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Chapter 7

Expert Systems

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What is an Expert System?

Expert systems are computer-based systems used to solve problems, such as providing a diagnosis of something.

They make use of the knowledge of a number of human experts within a specific field. They are unlike other problem solving software in that they use reasoning to produce possible solutions.

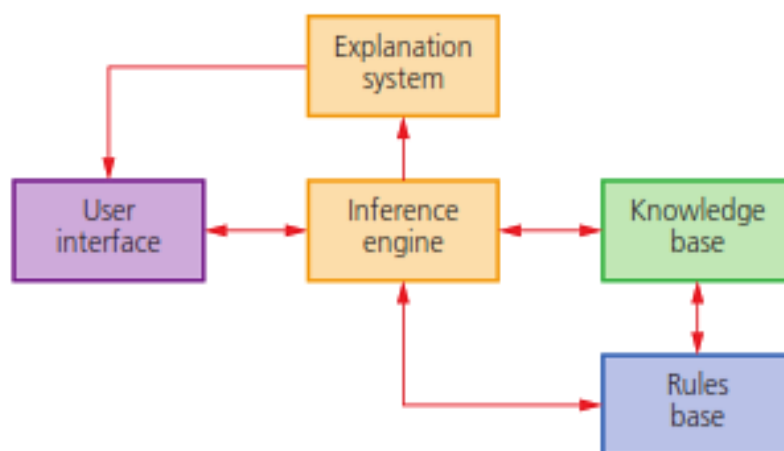
Expert systems can only be used in those areas where human experts already operate. Clearly defined rules and subject facts must already be in existence.

The person who designs and develops an expert system is called an expert system engineer.

Components of an Expert system

An expert system consists of several components. These include:

- User interface
- Knowledge base
- Rules base
- Inference engine
- Explanation system



User interface

- This is the method by which the expert system interacts with a user.
- It allows interaction through dialogue boxes, command prompts or other input methods.
- The questions being asked usually only have yes/no answers and are based on the responses to previous questions.

Knowledge base

- The knowledge base is a repository of facts.
- It stores all the knowledge about an area of expertise obtained from a number of expert resources.
- It is basically a collection of objects and their attributes.

The knowledge base of an expert system is a store of both, factual and heuristic knowledge.

Factual Knowledge – It is the information widely accepted by the Knowledge Engineers and scholars in the task domain.

Heuristic Knowledge – It is about practice, accurate judgement, one's ability of evaluation, and guessing.

Rules base

- The rules base is a set of inference rules.
- Inference rules are used by the inference engine to draw conclusions (the methods used closely follow human reasoning).
- They follow logical thinking, usually involving a series of 'IF' statements, for example:
IF continent = 'South America' AND language = 'Portuguese' THEN country = 'Brazil'.

Inference engine

- This is the main processing element of the expert system.
- The inference engine acts like a search engine examining the knowledge base for information/data that matches the queries.
- It is responsible for gathering information from the user by asking a series of questions and applying responses where necessary; each question being asked is based on the previous responses.
- The inference engine is the problem-solving part of the expert system, which makes use of inference rules in the rules base.

Explanation system

- This informs the user of the reasoning behind the expert system's conclusions and recommended actions.
- For example, suppose the user was investigating a series of symptoms in a patient and the expert system gave the diagnosis of mercury poisoning, the explanation system would explain its reasoning with a statement such as 'impaired vision, lack of coordination, weak muscles, slurred speech and the patient used to work in a paint factory'. The user could then probe deeper if necessary.
- The expert system will supply a conclusion and any suggested actions to take. The important thing is it will also give the percentage probability of the accuracy of its conclusions.

Chaining

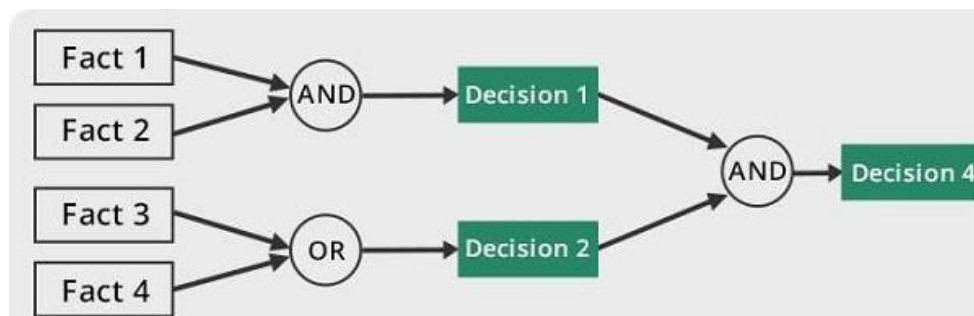
When an inference engine interrogates the knowledge base, it imitates the way a human would use reasoning. It uses what is known as chaining.

