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Design and implementation of an expert system for the diagnosis and treatment of water related diseases

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ABSTRACT

A nation has a moral obligation to ensure its citizens receive quality medical services as healthy citizens contribute to a thriving nation. The realm of medical science is vast and intricate, demanding a multitude of skills. Therefore, it seems that the progress of nations is linked to the management of the scarcity of medical science skills, a deficit that impacts the accuracy and effectiveness of disease diagnosis and treatment. This need is particularly significant in Cameroon, as indicated in the March-April 2019 issue of the GEOMATIC STRATEGY report. In the provided text, it is stated that there is a ratio of 1 doctor for every 10,000 people, whereas in certain health districts, the ratio is 1 doctor for every 500,000 people. That's why our focus at the GIA laboratory at ENSET of Douala, affiliated with the University of Douala, is to shorten waiting times in waiting areas or rooms, enhance the quality and precision of diagnoses, and ultimately improve the level of service offered to patients. To achieve this, we utilize an expert system, a software that relies on extensive databases of expert knowledge to offer guidance or make decisions in areas such as medical diagnosis, where it aids in identifying the underlying cause of illnesses or other health issues based on symptoms. This accurate rule-based expert system intends to identify water-related diseases, which are illnesses caused by water-transmitted pathogenic microorganisms, through diagnosis. Bathing, washing, consuming water, or eating food that has come into contact with polluted water can lead to the transmission of these illnesses. It has the capability to assist caregivers to improve the diagnosis of illnesses and deliver quality healthcare services to their patients. It can be achieved by utilizing a prolog, an expert system programming language connected with artificial intelligence and computational linguistics. The language employs predicates as a knowledge base to store intricate structured and unstructured data for the computer system. All of this information is presented to the user through a JAVA interface. In accordance with our nation's healthcare policy, this system is causing a genuine transformation in hospital and medical facilities, including the decrease in congestion in intake areas. The utilization of information technology in the medical field is experiencing a substantial surge, leading to numerous benefits in terms of effectiveness. The

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structure of our work is divided into three main sections: the method, which primarily addresses the technical and scientific approach; the results and discussion, which provide an overview of the implemented elements and the observations made; and lastly, a conclusion to summarize the completion of the work.

Keywords:

Expert system diagnosis prolog
water diseases knowledge base

1. INTRODUCTION

Throughout human history, the relationship between mankind and water, including its availability and usage, has always played a significant role. In Cameroon specifically, the issue of water scarcity significantly impacts the well-being of the people. The issue of water scarcity is persistent and when individuals reach the hospital, it is extremely difficult to obtain results or even see a doctor due to the low ratio of doctors to residents. Cameroon is currently experiencing a crisis in terms of human resources for health. Around 1.1 doctors and 7.8 nurses and midwives can be found for every 10,000 individuals in the population. So, in order to streamline the process and expedite the diagnosis, we have taken on the responsibility of establishing a specialized system for identifying water-related illnesses. However, in order to accomplish this goal, we were required to examine the current medical expert systems first. After that, we identified the problem faced within our hospital setting and established our own set of objectives to achieve. Finally, we assessed the extent of our study and its limitations.

An expert system in artificial intelligence refers to a computer system that replicates the decision-making capability of a human expert. Expert systems are created to address intricate issues by utilizing a collection of knowledge in the form of if-then rules rather than traditional procedural code [1]. These systems possess the capability to mimic human thinking, making informed judgments and reasoning based on relevant facts and rules [2]. In today's world, expert systems are extensively utilized in various fields to support users in decision-making processes. These systems are particularly useful in areas that demand the expertise of humans, such as medical diagnosis, expert decision making, policy making, strategy estimation, and analysis [2]. The main focus of medical artificial intelligence revolves around developing AI programs that can effectively diagnose illnesses and provide recommendations for therapy. Medical Expert Systems (MES's) can commonly be found in clinical laboratories and educational environments, serving purposes such as clinical

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surveillance or within data-abundant contexts such as the intensive care unit. It is now being understood that intelligent programs can provide significant advantages if they are implemented with proper regulations [3]. The utilization of MES's has been widely adopted since the early 1970s, when MYCIN was developed to identify the specific bacteria responsible for severe infections. The medical expert system PUFF was created to diagnose lung disease, while ANGY helps physicians identify and isolate coronary vessels in angiograms to diagnose vessel narrowing. BABY is designed to assist clinicians in monitoring patients in a Newborn Intensive Care Unit (NICU). [4][5].

