Unit-8
Expert System

Introduction

- An expert system is a computer program that simulates the thought process of a human expert to solve complex decision problems in a specific domain.
- It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.
- It solves the most complex issues as an expert by extracting the knowledge stored in its knowledge base.
- An expert system's knowledge is obtained from expert sources and coded in a form suitable for the system to use in its inference or reasoning process.
- These systems are designed for a specific domain, such as medicine, science, etc.
- The performance of an expert system is based on the expert's knowledge stored in its knowledge base.
- The more knowledge stored in the KB, the more that system improves its performance.

Why Expert Systems?

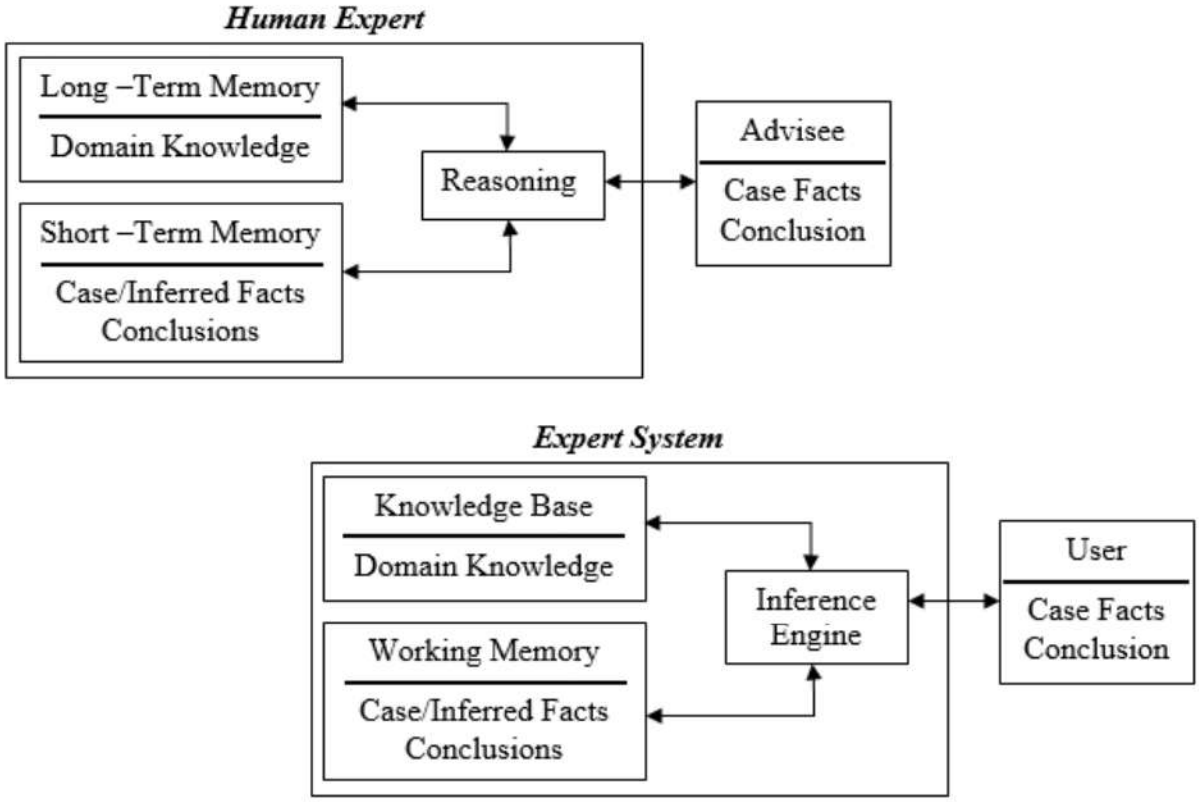
Expert systems offer several advantages that make them highly valuable in various domains:

- ***No Emotions:*** Unlike human experts, expert systems operate purely on logic and data without emotional biases, ensuring impartiality in decision-making.
- ***High Efficiency:*** They can process vast amounts of data quickly and accurately, delivering solutions faster than human experts.
- ***Expertise in a Domain:*** Expert systems are designed with in-depth knowledge in specific fields, providing expert-level advice and solutions.
- ***No Memory Limitation:*** They can store and recall extensive amounts of information without the limitations of human memory.
- ***High Security:*** You can design expert systems with advanced security measures to protect sensitive information and ensure data integrity.

