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Expert system for disease diagnosis

A report submitted to the department computer science of the requirements for Obtaining a bachelor's degree in computer science and information technology / computer department

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

((قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ))

صدق الله العظيم

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Contents

ABSTRACT

Diseases should be treated well and on time. If they are not treated on time, they can lead to many health problems and these problems may become the cause of death. These problems are becoming worse due to the scarcity of specialists, practitioners and health facilities. In an effort to address such problems, studies made attempts to design and develop expert systems which can provide advice for physicians and patients to facilitate the diagnosis and recommend treatment of patients. This review presents a comprehensive study of medical expert systems for diagnosis of various diseases. It provides a brief overview of medical diagnostic expert systems

Chapter One: Introduction to Artificial Intelligence and Expert Systems

1-1 Introduction

Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans. Some of the activities computers with artificial intelligence are designed for include:[1]

- Speech recognition
- Learning
- Planning
- Problem solving

Knowledge engineering is a core part of AI research. Machines can often act and react like humans only if they have abundant information relating to the world. Artificial intelligence must have access to objects, categories, properties and relations between all of them to implement knowledge engineering. Initiating common sense, reasoning and problem-solving power in machines is a difficult and tedious task.

Machine learning is also a core part of AI. Learning without any kind of supervision requires an ability to identify patterns in streams of inputs, whereas learning with adequate supervision involves classification and numerical regressions. Classification determines the category an object belongs to and regression deals with obtaining a set of numerical input or output examples, thereby discovering functions enabling the generation of suitable outputs from respective inputs. Mathematical analysis of machine learning algorithms and their performance is a well-defined branch of theoretical computer science often referred to as computational learning theory [2].

machine perception deals with the capability to use sensory inputs to deduce the different aspects of the world, while computer vision is the power to analyze visual inputs with a few sub-problems such as facial, object and gesture recognition.

Expert Systems are computer programs that are derived from a branch of computer science research called Artificial Intelligence (AI). AI's scientific goal is to understand intelligence by building computer programs that exhibit intelligent behavior. It is concerned with the concepts and methods of symbolic inference, or reasoning, by a computer, and how the knowledge used to make those inferences will be represented inside the machine [3].

Of course, the term intelligence covers many cognitive skills, including the ability to solve problems, learn, and understand language; AI addresses all of those. But most progress to date in AI has been made in the area of problem solving -- concepts and methods for building programs that reason about problems rather than calculate a solution.

AI programs that achieve expert-level competence in solving problems in task areas by bringing to bear a body of knowledge about specific tasks are called knowledge-based or expert systems. Often, the term expert systems is reserved for programs whose knowledge base contains the knowledge used by human experts, in contrast to knowledge gathered from textbooks or non-experts. More often than not, the two terms, expert systems (ES) and knowledge-based systems (KBS), are used synonymously. Taken together, they represent the most widespread type of AI application. The area of human intellectual endeavor to be captured in an expert system is called the task domain. Task refers to some goal-oriented, problem-solving activity. Domain refers to the area within which the task is being performed. Typical tasks are diagnosis, planning, scheduling, configuration and design. An example of a task domain is aircraft crew scheduling [4].

Building an expert system is known as knowledge engineering and its practitioners are called knowledge engineers. The knowledge engineer must make sure that the computer has all the knowledge needed to solve a problem. The knowledge engineer must choose one or more forms in which to represent the required knowledge as symbol patterns in the memory of the computer -- that is, he (or she) must choose a knowledge representation. He must also ensure that the computer can use the knowledge efficiently by selecting from a handful of reasoning methods [2].