Expert systems can be divided into two categories: rule-based expert systems, which rely on predetermined guidelines, and probabilistic expert systems or normative systems, which use probabilistic graphical models. Rule-based expert systems (RBES's) aim to capture human expertise using rules that take the form of if a certain condition is met, then a specific action should be taken. These systems have their roots in the MYCIN system developed by Buchanan and Shortliffe. There is conclusive evidence that demonstrates the capability of this rule to simulate the human thought process [7]. A collection of guidelines can be employed to encapsulate the pertinent domain expertise of a human expert, which can subsequently be utilized to replicate the expert's approach to problem solving in that particular domain. Probabilistic expert systems emerged as a result of the merging of statistics and AI research. RBES comprend à la fois des techniques conventionnelles, telles que les systèmes de gestion de bases de données (SGBD), et des techniques d'intelligence artificielle (IA) telles que les systèmes basés sur la connaissance (KBS) [8]. In MES, patient data is stored, retrieved, and manipulated using DBMSs, while ESs are primarily employed for diagnosing patients based on their data. ESs are capable of representing experts' reasoning and delivering solutions to the current problem [9].

2. METHOD

2.1. Proposed system

The context diagram below presents the system suggested for handling the diagnosis, illustrating the overall interactions among various components. Indeed, while observing the patient-doctor interaction, we have identified certain essential exchanges of information between the various individuals involved.

2.2. Hardware details

The project revolves around a computer system that operates globally, capable of running various software to create the necessary environment for our expert system. In this context, the term "hardware" refers to a computer system that incorporates either a 32-bit x86 processor architecture or a 64-bit x64 processor architecture.

2.2.1. X86Processor Architecture

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x86 refers to a group of instruction set architectures that were originally created by Intel and are based on the Intel 8086 microprocessor and its 8088 variants. The 8086 microprocessor was launched in 1978 as an expanded version of Intel's 8080 microprocessor. It was designed to address a larger amount of memory by utilizing memory segmentation, in addition to its original 16-bit address capability.

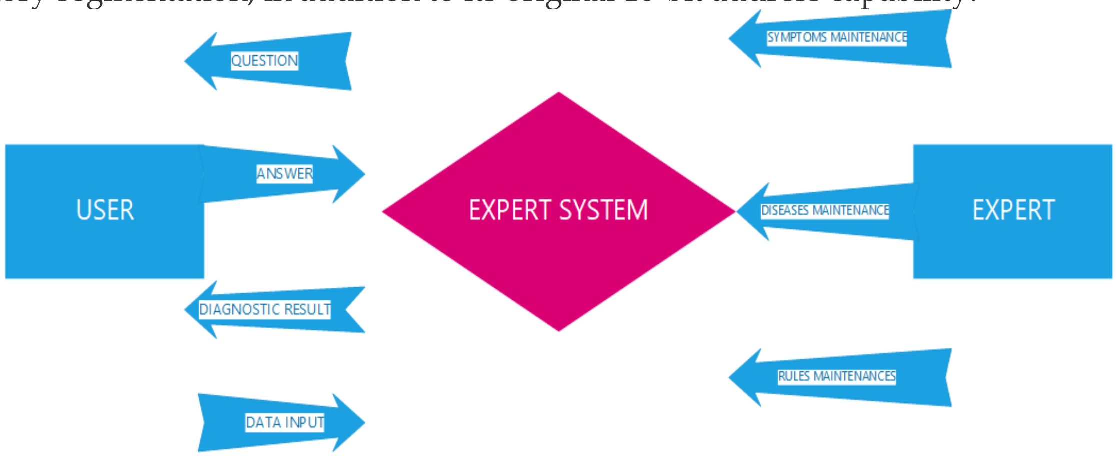

Figure 1: Context diagram of the system

The term "x86" originated from the fact that the names of various follow-up processors to Intel's 8086, such as the 80186, 80286, 80386, and 80486, all conclude with "86".

