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Department of CSE
Subject Name: Artificial Intelligence
Subject Code: Elective –I CSE505(2)
Semester: 5th

Artificial Intelligence (CSE)

Lecture Notes

Unit 1: Basics of AI and Search Techniques

1. Meaning and Definition of Artificial Intelligence

- **Artificial Intelligence (AI)**: A branch of computer science aimed at creating systems that can perform tasks that would normally require human intelligence. This includes tasks like problem-solving, understanding natural language, and pattern recognition.

2. Types of Production Systems

- **Production Systems**: An abstract model used to describe the behavior of intelligent systems. It consists of:
  - **Production Rules**: If-Then rules that define the actions of the system.
  - **Working Memory**: A database of facts or data items.
  - **Inference Engine**: The component that applies production rules to the working memory.
  - **Types**:
    - **Forward Chaining**: Starts from known facts and applies rules to derive new facts until a goal is achieved.
    - **Backward Chaining**: Starts from the goal and works backward to determine which facts need to be established.

3. Characteristics of Production Systems

- **Modularity**: Rules and facts are modular and can be updated independently.
- **Flexibility**: Can handle a wide range of problems and adapt to new situations.
- **Declarative Nature**: The focus is on what needs to be done, not how it is done.
- **Explicit Knowledge Representation**: Knowledge is explicitly represented in terms of rules and facts.

4. Search Techniques

- **Breadth-First Search (BFS)**:
  - **Approach**: Explores all nodes at the present depth level before moving on to nodes at the next depth level.
  - **Advantages**: Guarantees finding the shortest path in an unweighted graph.
  - **Disadvantages**: Memory-intensive.
- **Depth-First Search (DFS)**:
  - **Approach**: Explores as far as possible along each branch before backtracking.
  - **Advantages**: Lower memory usage compared to BFS.
  - **Disadvantages**: Can get stuck in infinite loops if not managed properly.
- **Comparison**:

- **BFS**: Complete and optimal for unweighted problems but requires more memory.
- **DFS**: More memory efficient but may not find the optimal solution.

5. Other Search Techniques

- **Hill Climbing**:
  - **Approach**: Evaluates nodes and moves towards the direction of increasing value.
  - **Types**: Simple Hill Climbing, Steepest-Ascent Hill Climbing.
  - **Issues**: Can get stuck in local optima, does not guarantee a solution.
- **Best-First Search**:
  - **Approach**: Uses a heuristic function to evaluate nodes and expands the most promising node first.
  - **Examples**: Greedy Best-First Search.
- *A Algorithm**:
  - **Approach**: Combines the benefits of Uniform Cost Search and Greedy Best-First Search by using the function $f(n) = g(n) + h(n)$, where $g(n)$ is the cost from the start node to node n, and $h(n)$ is the heuristic estimate to the goal.
  - **Advantage**: Guarantees finding the optimal solution if the heuristic is admissible.
- *AO Algorithm**:
  - **Approach**: Used for solving problems where the solution involves multiple subgoals. It operates on AND/OR trees.
  - **Advantage**: Effective for problems with complex goal structures.

6. Control Strategies

- **Control Strategies**: Methods to manage the execution of production systems.
  - **Refraction**: Avoiding the re-evaluation of already considered paths.
  - **Conflict Resolution**: Deciding which rule to apply when multiple rules are applicable.
  - **Search Strategies**: Implementing BFS, DFS, or heuristic approaches to guide the search process.

Unit 2: Knowledge Representation

1. Knowledge Representation

- **Definition**: Methods used to represent knowledge in a form that a computer system can utilize to solve complex tasks.

2. Problems in Representing Knowledge

- **Complexity**: Capturing intricate real-world scenarios accurately.

- **Scalability**: Handling large volumes of data and relationships.
- **Ambiguity**: Dealing with vague or imprecise information.

3. Propositional and Predicate Logic

- **Propositional Logic**:
  - **Definition**: Represents facts using propositions and logical connectives (AND, OR, NOT).
  - **Example**: "It is raining" can be represented as a proposition.
- **Predicate Logic**:
  - **Definition**: Extends propositional logic by including objects, properties, and relations. Uses quantifiers like ∀ (for all) and ∃ (exists).
  - **Example**: "All humans are mortal" can be represented as ∀x (Human(x) → Mortal(x)).
- **Comparison**:
  - **Propositional Logic**: Simpler but less expressive; does not handle relationships between objects.
  - **Predicate Logic**: More expressive; can handle complex relationships and quantify over objects.

4. Resolution and Refutation

- **Resolution**: A proof technique for propositional and predicate logic. It involves deriving contradictions to prove theorems.
- **Refutation**: Showing that a statement leads to a contradiction, thereby proving that the original assumption was false.

5. Deduction, Theorem Proving, and Inferencing

- **Deduction**: Deriving conclusions from premises using logical rules.
- **Theorem Proving**: Proving that a statement is a logical consequence of axioms and rules.
- **Inferencing**: The process of deriving new facts from known facts using logical rules.