Chapter two: expert system and components

2-1 expert system

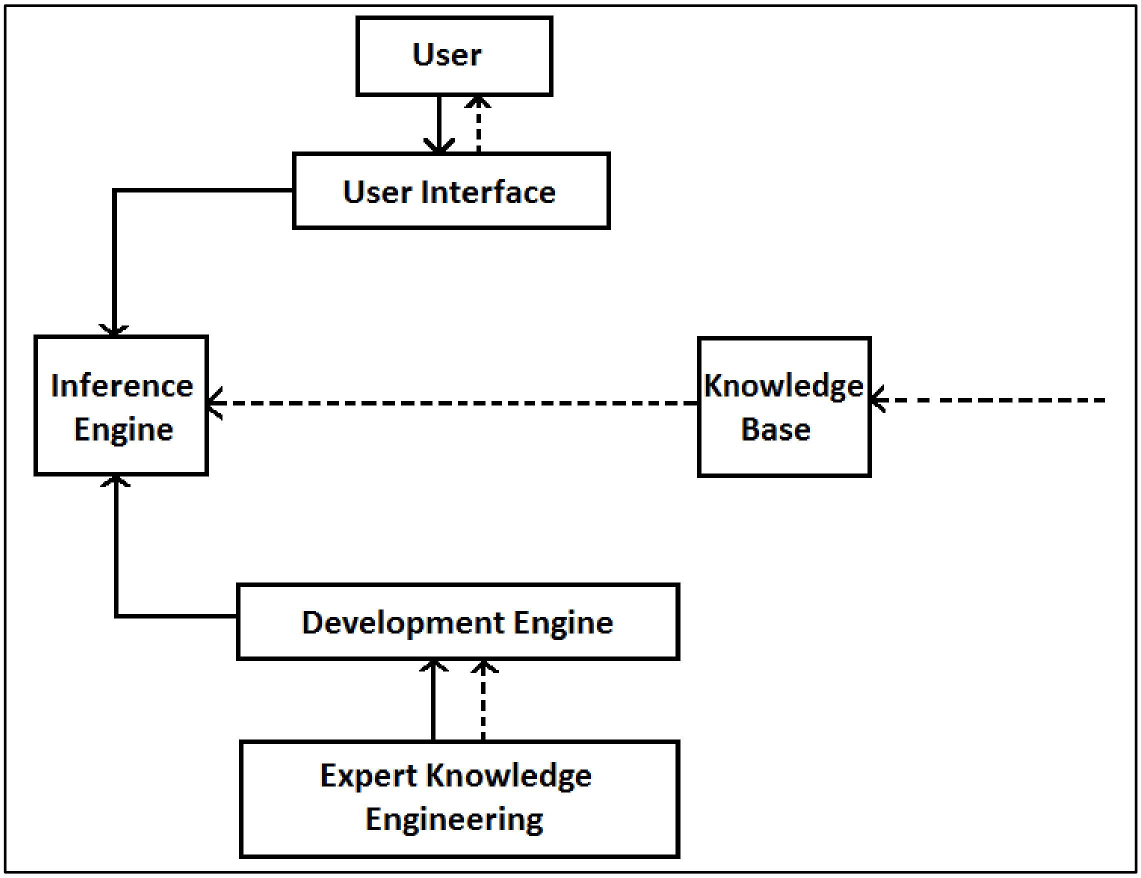
An expert system is a computer program or we can say an application that can solve complex of the complex problem in a particular domain**.** It is designed using the concept of **Artificial Intelligence** and was first introduced in the Department of Computer Science, Stanford University. The expert system can perform at the extraordinary level of human intelligence or human experts.

Basically, the expert system represents the knowledge of the human expert in the form of heuristic. It can be also considered as an instance of a decision support system. The knowledge base and decision rule are the most unique and distinguishing features of an expert system [3].

The concept of the expert system is normally based on assumption that an expert's knowledge can be stored in computer memory and then applied by other when needed. An expert system shares knowledge of a human expert in a specific area of study such as production engineering, genetic engineering and so on. It is found that the problem-solving capabilities of an expert system are as good as that of human experts or sometimes even better than the human experts now [1].

2-2 **components of an expert system**

. The components of the expert system consist of four major parts. They are – **User Interface, Inference Engine, Development Engine & Knowledge Base** [6].



Figure(2-1): Components of an expert system

2-2-1 User Interface :

It enables the users to enter instruction and information into the expert system and to receive information from it. The information is in the form of values assigned to certain variables. The user interface has two parts: **[7]**

1. **Expert System Input:** A user can use method for input command, natural language and customize the interface.
2. **Expert System Output:** Expert systems are designed to provide output or solution for a specific domain.