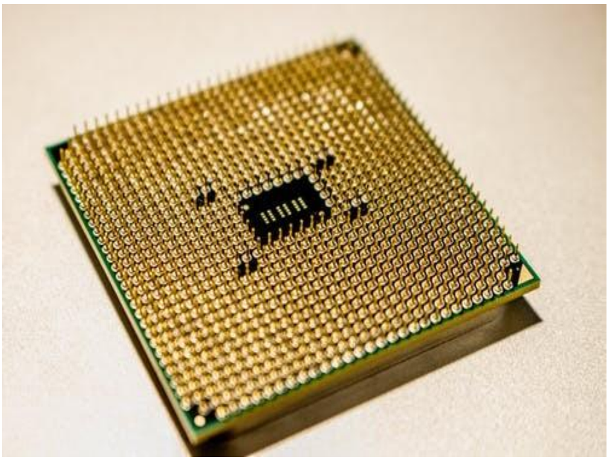

Figure 2: Intel Pentium 4631

2.2.2. X64ProcessorArchitecture

x86-64, also referred to as x64, x86-64, AMD64, and Intel64, represents the 64-

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bit iteration of the x86 instruction collection. It presents two fresh operating modes, namely 64-bit mode and compatibility mode, in addition to a novel 4-level paging mode. En utilisant le mode 64 bits et le nouveau mode de pagination, il permet de prendre en charge des quantités beaucoup plus importantes de mémoire virtuelle et physique que ce qui est possible sur ses prédécesseurs en 32 bits, permettant ainsi aux programmes de stocker des quantités plus importantes de données en mémoire. The x86-64 architecture not only increases the size of general-purpose registers to 64 bits, but also increases their number from 8 (some of which had limited or fixed functionality, such as for stack management) to 16 (fully general), and incorporates various other improvements [27].

2.2.3. Power details

♣ CPU Power

The expert system created in this project necessitates at least a Core i3 CPU or its equivalent, such as the AMD FX 63xxseries, to ensure smooth performance. The Core i3, developed and produced by Intel, is a computer processor with two cores and can be utilized in both desktop and laptop computers. It belongs to a group of three processors within the "i" series (known as the Intel Core family of processors).

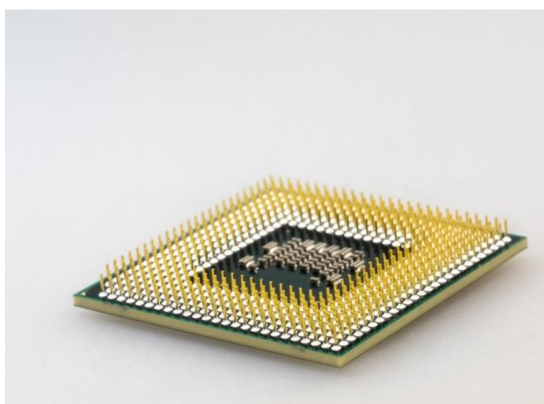

Figure 3: Intel Corei5750, Ivy Bridge

The various speeds offered for the Core i3 processor range from 1.30 GHz to 3.50 GHz, and it has a cache size of either 3 MB or 4 MB. Il utilise soit le socket LGA 1150, soit le socket LGA 1155 sur une carte mère. Dans la plupart des cas, les processeurs Core i3 sont dotés de deux cœurs, ce qui les rend des processeurs à double cœur. Nevertheless, only a select few top-tier Corei3 processors are quad-

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core, consisting of four cores.

The power consumption of Corei3 processors differs.

- Speeds ranging from 1.30 GHz to 1.80 GHz consume power levels of 11.5W, 15W, or 25W.
- Medium speeds, ranging from 2.00 GHz to 2.50 GHz, consume power between 28W, 35W, or 37W.
- Higher speeds (ranging from 2.90 GHz to 3.50 GHz) consume power of 35W, 37W or 54W.

The system's recommended processor for optimal performance is the Core i3, specifically one with a medium to fast speed. This choice is made to ensure that the system operates as smoothly and efficiently as possible, simulating the fluidity of human thinking.

♣ RAM Details

DDR3SD RAM, also known as Double Data Rate 3 Synchronous Dynamic Random-Access Memory, is a form of SD RAM used extensively since 2007. It features a high bandwidth interface that enables data transfer at twice the rate, hence the name "double data rate."

The DDR31333 or DDR31600 is the most frequently utilized RAM type compatible with a Core i3 processor. The terms 1333 and 1600 designate the theoretical transfer rates. Nevertheless, in reality, only a small number of applications are constrained by memory utilization, and the variations in performance between them are negligible, often falling within the range of statistical error and lacking significant significance.
The system should have a minimum of 4Gb.

2.3. Software details

In our project, we utilize the following software while working in a Windows 8.1 environment with an x86 microprocessor architecture and a Windows 10 environment with an x64 microprocessor architecture.

2.3.1. SWI-Prolog

SWI-Prolog (SWI-Prolog 8.0.3-1 for Microsoft Windows) is a freely available version of Prolog, a programming language commonly used for educational purposes and

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applications in the semantic web. It boasts a comprehensive range of functionalities and resources, including constraint logic programming libraries, multi reading capabilities, unit testing, GUI implementation, integration with Java, ODB, and similar platforms, literate programming support, a web server, SGML, RDF, RDFS, developer tools (including a GUI debugger and profiler available through an IDE), and extensive documentation. This software allows us to incorporate the foundation of the system by utilizing the principle of the rule-based methodology.

