

Describe the structure and functioning of a knowledge-based agent in the context of artificial intelligence.

A knowledge-based agent is an AI system that reasons and makes decisions using a structured knowledge base and inference mechanism. It consists of components like the knowledge base (which stores facts and rules), an inference engine (to apply logic), and a decision-making module. The agent perceives the environment, updates its knowledge base, and uses logical inference to choose actions that lead to goal achievement.

Outline the key components of propositional logic and their role in representing knowledge in AI systems.

Propositional logic uses propositions (statements that are either true or false), logical connectives (AND, OR, NOT, IMPLIES), and rules of inference. It allows simple reasoning by evaluating truth values using truth tables. Though limited in expressiveness, it forms the foundation for more advanced logical systems in AI.

Explain the key issues in knowledge representation.

Key issues in knowledge representation include how to handle incomplete or uncertain information, how to represent real-world entities and relationships clearly, and how to support efficient inference. Other concerns involve ensuring consistency, scalability, and flexibility in updating or querying the knowledge base.

Interpret the concept of semantic mapping in knowledge representation and explain its significance in understanding meaning in AI systems.

Semantic mapping refers to the process of connecting symbolic representations (like words or identifiers) to their actual meaning or real-world concepts. In AI, it helps translate between internal representations and external knowledge, making it possible for the system to understand, reason, and act based on meaningful data.

Describe the concept of a Bayesian network and its purpose.

A Bayesian network is a probabilistic graphical model representing a set of variables and their conditional dependencies using a directed acyclic graph (DAG). Each node is a variable, and each edge indicates a conditional dependency. These networks are used to reason under uncertainty, compute likelihoods, and make predictions by applying Bayes' theorem.

Illustrate the concept of Bayes' Rule and demonstrate how it is applied in AI for probabilistic reasoning.

Bayes' Rule provides a mathematical way to update the probability of a hypothesis based on new evidence. It is expressed as: $P(H|E) = [P(E|H) \times P(H)] / P(E)$. In AI, it is used in probabilistic reasoning, such as in spam filters, diagnosis systems, and Bayesian networks, to revise beliefs based on observations.

Explain the concept of conditional independence and how it simplifies computations in Bayesian inference.

Conditional independence occurs when two variables are independent given the value of a third variable. In Bayesian networks, this allows simplification of the joint probability distribution by factoring it into smaller, manageable components. It reduces computation and helps in efficient probabilistic reasoning.

Explain the Dempster-Shafer theory in the context of reasoning under uncertainty.

Dempster-Shafer theory is an alternative to probability theory that allows for representing and combining degrees of belief based on evidence. Unlike Bayesian probability, it assigns belief to sets or ranges of outcomes and includes a mechanism (Dempster's Rule) to combine evidence from multiple sources, making it useful when information is incomplete or conflicting.

Contrast fuzzy sets with classical sets, highlighting their differences in terms of membership and application in AI.

Fuzzy sets allow partial membership, where an element's inclusion in a set is expressed by a value between 0 and 1. In contrast, classical sets use binary membership (0 or 1). Fuzzy sets are used when concepts are vague or imprecise, such as "tall", "hot", or "slow", enabling AI to mimic human-like reasoning.

Describe the concept of fuzzy logic and its applications in various AI systems.

Fuzzy logic is a form of many-valued logic that handles reasoning with approximate or uncertain information. Instead of rigid true/false values, it works with degrees of truth. It is used in control systems, decision-making, and natural language processing. Common applications include air conditioning systems, washing machines, and autonomous vehicles.

Let $P(A)=0.4$, $P(B)=0$, and $A \cap B = \emptyset$. Find $P(A \cup B)$.

Solution:

Since A and B are disjoint:

$$P(A \cup B) = P(A) + P(B)$$

$$= 0.4 + 0.3$$

$$= 0.7$$

Analyse how fuzzy logic differs from probability theory in handling uncertainty.

Fuzzy logic is used when information is **imprecise or unclear**, like "the weather is warm." Probability theory is used when there

is **randomness or risk**, like “there’s a 70% chance of rain.”

In fuzzy logic, uncertainty comes from **vagueness in meaning**, while in probability it comes from **lack of knowledge**.

So, fuzzy logic handles **degree of truth**, and probability handles **likelihood of events**.

1. A die is rolled once. Find the probability of:

1. Getting a number less than 5
2. Getting a prime number

Solution:

Sample space = {1, 2, 3, 4, 5, 6}

1. Numbers less than 5 = {1, 2, 3, 4} → 4 outcomes

$$P = 4/6$$

$$= 2/3$$

1. Prime numbers = {2, 3, 5} → 3 outcomes

$$P = 3/6$$

$$= 1/2$$

1. Compare propositional logic and semantic networks for knowledge representation in AI.

Point	Propositional Logic	Semantic Network
Form	Uses symbols and logical statements.	Uses nodes and links to show relationships.
Meaning	Focuses on truth of statements.	Focuses on meaning and connections between things.
Structure	Flat, no hierarchy.	Hierarchical or network-based structure.
Use	Good for logical reasoning.	Good for representing real-world knowledge.

1. Assess the role of Bayes' Rule in enabling reasoning under uncertainty within knowledge-based systems.

Bayes' Rule provides a mathematical method to update the probability of a hypothesis based on new evidence. It allows knowledge-based systems to evaluate how likely a cause is given an observed effect, enabling more accurate and adaptive decision-making in uncertain environments.

Evaluate the advantages of using Bayesian Networks in knowledge representation.

1. They handle **uncertainty** effectively using probabilities.
2. They show **cause-and-effect** relationships clearly.
3. They allow **updating beliefs** when new data comes.
4. They make **reasoning and prediction** easier in complex systems.

Distinguish between syntactic processing and semantic

analysis in Natural Language Processing by examining their roles and contributions to language understanding.

Point	Syntactic Processing	Semantic Analysis
Focus	Checks grammar and sentence structure.	Finds the meaning of words and sentences.
Role	Ensures words are in correct order.	Ensures sentences make sense in context.
Output	Creates a parse tree or structure.	Creates a meaning or concept representation.
Example	Identifies subject, verb, and object.	Understands who did what to whom.

1. **Analyze how decision trees and explanation-based learning differ in their approach to machine learning.**
2. **Decision trees** learn from many examples, while **explanation-based learning (EBL)** learns from one or few examples.
3. Decision trees use **data patterns**, but EBL uses **prior knowledge and logic**.
4. Decision trees create **if-then rules** automatically, while EBL **explains and generalizes** a single case.
5. Decision trees are **data-driven**, whereas EBL is **knowledge-driven**.

Evaluate the importance of semantic and pragmatic processing in Natural Language Understanding.

Semantic processing helps determine the literal meaning of words and sentences, enabling machines to understand what is being communicated. Pragmatic processing goes further by interpreting meaning in context, such as speaker intent, social cues, or implied meanings. Together, they are essential for building intelligent systems like chatbots and virtual assistants that can understand and respond appropriately in real-world interactions.

Evaluate the strengths of genetic algorithms in learning and problem-solving.

Genetic algorithms are powerful in exploring large, complex solution spaces by simulating the process of natural selection. Their strengths include flexibility in handling nonlinear problems, robustness in finding global optima, and adaptability through operations like selection, crossover, and mutation. They are especially useful in optimization problems where traditional methods may fail or get stuck in local optima.