2-2-2 Knowledge Base :

It contains the fact that describes the problem area and knowledge representation technique that describes manner. That means the knowledge base contains a really high-quality and extraordinary knowledge in that particular domain. The term problem domain is used to describe the problem. Or basically, we can say that the knowledge base is the set of rules. The rules in the knowledge base are usually coded in the form- if x, then y where x is a condition, y is an action to be taken if the condition is true.

These kinds of rules are got from experience of human experts. The knowledge of human experts is translated into the “if-then” statements. It is a kind of job i.e. taking the knowledge from the experts and converting them into such statements. A person who does this job is known as Knowledge Engineer.

An exceptionally remarkable knowledge is required to model the intelligence system. Since the whole success of an expert system depends upon the knowledge that is so accurate and also the bug-free, that is why it is considered as one of the important components of an expert system. **[8]**

2-2-3 Inference Engine:

The inference engine is one of the most important components of an expert system. The inference engine of the expert system is the rule that defines how the expert process interprets the knowledge in an appropriate manner. The inference engine work in either forward chaining or backward chaining.

In simple, the inference engine takes the knowledge base and then it applies processing to it. The inference engine processes a massive amount of data in some kind of consistent way and it comes out with a conclusion. It works as a brain in an expert system.

Backward chaining process faster than the forward chaining because it doesn't make multiple passes through the rule set. Backward chaining is especially appropriate when-

1. There are multiple goal variables.
2. There are many rules.
3. All or most of the rules don't have examined in the process of reaching the solution.

Forward chaining is performed when the goal is to draw some conclusion from a given set of fact. **[9]**

2-2-4 Development Engine:

Development engine is used to create the expert system. This process usually involved building the rule set. There are two basic approaches-

1. Programming Language
2. Expert system shell

Programming Language: An expert system can be created using any programming language. However, two especially suited to the symbolical representation of knowledge is LISP and Prolog.

Expert System Shell: Expert system shell is a readymade processor that can be tailored to specific problem domain through the addition of the appropriate knowledge base. In most cases, the shell can be produced an expert system quicker and easier than by programming language. The first commercial shell was for knowledge engineering environment (K.E.E.). It was designed for the use of a computer design, especially for LISP language for a LISP machine. **[5]**

Chapter three: diseases diagnosis

3-1 introduction

For decades, the delivery of health care has proceeded with a blind spot: Diagnostic errors—inaccurate or delayed diagnoses—persist throughout all care settings and harm an unacceptable number of patients. Getting the right diagnosis is a key aspect of health care, as it provides an explanation of a patient's health problem and informs subsequent health care decisions (Holmboe and Durning, 2014). Diagnostic errors can lead to negative health outcomes, psychological distress, and financial costs. If a diagnostic error occurs, inappropriate or unnecessary treatment may be given to a patient, or appropriate—and potentially lifesaving—treatment may be withheld or delayed. However, efforts to identify and mitigate diagnostic errors have so far been quite limited. Absent a spotlight to illuminate this critical challenge, diagnostic errors have been largely unappreciated within the quality and patient safety movements. The result of this inattention is significant: It is likely that most people will experience at least one diagnostic error in their lifetime, sometimes with devastating consequences. [3]

3-2 common cold

The term "common cold" refers to a mild upper respiratory viral illness. It is self-limited therefore it will go away without treatment. It is the most frequent acute illness in the United States. It is separate and a distinctly different illness than influenza, throat infection, bronchitis, sinusitis, pertussis, and allergic rhinitis. The average person has two or three colds a year. Colds are caused by many viruses, which cause similar symptoms. The same virus can cause another cold after re-exposure. However, the second illness is usually milder and lasts for a shorter period of time. Seasonal patterns may be seen for some of the viruses. [10]

3-2-1 Symptoms

Symptoms of the common cold are mostly due to the response of the individual to the infection, rather than to direct damage to the respiratory tract from the virus. Symptoms vary from person to person and include: [11]

• Rhinitis (runny nose) and congestion are the most common symptoms.