2.3.2. Java Development Kit (JDK)

The Java Development Kit (JDK) version 8, released by Oracle Corporation, is a binary product designed for Java developers working on Solaris, Linux, macOS, or Windows operating systems. It serves as an implementation for any of the Java Platform, Standard Edition, Java Platform, Enterprise Edition, or Java Platform, Micro Edition platforms. The JDK consists of a private JVM and several additional tools to complete the development of a Java application.

2.3.3. Java Virtual Machine (JVM)

A Java virtual machine (JVM) version 7 is a software that allows a computer to execute Java programs and other programs written in different languages that have been compiled into Java byte code. The JVM is described by a specification that outlines the necessary elements for implementing a JVM. By having a specification in place, it guarantees that Java programs can work seamlessly with various implementations, eliminating concerns for developers using the Java Development Kit (JDK) regarding differences in hardware platforms.

By incorporating the JDK and the JVM, it becomes possible to create a graphical user interface for the system, enabling the integration of Java code into the Prolog source code.

2.4. PROGRAMMING LANGUAGE DETAILS

2.4.1. Prolog

Prolog is an artificial intelligence and computational linguistics associated programming language, which utilizes logic programming. Prolog originates from first-order logic, a formal logic. Unlike numerous other programming languages, Prolog is primarily designed as a declarative programming language. The program's logic is conveyed through relations, which are presented as facts and rules. The process begins by executing a query on these relations.

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2.4.2. Java

Java is an object-oriented programming language that is based on classes and designed to minimize implementation dependencies. The aim is to enable application developers to write code once and run it on any platform without having to recompile, which is known as "write once, run anywhere" (WORA). This means that compiled Java code can be executed on any Java-supported platform. Java programs are typically translated into byte code which is capable of being executed on any Java virtual machine (JVM) irrespective of the underlying computer structure.

2.5. Analysis

The analysis of our system was made as follow:

2.5.1. Functional Analysis

- The system must reason at the same level as a human expert.
- The responses time should be tolerable, especially for real time systems.
- Since purpose the expert systems is to get the behaviour that is same to human, therefore, expert system should be able to give a clear reasoning just like a human expert would do.
- Human experts also add to their knowledge with the passage of time. Expert systems should also have this functionality.

2.5.2. Non-Functional Analysis

Portability defines how a system or its element can be launched on one environment or another.

Performance defines how fast a software system or its particular piece responds to certain users' actions under certain workload.

Reliability. This quality attribute specifies how likely the system or its element would run without a failure for a given period of time under predefined conditions.

Maintainability defines the time required for a solution or its component to be fixed, changed to increase performance or other qualities, or adapted to a changing environment.

2.5.3. System Analysis

The analysis of the system is based on two important aspects which a represented by the following figures:

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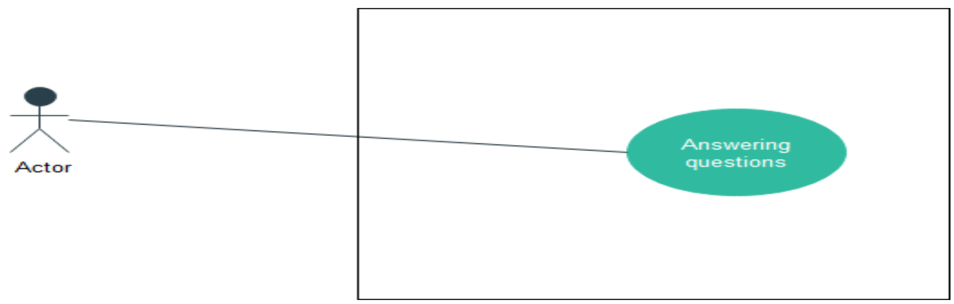

Figure 4: Use Case Diagram of the Expert System

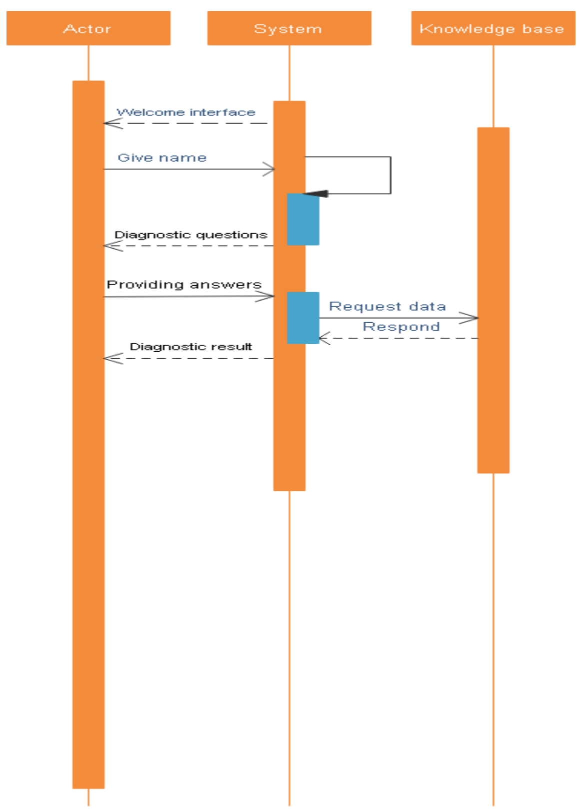

Figure 5: Sequence Diagram

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2.6. DESIGN OF THE MODEL ARCHITECTURE