6. Monotonic and Non-Monotonic Reasoning

- **Monotonic Reasoning**: Adding new knowledge does not invalidate previously drawn conclusions.
- **Non-Monotonic Reasoning**: Adding new knowledge can change previously drawn conclusions (e.g., in the presence of exceptions or new information).

Unit 3: Probabilistic Reasoning

1. Probabilistic Reasoning

- **Definition**: Using probability theory to handle uncertainty and make decisions based on incomplete information.

2. Bayes' Theorem

- **Definition**: A mathematical formula used to update probabilities based on new evidence.
- **Formula**: $P(A|B) = [P(B|A) * P(A)] / P(B)$
  - **P(A|B)**: Posterior probability.
  - **P(B|A)**: Likelihood.
  - **P(A)**: Prior probability.
  - **P(B)**: Evidence.

3. Semantic Networks

- **Definition**: Graph structures used to represent knowledge in terms of entities (nodes) and relationships (edges).

4. Scripts, Schemas, and Frames

- **Scripts**: Structures that represent typical sequences of events (e.g., dining at a restaurant).
- **Schemas**: Mental structures used to organize knowledge (e.g., the concept of a "book").
- **Frames**: Data structures that represent stereotypical situations, with slots for attributes and values.

5. Conceptual Dependency

- **Definition**: A theory that represents knowledge in terms of the relationships between concepts, aiming to capture the underlying meaning of sentences.

6. Fuzzy Logic

- **Definition**: A form of logic that handles the concept of partial truth, where truth values can range between completely true and completely false.

7. Forward and Backward Reasoning

- **Forward Reasoning**: Starts from known facts and applies inference rules to derive conclusions.
- **Backward Reasoning**: Starts from a goal and works backward to find supporting facts.

Unit 4: Game Playing and Planning

1. Game Playing Techniques

- **Minimax Procedure**:
  - **Definition**: A decision-making algorithm used in game theory for minimizing the possible loss in a worst-case scenario.
  - **Approach**: Chooses the move that maximizes the minimum gain of the player.
- **Alpha-Beta Pruning**:
  - **Definition**: An optimization technique for the minimax algorithm that reduces the number of nodes evaluated in the search tree.
  - **Approach**: Prunes branches that cannot affect the final decision, improving efficiency.

2. Planning

- **Definition**: The process of formulating a sequence of actions to achieve specific goals.
- **Techniques**:
  - **Strips**: A formal language used for representing actions and their effects.
  - **Hierarchical Planning**: Breaking down complex plans into simpler sub-plans.

3. Block World Problem in Robotics

- **Definition**: A classic problem in AI where the goal is to move blocks from an initial configuration to a goal configuration using a robot.
- **Approach**: Uses planning and problem-solving techniques to manipulate blocks and achieve the desired configuration.

4. Natural Language Processing (NLP)

- **Definition**: The field of AI concerned with the interactions between computers and human (natural) languages.
- **Components**:
  - **Syntax Analysis**: Analyzing sentence structure.
  - **Semantic Analysis**: Understanding the meaning of sentences.
  - **Pragmatics**: Understanding context and usage.

Unit 5: Learning and Neural Networks

1. Introduction to Learning

- **Learning**: The process by which AI systems improve their performance based on experience and data.
- **Types**:
  - **Supervised Learning**: Learning from labeled data.

    - **Unsupervised Learning**: Finding patterns in unlabeled data.
    - **Reinforcement Learning**: Learning by interacting with the environment and receiving feedback.

2. Techniques Used in Learning

- **Decision Trees**: A tree-like model used for classification and regression.
- **Support Vector Machines (SVMs)**: A classification technique that finds the optimal hyperplane separating classes.
- **k-Nearest Neighbors (k-NN)**: A classification technique based on the closest training examples.

3. Introduction to Neural Networks

- **Neural Networks**: Computational models inspired by the human brain, consisting of interconnected nodes (neurons) organized in layers.
- **Types**:
    - **Feedforward Neural Networks**: Networks where connections only move in one direction.
    - **Convolutional Neural Networks (CNNs)**: Used for image processing tasks.
    - **Recurrent Neural Networks (RNNs)**: Used for sequence data.

4. Applications of Neural Networks

- **Image Recognition**: Identifying objects and patterns in images.
- **Speech Recognition**: Converting spoken language into text.
- **Natural Language Processing**: Understanding and generating human language.

5. Common Sense Reasoning

- **Definition**: The ability of AI systems to make reasonable assumptions and inferences based on everyday knowledge and experience.

6. Examples of Expert Systems

- **Expert Systems**: AI systems that emulate the decision-making ability of human experts.
- **Examples**:
    - **MYCIN**: A medical diagnosis system for identifying bacterial infections.
    - **DENDRAL**: A system for chemical analysis and molecular structure determination