• Sore throat, sneezing, cough, malaise (feeling ill) • Fever is uncommon in adults but may be present in children

• Purulent (colored, thick drainage containing pus) drainage may be seen with the common cold. The presence of purulence does not distinguish between a cold or sinus infection. Incubation period/symptom duration

• From the time of contact until onset of symptoms is generally 24 to 72 hours but can be as early as 10 to 12 hours after exposure.

• Symptoms usually last 3 to 10 days, but can last up to two weeks in some people.

3-2-2 Treatments

Try treating your cold at home first. Call your provider right away, or go to the emergency room, if you have: [10]

- Difficulty breathing
- Sudden chest pain or abdominal pain
- Sudden dizziness
- Acting strangely
- Severe vomiting that does not go away

Also call your provider if:

- You start acting strangely
- Your symptoms get worse or do not improve after 7 to 10 days

3-3 Mumps

Mumps is a viral infection that primarily affects saliva-producing (salivary) glands that are located near your ears. Mumps can cause swelling in one or both of these glands.

Mumps was common in the United States until mumps vaccination became routine. Since then, the number of cases has dropped dramatically.

However, mumps outbreaks still occur in the United States, and the number of cases has crept up in recent years. These outbreaks generally affect people who aren't vaccinated, and occur in close-contact settings such as schools or college campuses.

Complications of mumps, such as hearing loss, are potentially serious but rare. There's no specific treatment for mumps.[12]

3-3-1 Symptoms

Some people infected with the mumps virus have either no signs or symptoms or very mild ones. When signs and symptoms do develop, they usually appear about two to three weeks after exposure to the virus.

The primary sign of mumps is swollen salivary glands that cause the cheeks to puff out. Other signs and symptoms may include: [13]

- Pain in the swollen salivary glands on one or both sides of your face
- Pain while chewing or swallowing

- Fever
- Headache
- Muscle aches
- Weakness and fatigue
- Loss of appetite

3-3-2 Treatment

Mumps is caused by a virus, so antibiotics aren't effective. But most children and adults recover from an uncomplicated case of mumps within a few weeks.

People with mumps are generally no longer contagious and can safely return to work or school about five days after the appearance of signs and symptoms. [13]

3-4 Chickenpox

Chickenpox is an infection caused by the varicella-zoster virus. It causes an itchy rash with small, fluid-filled blisters. Chickenpox is highly contagious to people who haven't had the disease or been vaccinated against it. Today, a vaccine is available that protects children against chickenpox. Routine vaccination is recommended by the Centers for Disease Control and Prevention (CDC).

The chickenpox vaccine is a safe, effective way to prevent chickenpox and its possible complications. [14]

3-4-1 Symptoms

The itchy blister rash caused by chickenpox infection appears 10 to 21 days after exposure to the virus and usually lasts about five to 10 days. Other signs and symptoms, which may appear one to two days before the rash, include: [15]

- Fever
- Loss of appetite
- Headache
- Tiredness and a general feeling of being unwell (malaise)

Once the chickenpox rash appears, it goes through three phases:

- Raised pink or red bumps (papules), which break out over several days
- Small fluid-filled blisters (vesicles), which form in about one day and then break and leak
- Crusts and scabs, which cover the broken blisters and take several more days to heal

3-4-2 Treatment

In otherwise healthy children, chickenpox typically needs no medical treatment. Your doctor may prescribe an antihistamine to relieve itching. But for the most part, the disease is allowed to run its course. [14]

3-5 Measles

Measles is a highly infectious viral illness that can be very unpleasant and sometimes lead to serious complications. It's now uncommon in the UK because of the effectiveness of vaccination.

Anyone can get measles if they haven't been vaccinated or haven't had it before, although it's most common in young children.