An expert system in artificial intelligence is a computer system that replicates the decision-making capacity of a human expert. Expert systems are specifically created to address intricate problems by utilizing knowledge databases, primarily composed of if-then rules, instead of traditional procedural code.

The expert system comprises three key elements illustrated in the diagram: knowledge base, inference engine, and user interface. The initial element, referred to as the knowledge-based component, encompasses all the information that the expert system operates within, such as knowledge, facts, and rules. The action is carried out by the inference engine when the conditions stipulated in the rules are met by the information supplied by the users. Finally, the user interface allows for engagement with individuals who are not experts in the field. It is crucial to establish how these different factors should influence the process of making decisions when creating a decision-making system. This can be accomplished by conducting a survey of experts in the industry to create a knowledge base that aligns with their current perspectives.

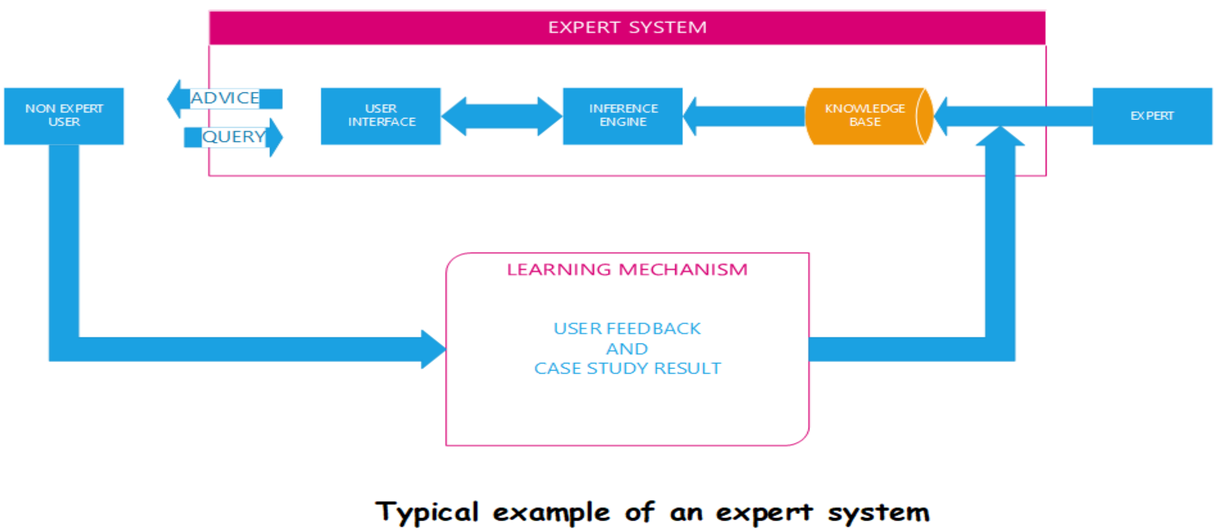

Figure6: Typical architecture of LYDIA expert system

3. RESULTS AND DISCUSSION

As a result of our investigation, we have developed an expert system powered by artificial intelligence that generates disease suggestions based on the symptoms provided in the input data. Initially, we examined both the clinical and physiological symptoms, followed by our attempt to promptly establish a

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standardization for these symptoms. This was done in order to correlate each symptom with a specific illness based on its prevalence, as well as its occurrence alongside other symptoms.

3.1. Knowledge Based

The Knowledge Base is nothing more than a compilation of information. Facts are employed to express statements that are unequivocally accurate regarding a particular situation of importance.

Rules are commonly presented in the form of If/Then statements, which follow a structured format

IF<**antecedent**>THEN<**consequent**>

The antecedent refers to the condition that needs to be met. When the condition is met, the rule is activated and is referred to as "firing". The outcome is the behavior that is executed when the rule triggers.