The reasoning that the inference engine uses consists of **forward chaining** or **backward chaining**. Often it uses a combination of both.

Forward chaining

- In forward chaining, the expert system begins with an initial set of known facts or data.
- It then applies a set of predefined rules to infer new facts or conclusions based on the existing information.
- These derived facts are added to the knowledge base, and the process continues iteratively until a specific goal or condition is met.

Forward chaining is particularly useful when the problem-solving process requires starting with the available data and incrementally building upon it.



Here are some examples of how forward chaining can be used in expert systems:

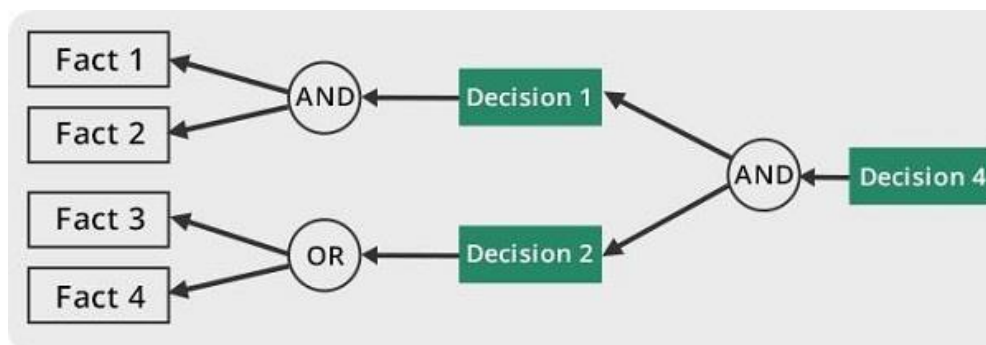
1. **Medical diagnosis:** An expert system can use forward chaining to diagnose a patient's medical condition. The system can start by gathering information about the patient's symptoms and medical history. It can then use a set of rules to determine possible diagnoses based on the symptoms and medical history. The system can continue to gather more information and use the rules to narrow down the possible diagnoses until it arrives at a final diagnosis.
2. **Fraud detection:** An expert system can use forward chaining to detect fraud in financial transactions. The system can start by analyzing the transaction data and identifying any suspicious patterns or behaviors. It can then use a set of rules to determine the likelihood of fraud based on the identified patterns. The system can continue to gather more information and use the rules to further analyze the transaction until it arrives at a final decision about whether fraud has occurred.
3. **Quality control:** An expert system can use forward chaining to ensure the quality of manufactured products. The system can start by analyzing the product specifications and identifying any potential issues or defects. It can then use a set of rules to determine the likelihood of defects based on the identified issues. The system can continue to gather more information and use the rules to further analyze the product until it arrives at a final decision about its quality.

- 4. Inventory management:** An expert system can use forward chaining to manage inventory levels for a business. The system can start by analyzing sales data and identifying any trends or patterns in customer behavior. It can then use a set of rules to determine the optimal inventory levels based on the identified patterns. The system can continue to gather more information and use the rules to adjust inventory levels as needed to ensure efficient operations.

Backward chaining

- In backward chaining, the system begins with the desired outcome or goal and then tries to find the conditions or facts that directly lead to that goal.
- It does this by asking a series of questions or making logical deductions based on the available information and rules.
- Each question or deduction leads to additional questions or deductions until a set of initial facts or conditions is identified.
- Once the initial facts or conditions are identified, backward chaining uses the available rules and facts to determine if those conditions are satisfied.

Backward chaining is particularly useful when the problem-solving process starts with a known goal or outcome and the system needs to work backward to determine the necessary conditions or steps to reach that goal.