The infection usually clears in around 7 to 10 days. [16]

3-5-1 symptoms

The initial symptoms of measles can include: [17]

- a runny or blocked nose
- sneezing
- watery eyes
- swollen eyelids
- sore, red eyes that may be sensitive to light
- a high temperature (fever), which may reach around 40C (104F)
- small greyish-white spots in the mouth
- aches and pains
- a cough
- loss of appetite
- tiredness, irritability and a general lack of energy

3-5-2 Treatment

There are several things you can do to help relieve your symptoms and reduce the risk of spreading the infection. [16]

These include:

- taking paracetamol or ibuprofen to relieve fever, aches and pains (aspirin should not be given to children under 16 years old)
- drinking plenty of water to avoid dehydration
- closing the curtains to help reduce light sensitivity
- using damp cotton wool to clean the eyes
- staying off school or work for at least 4 days from when the rash first appears

In severe cases, especially if there are complications, you or your child may need to be admitted to hospital for treatment.

3-6 Influenza

Influenza is a viral infection that attacks your respiratory system — your nose, throat and lungs. Influenza is commonly called the flu, but it's not the same as stomach "flu" viruses that cause diarrhea and vomiting. [18]

3-6-1 Symptoms

Initially, the flu may seem like a common cold with a runny nose, sneezing and sore throat. But colds usually develop slowly, whereas the flu tends to come on suddenly. And although a cold can be a nuisance, you usually feel much worse with the flu.

Common signs and symptoms of the flu include: [19]

- Fever over 100.4 F (38 C)

- Aching muscles
- Chills and sweats
- Headache
- Dry, persistent cough
- Fatigue and weakness
- Nasal congestion
- Sore throat

3-6-2 Treatment

Usually, you'll need nothing more than bed rest and plenty of fluids to treat the flu. But in some cases, your doctor may prescribe an antiviral medication, such as oseltamivir (Tamiflu) or zanamivir (Relenza). If taken soon after you notice symptoms, these drugs may shorten your illness by a day or so and help prevent serious complications.

Oseltamivir is an oral medication. Zanamivir is inhaled through a device similar to an asthma inhaler and shouldn't be used by anyone with respiratory problems, such as asthma and lung disease.

Antiviral medication side effects may include nausea and vomiting. These side effects may be lessened if the drug is taken with food. Oseltamivir has also been associated with delirium and self-harm behaviors in teenagers. [18]

Some strains of influenza have become resistant to amantadine and rimantadine (Flumadine), which are older antiviral drugs.

3-7 German Measles

is a very contagious (easily spread) illness caused by the rubella virus. It is usually a mild illness. But in rare cases, it may cause more serious problems.

If you are pregnant and get infected with the rubella virus, your baby (fetus) could become infected too. This can cause birth defects, including serious defects known as congenital rubella syndrome (CRS). CRS can cause hearing loss, eye problems, heart problems, and other complications.

Rubella also is called German measles or 3-day measles. [20]

3-7-1 Symptoms

German Measles "little red" and the disease features a red rash, "rubella" is Latin for "little red."

Symptoms normally appear 14 to 21 days after infection.

The rash often starts on the face and moves to the trunk and limbs. After 3 to 5 days, it fades and disappears. It can be itchy.

Other symptoms include: [21]

- headache
- a mild fever a stuffy or runny nose
- red, inflamed eyes
- nerve inflammation
- enlarged and tender lymph nodes

- aching joints

Though infection can happen at any age, Rubella rarely affects young infants or people over 40 years. A person who is infected with rubella at an older age will normally have more severe symptoms.

3-7-2 Treatment

No medications can shorten the rubella infection, and symptoms are usually mild enough that no treatment is necessary.

Bed rest and acetaminophen may help relieve any symptoms.

If a woman contracts the virus during pregnancy, hyperimmune globulin may be prescribed to help fight off the virus and reduce the chance of congenital rubella syndrome.

A person with a rubella infection should avoid coming into contact with anyone who may be pregnant and anyone who has a weakened immune system until 1 week after the rash appears.

If a child has rubella, their school should be informed. [20]

3-8 Programming in Prolog

- declare facts describing explicit relationships between objects and properties objects might have (e.g. Mary likes pizza, grass has_colour green, Fido is_a_dog, Mizuki taught Paul Japanese)
- define rules defining implicit relationships between objects (e.g. the sister rule above) and/or rules defining implicit object properties (e.g. X is a parent if there is a Y such that Y is a child of X).