Once the program fulfills the rules, they are included in a queue known as the *agenda*. The list of rules in the *agenda* is not organized and includes all the rules that currently have satisfied antecedents. In expert systems, the role of order is usually insignificant, which is why knowledge bases are commonly unordered. The order in which rules are placed on the *agenda* is flexible, and they can also be removed in any order once they are on the *agenda*.

```
symptom(Patient,a_fever_that_increases_gradually) :- verify(Patient," have fever that increases gradually (y/n) ?").
symptom(Patient,headache) :- verify(Patient," have headache (y/n) ?").
symptom(Patient,fatigue) :- verify(Patient," felling fatigue (y/n) ?").
symptom(Patient,muscle_aches) :- verify(Patient," have muscle aches (y/n) ?").
symptom(Patient,sweating) :- verify(Patient," sweating(y/n) ?").

symptom(Patient,nausea) :- verify(Patient," have nausea(y/n) ?").
symptom(Patient,vomiting) :- verify(Patient," have vomiting(y/n) ?").
symptom(Patient,diarrhea) :- verify(Patient," have diarrhea(y/n) ?").
symptom(Patient,muscle_cramps) :- verify(Patient," have muscle cramps (y/n) ?").
```

Figure 7: Prolog symptoms code

```
hypothesis(Patient,typhoid_Fever) :-
        symptom(Patient,a_fever_that_increases_gradually),
        symptom(Patient,headache),
        symptom(Patient,muscle_aches),
        symptom(Patient,fatigue),
        symptom(Patient,sweating).

hypothesis(Patient,cholera) :-
        symptom(Patient,nausea),
        symptom(Patient,vomiting),
        symptom(Patient,diarrhea),
        symptom(Patient,loss_of_appetite),
        symptom(Patient,muscle_cramps).

hypothesis(Patient,giardia) :-
        symptom(Patient,abdominal_pain),
        symptom(Patient,cramps_and_bloating),
        symptom(Patient,diarrhea),
        symptom(Patient,nausea),
        symptom(Patient,weight_loss).
```

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Figure 8: Prolog hypothesis code

The information and assumptions in this collection of symptoms form the system's knowledge base. During the diagnostic process and solution proposal, the inference engine will analyze and make deductions based on the data provided by the patient through nursing and medical staff.

3.2. Inference Engine

In the realm of artificial intelligence, an inference engine is a system component that utilizes logical rules on the knowledge base in order to derive fresh insights. The initial inference engines were included in expert systems. The standard expert system comprised of a knowledge base and an inference engine. The knowledge bases contain information regarding the world's facts. The logical rules are utilized by the inference engine to apply to the knowledge base, resulting in the deduction of new knowledge. This procedure would repeat itself because whenever a new piece of information is added to the database, it has the potential to activate further rules in the deduction engine. Inference engines primarily operate in two modes: forward chaining or backward chaining, which rely on either special rules or facts. La méthode de propagation en avant commence par les faits connus et établit de nouveaux faits. The process of backward chaining commences with the identification of goals and then proceeds in reverse to ascertain the facts that need to be stated in order to attain those goals.

Prolog [22] [28] includes an internal inference engine based on backward chaining, which can be utilized to partially execute certain components of expert systems. Prolog rules are employed for the purpose of knowledge representation, and the Prolog inference engine is utilized to draw conclusions. Additional parts of the system, like the user interface, need to be implemented using Prolog as the programming language. The Prolog inference engine performs straightforward backward chaining. Every rule consists of an objective and several smaller goals. L'instrument d'inférence Prolog vérifie soit la validité, soit l'invalidité de chaque objectif. The results are free from any doubt.

This rule format and reasoning approach is sufficient for numerous expert system uses. The only aspect that requires enhancement for the creation of a basic expert system is the conversation with the user.

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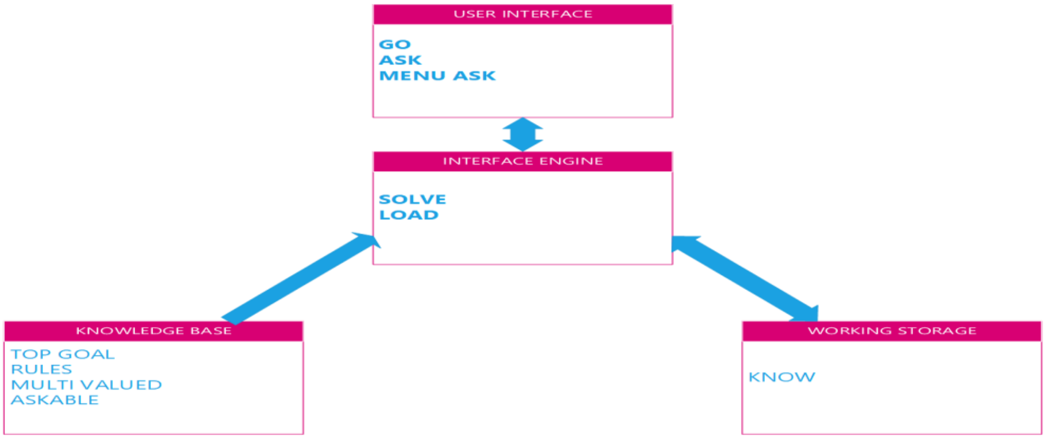

