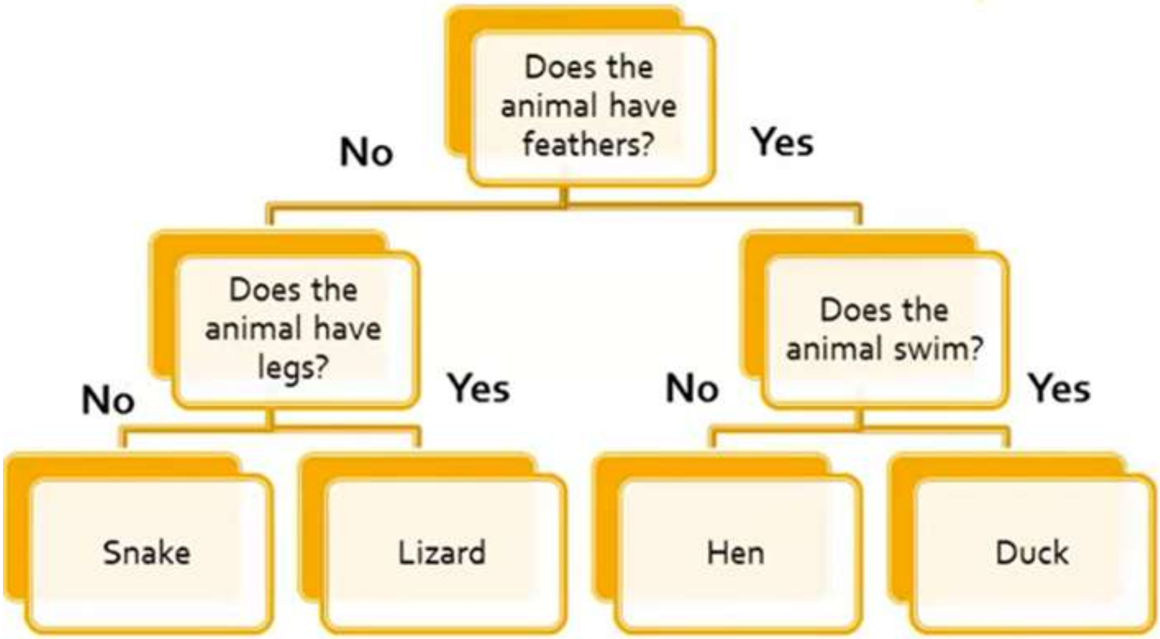
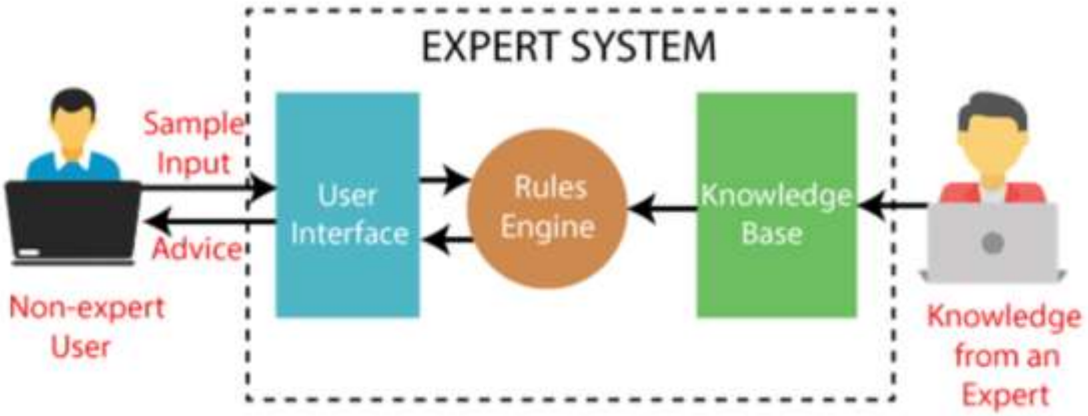
MODULE 5: EXPERT SYSTEM

➢ Introduction

- An expert system is a computer program designed to solve complex problems and provide decision-making abilities similar to that of a human expert.
- It extracts knowledge from its knowledge base using reasoning and inference rules to respond to user queries.
- The concept of expert systems emerged in the 1970s, marking a significant milestone in artificial intelligence.
- The first successful expert system was developed in this period, showcasing the potential of AI in problem-solving.
- Expert systems represent the expert knowledge of a specific domain and can tackle complex problems within that domain.
- Let's assume we want to identify an animal either as a duck, snake, lizard or Hen.