One then uses the system by:

- asking questions above relationships between objects, and/or about object properties (e.g. does Mary like pizza? is Joe a parent?)

3-9 Steps of algorithem:-

1-Enter the patients' name .

2- Ask the patient about symptoms.

3- If yes ,continue with symptoms of the same disease ,if the answer doesn’t go to the symptoms of another disease.

4-If all symptoms of the disease match , we will diagnose the disease .

5- In the absence of any matte , he says the disease is unknow

Chapter four : Convert the algorithm into programming code using the language of the prolog

In short , the program is a set of questions, these questions are symptomatic of diseases and according to your answer to questions ,yes or no ,it diagnoses the disease

in this step of implementing the program we enter the name of the patient, As shown in figure below :

Figure(4-1)

in this step of implementation on the program will ask some questions to the patient As shown in figure below :

Figure(4-2)

in this step the program makes a decision and diagnoses the disease according to the patients' answer to the questions posed As shown in figure below:

Figure(4-3)

the first part of the program is the classification of variables only

Domains

Disease, indication =symbol

Patient, name=string

in this part of the program the decision and diagnosis of the disease is taken according to the patients' answer to the question

```
response(reply):-

readchar (reply),

write(reply),
```

(**Programming in Logic**) or Prolog is a high-level programming language that has its roots in first-order logic or first-order predicate calculus. The language was conceived in Marseilles, France in the early 1970s by a group led by Alain Colmerauer. It is one of the first logic programming languages and it remains popular today. It is a programming language commonly associated with computational linguistics and artificial intelligence and is used in expert systems, theorem proving and pattern matching over natural language parse trees and natural language processing.

The first Prolog system was developed in 1972 by Colmerauer together with Philippe Roussel and was based on Robert Kowalski's procedural interpretation of Horn clauses. It was also partly motivated by the desire to reconcile the use of logic as a declarative knowledge representation language with procedural representation of knowledge. Prolog was purposely developed for natural language processing – concerned with computer and human (natural) language interactions.

Prolog differs from other programming languages as it is declarative rather than sequences of commands. It is sometimes called a rule-based or declarative language since it is expressed in terms of relationships among objects' properties, presented as facts and rules. A computation is initiated by running a query over these relations.

Applications include:

Machine learning

Robot planning

Automated reasoning

Problem solving

Intelligent database retrieval

Natural language understanding

Specification language

Prolog is a logic programming language associated with artificial intelligence and computational linguistics.

Prolog has its roots in first-order logic, a formal logic, and unlike many other programming languages, Prolog is intended primarily as a declarative programming language: the program logic is expressed in terms of relations, represented as facts and rules. A computation is initiated by running a *query* over these relations.

The language was first conceived by Alain Colmerauerand his group in Marseille, France, in the early 1970s and the first Prolog system was developed in 1972 by Colmerauer with Philippe Roussel.

Prolog was one of the first logic programming languages, and remains the most popular among such languages today, with several free and commercial implementations available. The language has been used for theorem proving, expert systems,] term rewriting,]type systems, and automated planning,] as well as its original intended field of use, natural language processing. Modern Prolog environments support the creation of graphical user interfaces and networked applications, as well , PROLOG is particularly strong in solving problems characterized by requiring complex symbolic computations. As conventional imperative programs for solving this type of problems tend to be large and impenetrable, equivalent PROLOG programs are often much shorter and easier to grasp. The language in principle enables a programmer to give a formal specification of a program; the result is then almost directly suitable for execution on the computer. Moreover, PROLOG supports stepwise refinement in developing programs because of its modular nature. These characteristics render PROLOG a suitable language for the development of prototype systems. There are several dialects of PROLOG in use, such as for example, C-PROLOG, SWIPROLOG, Sicstus-PROLOG, LPA-PROLOG. C-PROLOG, also called Edinburgh PROLOG, was taken as a basis for the ISO standard. C-PROLOG itself is now no longer in use. The language definition of C-PROLOG is derived from an interpreter developed by D.H.D. Warren, D.L. Bowen, L. Byrd, F.C.N. Pereira, and L.M. Pereira, written in the C programming language for the UNIX operating system. Most dialects only have minor syntactical and semantical differences with the standard language. However, there are a small number of dialects which change the character of the language in a significant way, for example by the necessity of adding data-type information to a program. A typical example is offered by the version of the PROLOG language supported by Visual PROLOG. In recent versions of PROLOG, several features have been added to the ISO standard. Modern PROLOG versions provide a module concept and extensive interfaces to the operating system, as well as tools for the development of graphical user interfaces. Applications of Prolog

Some applications of Prolog are:

intelligent data base retrieval
natural language understanding

expert systems

specification language

machine learning

robot planning

automated reasoning

problem solving

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Program

```
domains
    disease,indication = symbol
    Patient,name = string

predicates
    hypothesis(string,disease)
    symptom(name,indication)
    response(char)
    go
clauses
    go :-
        write("What is the patient's name? "),
        readln(Patient),
        hypothesis(Patient,Disease),
        write(Patient,"probably has ",Disease,"."),nl.

    go :-
        write("Sorry, I don't seem to be able to"),nl,
        write("diagnose the disease."),nl.

    symptom(Patient,fever) :-
        write("Does ",Patient," have a fever (y/n) ?"),
```

```
    response(Reply),
    Reply='y'.

symptom(Patient,rash) :-
    write("Does ",Patient," have a rash (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,headache) :-
    write("Does ",Patient," have a headache (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,runny_nose) :-
    write("Does ",Patient," have a runny_nose (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,conjunctivitis) :-
    write("Does ",Patient," have a conjunctivitis (y/n) ?"),
    response(Reply),
    Reply='y'.
```

```
symptom(Patient,cough) :-
    write("Does ",Patient," have a cough (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,body_ache) :-
    write("Does ",Patient," have a body_ache (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,chills) :-
    write("Does ",Patient," have a chills (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,sore_throat) :-
    write("Does ",Patient," have a sore_throat (y/n) ?"),
    response(Reply),
    Reply='y'.

symptom(Patient,sneezing) :-
    write("Does ",Patient," have a sneezing (y/n) ?"),
    response(Reply),
```

```
    Reply='y'.

symptom(Patient,swollen_glands) :-
    write("Does ",Patient," have a swollen_glands (y/n) ?"),
    response(Reply),
    Reply='y'.

hypothesis(Patient,measles) :-
    symptom(Patient,fever),
    symptom(Patient,cough),
    symptom(Patient,conjunctivitis),
    symptom(Patient,runny_nose),
    symptom(Patient,rash).

hypothesis(Patient,german_measles) :-
    symptom(Patient,fever),
    symptom(Patient,headache),
    symptom(Patient,runny_nose),
    symptom(Patient,rash).

hypothesis(Patient,flu) :-
    symptom(Patient,fever),
    symptom(Patient,headache),
```

```
    symptom(Patient,body_ache),
    symptom(Patient,conjunctivitis),
    symptom(Patient,chills),
    symptom(Patient,sore_throat),
    symptom(Patient,runny_nose),
    symptom(Patient,cough).

hypothesis(Patient,common_cold) :-
    symptom(Patient,headache),
    symptom(Patient,sneezing),
    symptom(Patient,sore_throat),
    symptom(Patient,runny_nose),
    symptom(Patient,chills).

hypothesis(Patient,mumps) :-
    symptom(Patient,fever),
    symptom(Patient,swollen_glands).

hypothesis(Patient,chicken_pox) :-
    symptom(Patient,fever),
    symptom(Patient,chills),
    symptom(Patient,body_ache),
    symptom(Patient,rash).
```

```
hypothesis(Patient,measles) :-
    symptom(Patient,cough),
    symptom(Patient,sneezing),
    symptom(Patient,runny_nose).

response(Reply) :-
    readchar(Reply),
    write(Reply),nl.
```