Here are some examples of the use of backward chaining in expert systems:

- 1. Medical diagnosis:** An expert system for medical diagnosis might use backward chaining to determine the cause of a patient's symptoms. The system would start with the patient's symptoms and work backwards through a set of rules and facts to determine the underlying condition.
- 2. Fault diagnosis:** An expert system for diagnosing faults in a complex system, such as a computer network or a manufacturing plant, might use backward chaining to identify the root cause of a problem. The system would start with the symptoms of the problem and work backwards to identify the faulty component or process.
- 3. Financial planning:** An expert system for financial planning might use backward chaining to help a user reach a financial goal, such as saving for retirement. The system would start with the user's financial goals and work backwards to identify the savings and investment strategies necessary to achieve those goals.
- 4. Legal reasoning:** An expert system for legal reasoning might use backward chaining to determine the validity of a legal argument. The system would start with the conclusion

of the argument and work backwards through a set of rules and facts to determine whether the argument is valid.

5. **Natural language processing:** An expert system for natural language processing might use backward chaining to determine the meaning of a sentence. The system would start with the meaning of the sentence and work backwards through a set of rules and facts to determine the individual words and their meanings.

Setting up an Expert system

- Information needs to be gathered from human experts or from written sources such as textbooks, research papers or the internet.
- Information gathered is used to populate the knowledge base, which needs to be first created.
- A rules base needs to be created, this is made up of a series of inference rules so that the inference engine can draw conclusions.
- The inference engine itself needs to be set up. It is a complex system since it is the main processing element, making reasoned conclusions from data in the knowledge base.
- The user interface needs to be developed to allow the user and the expert system to communicate.
- Once the system is set up, it needs to be fully tested. This is done by running the system with known outcomes so that results can be compared and any changes to the expert system made.

Advantages of Expert systems

- They offer a high level of expertise.
- They offer high accuracy.
- The results are consistent.
- They have the ability to store vast amounts of ideas and facts.
- They can make traceable logical solutions and diagnostics.
- It is possible for an expert system to have multiple types of expertise.
- They offer a very fast response time.
- They provide unbiased reporting and analysis of the facts.
- They indicate the probability of any suggested solution being correct.

Disadvantages of Expert systems

- Users of the expert system need considerable training in its use to ensure the system is being used correctly.
- The set-up and maintenance costs are very high.
- They tend to give very 'cold' responses which may not be appropriate in certain medical situations.
- They are only as good as the information/facts entered into the system.
- Users sometimes make the very dangerous assumption that they are infallible.

Different scenarios where Expert systems are used

There are many different uses to which expert systems can be put. These include:

- Prospecting for oil and minerals
- Diagnostics (finding faults in a car engine, finding faults on a circuit board, etc.)
- Medical diagnosis
- Strategy games (e.g. chess)
- Tax and financial planning
- Route scheduling for delivery vehicles
- Identification of plants, animals and chemical compounds

Example 1: Prospecting for oil and minerals

- An interactive user screen appears (this is often made up of multiple-choice questions or yes/no responses).
- Questions are asked about geological profiles.
- Answers to questions/geological profiles are typed in by the operator.
- The next questions asked are based on the previous response(s) input by the operator.
- The inference engine searches the knowledge base using the rules base.
- The system suggests the probability of finding oil as an output.
- It also indicates the probable depth of deposits (usually as a % probability).
- The explanation system will also explain how the expert system arrived at its conclusions.
- It makes predictions about geological deposits above the soil.
- It produces contour maps showing concentration of minerals, rocks, oil, etc.

Example 2: Medical diagnosis

- First of all an interactive screen is presented to the user.
- The system asks a series of questions about the patient's illness.
- The user answers the questions asked (either as multiple-choice or yes/no questions).
- A series of questions are asked based on the user's responses to previous questions.
- The inference engine compares the symptoms entered with those in the knowledge base looking for matches.
- The rules base is used in the matching process.
- Once a match is found, the system suggests the probability of the patient's illness being identified accurately.
- The expert system also suggests possible solutions and remedies to cure the patient or recommendations on what to do next.
- The explanation system will give reasons for its diagnosis so that the user can determine the validity of the diagnosis or suggested treatment.
- The diagnosis can be in the form of text or it may show images of the human anatomy to indicate where the problem may be.

- The user can request further information from the expert system to narrow down the possible illness and its treatment.

Example 3: Route scheduling for delivery vehicles

- The system will determine the fastest and least expensive route.
- It will suggest the number of vehicles and drivers that should be used.

The inputs needed for the delivery system are:

- The number of drop-off points and their location.
- The distance between the drop-off points.
- The type of vehicle used.
- Delivery times expected at each drop-off point.
- Layout of the road network.