Figure 9: Scheme of work of inference engine

3.3. User Interface

As expert systems are introduced in intricate real-world applications, the significance of user interface is heightened. Graphical depictions of the domain model can frequently serve as a foundation for the interface, especially in domains where there are significant spatial connections that can be illustrated through visuals like drawings, blueprints, or maps.

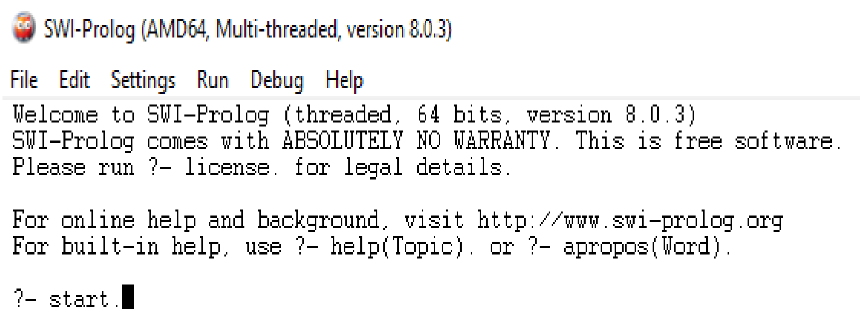

Figure 10: Launching interface of the expert system

An interface for users is the means through which the expert system engages with a user. These can be accomplished using dialog boxes, command prompts, forms, or any other means of input. Certains systèmes experts interagissent avec d'autres applications informatiques sans interagir directement avec un être humain. In such situations, the expert system will possess a mechanism of interaction for conducting transactions with the other application, without the presence of a user interface.

