.querySelector(".format1").innerHTML
= " Incorrect last name format ";
        setTimeout(() => {
document.querySelector(".format1").innerHTML = "";
        }, 2000);
        return false;
    }
```

4.2.2. Check if the Variables are Protected

It sounds like you need to verify whether or not specific variables exist in a secure environment. When it comes to security, variables are only as safe as the language you're using and the context in which they're specified. In order to ensure efficient security, functions are used to clean the text string that is entered in the boxes to prevent the user from entering strange characters that allow data to be extracted from the database, and the password is encrypted so that it is not displayed in the database.

```
$user = clean_chain($_POST["user"]);
$password = clean_chain (md5($_POST["password"]));
```

In this section, a function is performed; inside it, different methods are applied to avoid entering strange words inside the text boxes to avoid information theft by evaluating each data inside the function so that it cleans all the strange characters.

Sounds like you're describing a function that checks and cleans user input before allowing it into a form or text field, which is a common security measure. This is a standard precaution taken by security experts to stave against threats like SQL injection and XSS.

```
function clean_chains ($chain){
  $chain=trim($chain);
  $chain =stripslashes($chain);
  $chain =str_ireplace("<script>", "", $chain);
  $chain =str_ireplace("</script>", "", $chain);
  $chain =str_ireplace("<script src", "", $chain);
  $chain =str_ireplace("<script type=", "", $chain);
  $chain =str_ireplace("SELECT * FROM", "", $chain);
  $chain =str_ireplace("DELETE FROM", "", $chain);
  $chain =str_ireplace("INSERT INTO", "", $chain);
  $chain =str_ireplace("DROP TABLE", "", $chain);
  $chain =str_ireplace("DROP DATABASE", "", $chain);
  $chain =str_ireplace("TRUNCATE TABLE", "", $chain);
  $chain =str_ireplace("SHOW TABLES;", "", $chain);
  $chain =str_ireplace("SHOW DATABASES;", "", $chain);
  $chain =str_ireplace("<?php", "", $chain);
  $chain =str_ireplace("?>", "", $chain);
  $chain =str_ireplace("--", "", $chain);
  $chain =str_ireplace("^", "", $chain);
  $chain =str_ireplace("<", "", $chain);
  $chain =str_ireplace("[", "", $chain);
  $chain =str_ireplace("]", "", $chain);
  $chain =str_ireplace("==", "", $chain);
  $chain =str_ireplace(";", "", $chain);
  $chain =str_ireplace("::", "", $chain);
  $chain =trim($chain);
  $chain =stripslashes($chain);
  return $chain;
}
```

Table 11. Customer questionnaire

No	Questions
Design	
P-1	Is the design understandable when entering data and predicting the type of Tuberculosis?
P-2	Are the colors interactive for you?
P-3	Do you agree that the answer should be displayed in a text box?
P-4	In your design, do you wish to add any additional components to the proposed design?
P-5	Does the interface meet your required expectations?
Functionality	
P-6	Do you have any problems registering your data?
P-7	For you, does it cause you any inconvenience when the system corrects errors when placing data in text fields?
P-8	Does the modal result provide you with the necessary information you need?
P-9	When logging in, does error correction cause you any discomfort?
P-10	When answering the questionnaire questions, is it interactive to give the answer?
Security	
P-11	Do you feel safe registering your data in our system?
P-12	Has your registered user and password been the victim of data theft in our system?
P-13	Do you believe that the system complies with rigorous security measures to protect your data?
P-14	Do you consider that the system's security measures should be improved?
P-15	Do you agree that the result of the prediction should be supervised by a medical expert in the field?

Table 12. Calculation of descriptive grouped mean

Total, Descriptive Mean		
N	Valid	50
	Lost	0
Half		2,7453
Median		2,7333
Fashion		2,27[a]
Desv. Deviation		,46437
Variance		,216
Asymmetry		,056
Standard error of skewness		,337
Kurtosis		-,716
Standard error of kurtosis		,662
Percentiles	25	2,3833
	50	2,7333
	75	3,0667

Table 13. Total, grouped average

Vtotalaverage (Grouped)				
	Frequency	Percentage	% valid	% Cum.
Medium	2	4,0	4,0	4,0
High	33	66,0	66,0	70,0
Very high	15	30,0	30,0	100,0
Total	50	100,0	100,0	

Table 14. Calculation of average by dimensions

Average By Dimensions				
		D1 Design	D2 Functionality	D3 Security
Nro. Valid		50	50	50
Nro. Lost		0	0	0
Half		3,20	3,06	3,20
Median		3,00	3,00	3,00
Fashion		3	3	3
Deviation		,535	,620	,670
Variance		,286	,384	,449
Asymmetry		,167	-,036	-,254
Standard error of skewness		,337	,337	,337
Kurtosis		,085	-,270	-,730
Standard error of kurtosis		,662	,662	,662
Percentiless.	25	3,00	3,00	3,00
	50	3,00	3,00	3,00
	75	4,00	3,00	4,00

Table 15. Calculation of average by dimension 1

D1 average (Grouped)				
	Frequency	Percentage	% valid	% Cum.