➢ Components of expert system



Components of an Expert System

1. **User Interface:**
    - Facilitates interaction between the user and the expert system.
    - Takes queries from the user in a readable format and passes them to the inference engine.
    - Displays the system's response to the user.

2. **Inference Engine:**
    - Acts as the brain of the expert system, processing user queries and deriving conclusions.
    - Applies inference rules to the knowledge base to deduce new information or conclusions.
    - Two types:
        - **Deterministic Inference Engine:** Based on facts and rules, assumes conclusions to be true.
        - **Probabilistic Inference Engine:** Introduces uncertainty in conclusions based on probabilities.
    - Modes of inference:
        - **Forward Chaining:** Starts from known facts and rules, adding their conclusions to the known facts.
        - **Backward Chaining:** Starts from the goal and works backward to prove known facts.

3. **Knowledge Base:**
    - Stores knowledge acquired from domain experts, serving as a repository of expertise.
    - Contains factual and heuristic knowledge:

- **Factual Knowledge:** Based on facts and accepted by knowledge engineers.
- **Heuristic Knowledge:** Derived from practical experience, guessing, evaluation, and past experiences.

- **Knowledge Representation:**
  Formalizes knowledge stored in the knowledge base using if-else rules.
  IF an animal has feathers THEN it is a bird
- **Knowledge Acquisition:**
  - Process of extracting, organizing, and structuring domain knowledge.
  - Specifies rules to acquire knowledge from experts and store it in the knowledge base.

➢ Database vs Knowledge base

Aspect	Knowledge Base	Database
Content	Contains domain-specific knowledge, rules, and heuristics	Contains structured data, often relational or hierarchical
Purpose	Stores information for reasoning and decision-making	Stores structured data for retrieval and manipulation
Structure	Organized to facilitate inference and problem-solving	Organized for efficient storage and retrieval
Flexibility	Flexible structure for accommodating complex knowledge	Fixed schema for consistent data storage
Usage	Used by expert systems for knowledge processing	Used by various applications for data management
Examples	Production rules, domain facts, expert insights	Customer records, product inventory, transaction logs

➢ Characteristics of ES:

1. **Should Solve Difficult Problems Effectively:**
   - Capable of effectively tackling complex problems, often surpassing the performance of human experts in certain domains.

2. **Should Possess Comprehensive Domain-Specific Knowledge:**
    - Should possess extensive and detailed knowledge relevant to the problem domain, covering a wide range of topics and intricacies.
3. **Should Employ Heuristic Search Strategies:**
    - Should utilize heuristic search techniques to efficiently explore problem spaces and find satisfactory solutions in a timely manner.
4. **Should Provide Transparent Reasoning:**
    - Should offer clear explanations for the questions posed and justify its conclusions, enhancing user understanding and confidence in the system's output.
5. **Should Adapt and Learn Over Time:**
    - Should be capable of adapting to new information, learning from past experiences, and continuously improving its performance over time.
6. **Should Handle Uncertainty and Irrelevance:**
    - Should effectively manage uncertain and irrelevant data, employing robust reasoning mechanisms to make informed decisions even in uncertain environments.
7. **Should Facilitate Natural Language Interaction:**
    - Should enable users to interact with the system using natural language, making it more accessible and user-friendly.
8. **Should Personalize Recommendations:**
    - Should tailor its recommendations and solutions to the individual preferences and requirements of users, providing personalized experiences.
9. **Should Emphasize Symbolic Processing:**
    - Should prioritize symbolic processing techniques over numeric processing, emphasizing logical reasoning and pattern recognition.
10. **Should Be Resource-Efficient:**
    - Should utilize resources efficiently, minimizing computational overhead while generating effective solutions in a timely manner.

➢ Forward and Backward chaining:

A. Forward Chaining:

- Also known as forward deduction or forward reasoning method.
- Begins with atomic sentences in the knowledge base.
- Applies inference rules (like Modus Ponens) in the forward direction.
- Starts from known facts and triggers rules whose premises are satisfied.
- **Adds conclusions to known facts, repeating the process until the goal is reached.**
- **Properties:**
  - Down-up approach, moving from bottom to top.
  - Data-driven approach, utilizing available data to reach the goal.
  - Commonly used in expert systems, business, and production rule systems.