Human Expert vs. Expert System

Human Expert	*Expert System*
Use knowledge in the form of rules of thumbs or heuristics to solve problem in a narrow domain.	It process knowledge expressed in the form of rules and use symbolic reasoning in narrow domain.
In a human expert we deal with human brain in which knowledge exists in a compiled form.	It provide a clear separation of knowledge from its processing.
Explains reasoning and provides detailed explanations.	Traces rules used in problem-solving and explains conclusions.
Improves problem-solving through experience and training.	Improves by adding or adjusting rules in the knowledge base.

Human expert can be available at a specific working day.	Expert system can be available wherever and at any time.
To solve any problem, human expert can take variable time.	To solve any problem, expert system takes a very short interval of time.
It is not replaceable.	It can be replaceable.
Can generate new ideas and solutions.	Lacks creativity and works only within predefined parameters.



Architecture of an Expert System

The Expert System consists of the following given components:

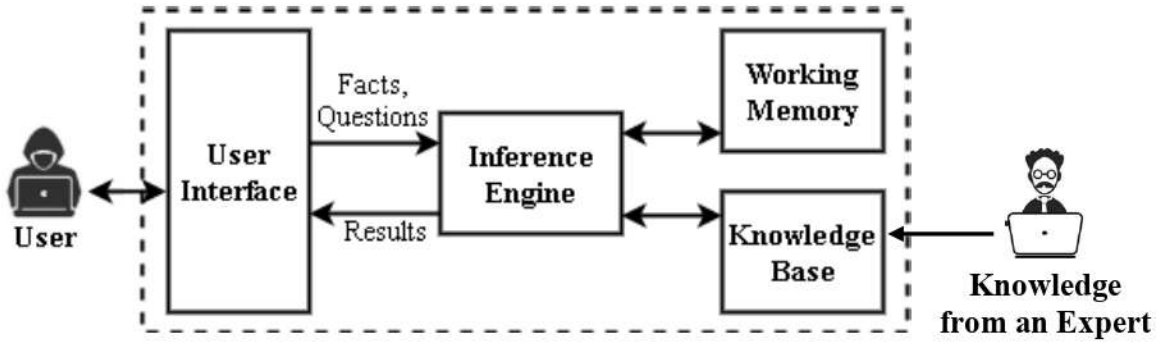


Fig: Architecture of an expert system

1. ***Knowledge Base:*** The knowledge base is a repository of facts. It stores all the knowledge about the problem domain. It is like a large container of knowledge which is obtained from different experts of a specific field. Knowledge base contains knowledge in the form of rules, generally an IF-THEN statement.

2. ***Working Memory:*** It is a data structure that contains problem specific knowledge. It describes the current problem & record intermediate results.
3. ***Inference Engine:*** It works with knowledge base and working memory. It carries out reasoning by interplaying the information or facts obtained from the user with the knowledge stored in knowledge base whereby the expert system reaches a solution.
4. ***User Interface:*** It's an interface that helps the user to communicate with the expert system to find a solution. It takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user.

Examples of Expert Systems

- ***MYCIN:*** MYCIN is a well-known expert system that was developed in the 1970s at Stanford University. It was designed to assist doctors in diagnosing and treating bacterial infections. MYCIN used a knowledge base of medical information and rules to provide recommendations on appropriate antibiotics and dosages.
- ***DENDRAL:*** DENDRAL is a pioneering expert system that was developed in the 1960s at Stanford University. It was designed to interpret complex data from mass spectrometry and deduce the molecular structure of organic compounds. DENDRAL was widely used in the field of chemistry and played a crucial role in the development of computational chemistry.
- ***PXDES:*** Pneumoconiosis X-Ray Diagnosis Expert System (PXDES) is an expert system which is used to diagnose Lung diseases. It takes our lunge picture from the upper side of the body which looks like the shadow. The shadow is used to determine the type and degree of lung cancer
- ***CaDeT:*** CaDeT (Cancer Diagnosis and Treatment) is an expert system developed by the National Cancer Institute (NCI) for assisting oncologists in diagnosing and treating various types of cancer. CaDeT uses a knowledge base of medical data and rules to provide recommendations on treatment options based on the specific type and stage of cancer.
- ***DXplain:*** This is also a clinical support system that is capable of suggesting a variety of diseases based on just the findings of the doctor.
- ***R1/XCON:*** R1/XCON is an early manufacturing expert system that automatically selects and orders computer components based on customer specifications.

Characteristics of an Expert System

An expert system is usually designed to have the following general characteristics:

1. ***High-Level Performance:*** The system should provide expert-level advice with high accuracy and reliability.
2. ***Domain Specificity:*** It is designed for a specific domain and performs tasks like a human expert within that field.
3. ***Good Reliability:*** The expert system must be as reliable as a human expert.
4. ***Understandable:*** The system should be understandable i.e. be able to explain the steps of reasoning while executing.

5. ***Adequate Response Time:*** The system should deliver solutions quickly, comparable to a human expert.
6. ***Symbolic Representation:*** Uses symbols (rules, networks, or frames) for knowledge representation and reasoning.
7. ***Metaknowledge:*** It reasons about its own knowledge and limitations to improve problem-solving.
8. ***Expertise Knowledge:*** The system should apply its knowledge efficiently to find accurate solutions.
9. ***Justified Reasoning:*** Expert systems justify their answers or advice by explaining their reasoning.
10. ***Explaining Capability:*** The system must clarify how conclusions were reached to enhance user confidence.

Knowledge Acquisition

Knowledge acquisition refers to the process of extracting, structuring, and organizing knowledge from various sources, such as human experts, books, documents, sensors, or computer files, so that it can be used in software such as expert system.

The methods of knowledge acquisition can be divided into ***manual***, ***semi-automated*** and ***automated***.

- ***Manual Knowledge Acquisition:*** The primary manual approach is interviewing, ranging from completely unstructured to highly structured interviews. For example, a knowledge engineer interviews doctors to build a medical expert system.
- ***Semi-automated Knowledge Acquisition:*** It combines manual efforts with software tools to help extract and structure knowledge.
- ***Automated Knowledge Acquisition (Machine Learning):*** Automated knowledge acquisition uses an induction system with case histories and examples as input to derive the knowledge base. It eliminates the role of the knowledge engineer and expert by automatically deriving rules.

Knowledge Base

The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as big storage of knowledge. The more the knowledge base, the more precise will be the Expert System. It is similar to a database that contains information and rules of a particular domain or subject.

Components of Knowledge Base:

- ***Factual Knowledge:*** The knowledge which is based on facts and accepted by knowledge engineers comes under factual knowledge.
- ***Heuristic Knowledge:*** This knowledge is based on practice, the ability to guess, evaluation, and experiences.

Knowledge representation is used to formalize the knowledge stored in the knowledge base using the *If-else rules*.

Inference Engine

The inference engine is known as the brain of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution of queries asked by the user. With the help of an inference engine, the system extracts the knowledge from the knowledge base.

There are two types of inference engine:

- ***Deterministic Inference engine:*** The conclusions drawn from this type of inference engine are assumed to be true. It is based on facts and rules.
- ***Probabilistic Inference engine:*** This type of inference engine contains uncertainty in conclusions, and based on the probability.

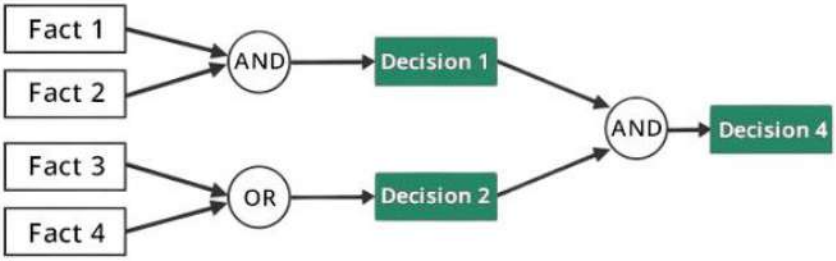
Three basic techniques are identified when inferring facts or conclusions from the knowledge base:

- ***Forward Chaining:*** It starts from the known facts and rules, and applies the inference rules to add their conclusion to the known facts.
- ***Backward Chaining:*** It is a backward reasoning method that starts from the goal and works backward to prove the known facts.
- ***Hybrid Chaining:*** Using both forward and backward chaining.

Forward Chaining and Backward Chaining

Forward Chaining

Forward chaining, also known as the data-driven approach, is a method used to arrive at a conclusion based on a set of facts or observations. In this technique, the system starts with an initial set of facts and applies rules and knowledge to derive new knowledge until a conclusion is achieved. Forward chaining begins with the premises and works towards the conclusion.



Consider an example of a medical diagnosis system. The algorithm starts with an initial set of symptoms and applies medical knowledge to derive a diagnosis for the patient. For example, suppose the patient has a fever, cough, and sore throat. Based on these symptoms, the system may apply a rule that states: "***If the patient has a fever, cough, and sore throat, then they may have a viral infection.***" The algorithm continues to apply rules until it arrives at a conclusive diagnosis.

Advantages of Forward Chaining:

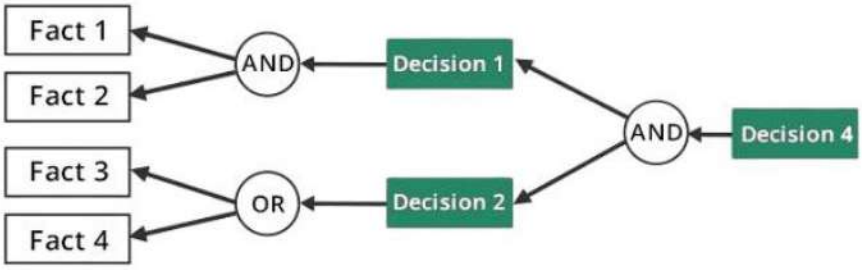
- It is an efficient way of processing a large amount of data to arrive at a conclusion.
- It is easy to understand and implement in rule-based systems and expert systems.
- It is suitable for problems where the data is readily available, and the goal is unknown or cannot be easily defined.

Disadvantages of Forward Chaining:

- It may be time-consuming and computationally expensive to apply many rules and derive a large number of new facts.
- It may not be an efficient way to solve problems where the data is incomplete or ambiguous, requiring further exploration or input.
- It is not suitable for problems where the goal is already defined, and it is only a matter of finding the supporting facts.

Backward Chaining

Backward chaining, also known as the goal-driven approach, starts with a conclusion or goal and works backwards to arrive at the set of facts that support the goal. In this technique, the system uses a set of rules and knowledge to derive the necessary facts to achieve the goal. Backward chaining begins with the conclusion and works towards the premises.



Consider an example of an AI system that controls a drone. The algorithm starts with a goal, for example, "fly the drone to a particular location." The system then works backward and applies rules and knowledge, such as the drone's current location, the destination's GPS coordinates, wind direction and speed, and obstacles in the path, to derive a flight path towards the goal.

Advantages of Backward Chaining:

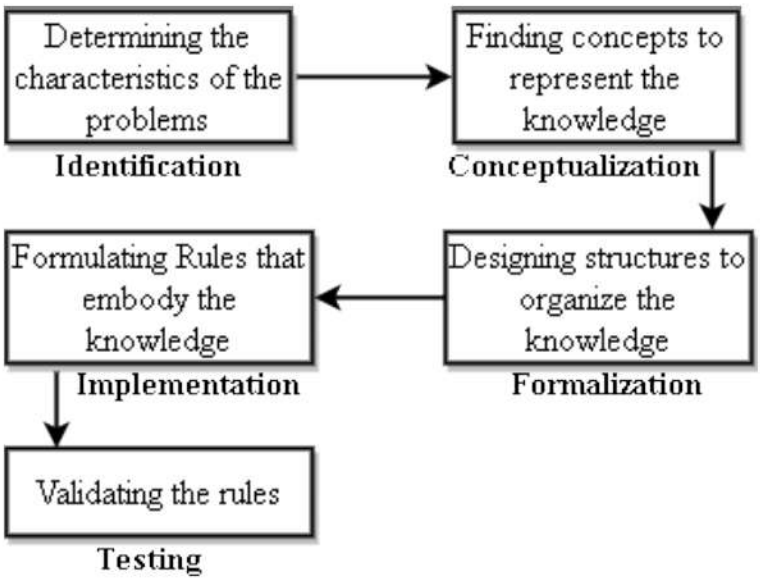
- It is an efficient way of arriving at the set of facts required to achieve a specific goal.
- It is well suited for problems where the goal is well-defined, and the necessary facts need to be properly identified.
- It is suitable for problems where there may be incomplete or ambiguous data, as the system can work backward to identify the necessary data to achieve the goal.

Disadvantages of Backward Chaining:

- The algorithm may get stuck in an infinite loop if there are no rules or facts to derive the goal.
- The algorithm may not be able to explore all possible paths to arrive at the goal, thereby missing some valuable solutions.
- The algorithm may be computationally expensive if there are many possible paths to the goal.

Design of Expert System

Different phases of expert system development are given below:



1. ***Identification:***
   - It involves a formal task analysis to determine external requirements, form of the input and output, setting where the program will be used and determines the user.
   - The participants, the problems, the objectives, the resources, the costs and time frame needed to be clearly identified at this stage.

2. ***Conceptualization:***
   - In involves designing the proposed program to ensure that specific interactions and relationships in the problem domain are understood and defined.
   - The key concepts, relationships between objects and processes and control mechanisms are determined.

3. ***Formalization:***
   - It involves organizing the key concepts, sub-problems and information flow into formal representations. In effect, program logic is designed at this stage.
   - Two most important items are:
     1. Refinement of the knowledge pieces into their specific relationships and hierarchy.
     2. More accurate determination of the expected user interaction with the system.

4. ***Implementation:***
   - The formalized knowledge is mapped or coded into the framework of the development tool to build a working prototype.
   - Consideration must be given to long term maintenance with extensive justifications and explanations should be included.

5. ***Testing:***
   - It provides opportunities to identify the weakness in the structure and implementation of the system and to make the appropriate corrections.

Advantages and Disadvantages of an Expert System

Advantages

- It provides consistent answer for repetitive decisions, processes and tasks.
- It holds and maintain levels of information.
- It can tackle very complex problems that are difficult for human expert to solve.
- It improves the decision quality.
- It reduces the cost of consulting experts for problem solving.
- It provides quick and efficient solutions to problem in narrow area of specialization.
- It can discover new knowledge.

Disadvantages

- It lacks common sense needed in decision making.
- The knowledge base may not be complete.
- Expensive to build & maintain.
- Takes long time to develop.
- Errors in the knowledge base can lead to wrong decisions.
- Unable to make creative response in an extraordinary situations.

Applications of Expert System

Expert systems are used in various domains to simulate human expertise and decision-making. Some key applications include:

- ***Medical Diagnosis:*** Assisting doctors in diagnosing diseases (e.g., MYCIN for bacterial infections).
- ***Finance and Banking:*** Fraud detection, risk assessment, and loan approvals.
- ***Industrial Maintenance:*** Predictive maintenance and troubleshooting machinery issues.
- ***Customer Support:*** AI-driven chatbots and virtual assistants.
- ***Agriculture:*** Crop disease diagnosis and yield prediction.
- ***Education:*** Intelligent tutoring systems for personalized learning.
- ***Legal Advisory:*** Assisting in legal case analysis and contract review.
- ***Weather Forecasting:*** Analyzing climate patterns for accurate predictions.
- ***Cybersecurity:*** Intrusion detection and threat analysis.
- ***Manufacturing:*** Process optimization and quality control.