Medium	3	6,0	6,0	6,0
High	34	68,0	68,0	74,0
Very high	13	26,0	26,0	100,0
Total	50	100,0	100,0	

Table 16. Calculation of average by dimension 2

D2average (Grouped)				
	Frequency	Percentage	% valid	% Cum.
Medium	8	16,0	16,0	16,0
High	31	62,0	62,0	78,0
Very high	11	22,0	22,0	100,0
Total	50	100,0	100,0	

Table 17. Calculation of average by dimension 3

D3average (Grouped)				
	Frequency	Percentage	% valid	% Cum.
Medium	7	14,0	14,0	14,0
High	26	52,0	52,0	66,0
Very high	17	34,0	34,0	100,0
Total	50	100,0	100,0	

4.3. About the Survey

To determine the results of the research, a questionnaire of questions was designed for the users of the system. The questions were asked according to the functionalities and the user experience when using the system, as shown in Table 11. Also, Table 12 shows the descriptive results grouped by calculating different concepts such as mean, median, and mode, among others, that allow obtaining results according to the user survey. Table 13 shows the results of the grouped mean according to the most outstanding answers selected by the surveyed users, calculating the frequency, percentage, valid percentage, and cumulative percentage.

Table 14 shows the descriptive results by dimension, taking into account calculated concepts such as mean, median, and mode, among others presented in the table. Table 15 shows the most outstanding results according to each concept established as frequency, percentage, valid percentage, and cumulative percentage, as shown in the table above. Table 16 shows the most outstanding results according to each concept established as frequency, percentage, valid percentage, and cumulative percentage, as shown in the table above. Table 17 shows the most outstanding results according to each concept established as frequency, percentage, valid percentage, and cumulative percentage, as shown in the table above.

Table 18. Comparison of methodologies

Buchanan Methodology	Rup Methodology	Scrum Methodology
The Buchanan methodology is also performed using the cascading life cycle.	It is implemented through the interactive and incremental cycle.	It is implemented through short interactions called Sprints, which last from 1 to 4 weeks.
Collaboration between the expert and the knowledge engineer is essential.	This methodology is used in large projects with a number of teams.	Complex projects are carried out, which can change during the process.

4.4. Comparison of Methodologies

Table 18 shows the difference between the 3 methodologies. The Buchanan approach is more suitable for well-defined and coherent projects, which was the one used in the project. At the same time, RUP works best for large-scale, complex projects where requirements are subject to change. Scrum stands out for its flexibility, which makes it ideal for projects whose requirements are likely to evolve over the course of the project.

5. Discussion

The present study is based on the realization of an expert API that adds direct chaining algorithms related to the detection of Tuberculosis, which, as materials to extract the information, experts in the field were consulted to extract information and consolidate it in an expert system [15]. Most of the population of Indonesia there is a high percentage of people who contract lung diseases such as Tuberculosis has killed many Indonesian citizens; the lack of specialists in the field has allowed the disease to expand in the city of Tasikmalaya as there is a great predisposition to the disease by the large population that brings as a consequence the lack of medical centers to serve people [16]. On the other hand, another research in Indonesia resulted in the persistence of lung disease for the year 2018 as the prevalence is estimated between 4.0% and 0.4% according to respiratory diseases such as pulmonary Tuberculosis and pneumonia also related to the lack of expert specialists in these diseases [17]. According to other authors' research conducted in Vietnam, which is one of the countries most affected by tuberculosis disease, the mortality rate is increasing every year, so anexpert system was implemented to make a tool to help medical experts, especially in rural areas where the increase of the disease has a degree of danger, In order to decongest the high demand of public hospitals that receive many cases of Tuberculosis every day, the development of a medical expert system related to the idea of conceptualizing the information with rules associated to fuzzy logic to offer an accurate diagnosis and treatment related to Tuberculosis was carried out [18].

6. Conclusion

Finally, the conclusion established in the proposed research is based on Expert Systems and Epidemiological Surveillance of Tuberculosis: Innovative Tools for the Prevention and Control of Diseases, verifying certain criteria such as the application of expert systems related to web environments for the prediction of types of diseases and diagnosis of Tuberculosis. The web application aims to make a prediction of the type of Tuberculosis that exists worldwide and what consequences it brings through its symptoms established by expert researchers in the disease.

The high demand for health centers at the state level brings as a main problem the high influx of people with this disease. The long queues and waiting times have led to unfortunate consequences such as medical negligence and specific cases such as the severity of the symptoms contracted by patients. The development of this project is based on the conceptualization of several types of research that allow an understanding of how information technologies are reflected in society for the prediction of dangerous diseases such as Tuberculosis. For this purpose, the Buchanan methodology was applied for the organization of the information, which has the following stages: identification, conceptualization, formalization, implementation, and testing, each with its own specific particularities.

On the other hand, in order to validate the users' opinions about the project, a survey was conducted, showing calculated results about the established questions. Finally, it is recommended that future researchers encourage the implementation of expert systems or other areas related to Artificial Intelligence. Other technologies, such as the Internet of Things, can make improvements based on predictions of intelligent systems, having a more accurate result in the prediction of respiratory diseases.

Acknowledgements

Thank everyone involved who made the project successful.

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