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```
interface(X,Y,Z) :-
        atom_concat(Y,X, FAtom),
        atom_concat(FAtom,Z,FinalAtom),
        jpl_new('javax.swing.JFrame', ['Expert System'], F),
        jpl_new('javax.swing.JLabel',['--- LYDIA MEDICAL EXPERT SYSTEM ---'],LBL),
        jpl_new('javax.swing.JPanel',[],Pan),
        jpl_call(Pan,add,[LBL],_),
        jpl_call(F,add,[Pan],_),
        jpl_call(F, setLocation, [400,300], _),
        jpl_call(F, setSize, [400,300], _),
        jpl_call(F, setVisible, [@(true)], _),
        jpl_call(F, toFront, [], _),
        jpl_call('javax.swing.JOptionPane', showInputDialog, [F,FinalAtom], N),
        jpl_call(F, dispose, [], _),
        write(N),nl,
        ( (N == yes ; N == y)
      ->
       assert(yes(Z)) ;
       assert(no(Z)), fail).
```

Figure 11: Java interface code for the expert system

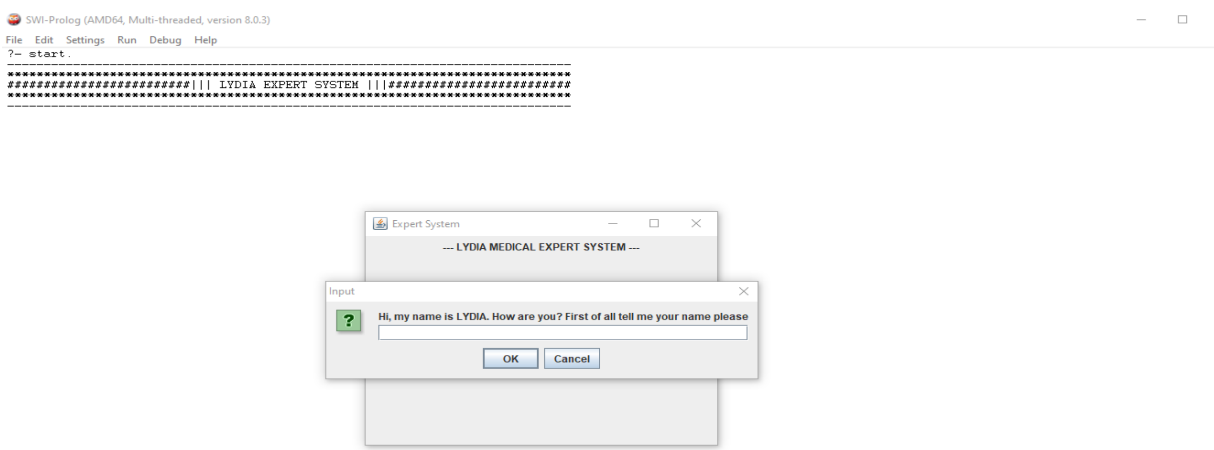

Figure 12: Interface of the expert system

3.4. Working Memory

Working memory holds the information that is obtained from the user throughout the expert system session. Les valeurs stockées en mémoire de travail sont employées pour évaluer les antécédents dans la base de connaissances. The outcomes resulting from regulations in the knowledge base can lead to the formation of fresh information in working memory, modify previously stored information, or eliminate current data. The information regarding the given case is stored in the working memory, which

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functions as a surface where the knowledge about the specific situation is gathered. The working memory is continuously modified by the inference engine as it applies the rules, incorporating fresh data derived from the conclusions of the rules, until a goal state is achieved or verified.

In SWI PROLOG, the (memfile) library offers a substitute for temporary files that is designed for temporary storage of data. Memory files, in comparison to temporary files, exhibit superior speed and are not subject to security vulnerabilities or naming conflicts commonly experienced in temporary-file handling.

There are no restrictions on the quantity or dimensions of memory streams. Nevertheless, it is not feasible for a memory file to contain numerous streams concurrently, and opening a memory file multiple times, even for mere reading purposes, is simply not possible. Memory files can be used by multiple threads simultaneously, and they can be cleared away by efficient garbage collection processes.

3.5. Domain of Application

Lydia's treatment plan at UNIVERSITE DES MONTAGNES and BUKWEME HOSPITAL was evaluated by four independent specialists in 225 cases, resulting in an acceptability rating of 93%.

The system has the capability to suggest a medication for treatment, but its effectiveness is constrained by the frequent changes in medical regulations. As a result, the system is restricted to providing diagnoses, interpretations, and the names of illnesses. This is also attributed to the fact that a particular drug can be regularly utilized in one country, whereas it is entirely prohibited in another country.

3.6. Use of the System

LYDIA was never applied in practical circumstances. This was not due to any lack of efficacy in its performance. A few individuals observing the situation and directors of hospitals have expressed concerns regarding the ethical and legal aspects associated with the integration of computers into the field of medicine. Nevertheless, the primary issue, which caused LYDIA to not be utilized in everyday practice, pertained to the inadequate state of technology for system integration, particularly during its development period in our nation. LYDIA, an independent system, necessitated users to manually input patient data through typing responses to questions. Unfortunately, the inadequate computerization within our medical system, as well as the limited computer proficiency among nurses and doctors, posed a significant challenge in implementing this expert system in practice.

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3.7. Users Experience and Feedback

The essence of user experience design entails presenting users with the desired information in the most streamlined and user-friendly manner possible. Nevertheless, in order to accomplish this efficiently, the designer should comprehend the possible user journey within the system, which can become challenging without the appropriate resources.

The key indicator of user experience is the feedback from users. Being able to utilize a team of doctors and nurses during the interface examination provides a competitive edge. In reality, user feedback will also help determine the importance of certain issues that arise at the interface.

4. CONCLUSION

In this particular project, we offered a diagnostic assistance tool aimed at ensuring efficient decision-making and facilitating the smooth flow of medical consultations. The aim of our final project is to develop an expert system called LYDIA. This project was divided into two phases: a theoretical component and a simulation.

The central focus of this project revolves around our particular case study, which involves the integration of an expert system. Our initial aim was to present the necessary material in its simplest form, ensuring that it can be effectively utilized within a reasonable timeframe. Next, our attention was directed towards the software, programming languages, and applications needed to execute the mentioned system. We have concluded from this study that the expert system effectively served as a valuable tool for medical decision-making. This new technology has greatly improved our approach in the field of healthcare facilities, compared to our previous experiences. The focus of the study centers around the consequences of employing Artificial Intelligence in Clinical Research. It explores the potential risks associated with AI and gathers perspectives from researchers on the possibility of machines replacing humans and the ethical implications that arise from this. Initially, in relation to the job decrease in Clinical Research, I believe that Artificial Intelligence could serve as a potent tool, assisting and expediting tasks that typically require extensive time, possibly lasting hours or even days. However, with its aid, these tasks could be completed in mere seconds.

In the realm of clinical research and healthcare, the idea of replacing humans with machines appears beyond my imagination. While a machine may alleviate the burdens of healthcare professionals, it still remains devoid of emotions and empathy. She is present to carry out tasks assigned by Man, but it will require her to upkeep, ensure its proficiency, modify if needed, and adjust.

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