B. Backward Chaining:

- Also known as backward deduction or backward reasoning method.
- Begins with the goal and works backward, chaining through rules to find known facts supporting the goal.
- **Properties:**
  - Top-down approach.
  - Based on the modus ponens inference rule.
  - Breaks the goal into sub-goals to prove facts true.
  - Goal-driven approach, where a list of goals selects and uses rules.
- Used in game theory, automated theorem proving tools, inference engines, proof assistants, and various AI applications.
- Often employs a **depth-first search** strategy for proof.

➢ Difference of forward and backward chaining:

Aspect	Forward Chaining	Backward Chaining
Process Description	Takes a decision based on available data.	Starts from the goal and works backward to determine required facts.
Data-Driven vs Goal-Driven	Data-driven technique, utilizes available data to reach the goal.	Goal-driven technique, starts from the goal and reaches the initial state.
Approach	Bottom-up approach	Top-down approach
Search Strategy	Breadth-First Strategy	Depth-First Strategy
Goal	To obtain the conclusion	To identify possible facts or acquire required data
Speed	Slower, as it needs to consider all rules	Faster, as it requires only a few rules
Direction of Operation	Forward direction, from initial state to final decision	Backward direction, from goal to initial state
Applications	Planning, monitoring, control, interpretation	Automated inference engines, theorem proofs, proof assistants

➢ Example of forward and backward chaining:

Let's explain how forward chaining is done with an example. Let A_1, A_2, A_3, A_4, A_5 be a set of antecedents and C_1,C_2,C_3,C_4,C_5 be the consequents. The rules for operation are

1. IF A_1 and A_2 then C_1
2. IF A_3 and C_1 then C_2
3. IF A_3 then C_3
4. IF A_2 and C_3 then C_4
5. IF C_4 then C_5
6. IF C_2 then C_5
7. IF C_5 then C_6.

Assume that the user, in the initial situation has given that A_3 and A_2 are true. The system has to prove the consequent C_6. The steps are shown in Table 11.1.

In fact, by triggering one rule, a series of rules are triggered. This method of matching only the IF conditions is called forward chaining.

Using forward chaining:

Using backward chaining:

Table 11.2 Steps in backward chaining

Step	What is done	Rule to be proved	Whether conditions exist	Inferred
1.	C_6 is taken	7	yes	A_3
2.	C_5 is taken	5	yes	A_2
3.	C_4 is taken	4	yes condition A_4 and C_3.	
4.	A_2 is compared. Succeeds as A_2 is true	3	yes	
5.	C_3 is taken and compared and succeeds		proving C_6.	

3.	C_3 inferred		C_3
4.	Takes A_2 and compares. Rule 1 fails		
5.	Rule 2 fails		
6.	Rule 4 succeeds because C_3 is inferred	Rule 4 C_4 inferred	C_4
7.	Takes C_3 and tries to match. All rules fail.		
8.	Takes C_4 and tries to match. Rule 5 succeeds	Rule 5 C_5 inferred	C_5
9.	Takes C_5 and tries to match Rule 7 succeeds	Rule 7 C_6 inferred	C_6 – the goal

➢ Application of expert system:

1. **Medical Diagnosis**: Expert systems aid physicians in diagnosing diseases and recommending treatments based on symptoms and patient data.
2. **Financial Advising**: These systems offer personalized financial advice by analyzing investment opportunities and market conditions.

3. **Customer Support**: Expert systems provide immediate assistance and troubleshooting guidance in customer service interactions.
4. **Industrial Automation**: They optimize manufacturing processes and predict maintenance needs to improve efficiency.
5. **Fault Diagnosis**: Expert systems accurately identify faults in machinery and recommend corrective actions.
6. **Educational Tutoring**: These systems deliver personalized learning experiences to students, assessing strengths and weaknesses.
7. **Legal Decision Support**: Expert systems assist legal professionals in researching case law and formulating legal strategies.
8. **Natural Language Processing**: They enable communication between humans and machines through virtual assistants and chatbots.
9. **Environmental Monitoring**: Expert systems analyze environmental data to predict trends and recommend conservation measures.
10. **Agricultural Planning**: They help farmers optimize crop selection and management practices based on environmental factors and market trends.

Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query.

Limitations of Expert System

- The response of the expert system may get wrong if the knowledge base contains the wrong information.

- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates