ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING (IT3201)

(Sem: 6th (Section B and E))

Lecture 4-8

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Problems, and Problem Spaces in AI

Problems in AI are specific tasks or challenges that AI aims to address, such as image recognition or natural language understanding.

Problem Spaces in AI represent the abstract frameworks that define the scope, constraints, and possible solutions for a given problem, aiding in algorithm design and problem-solving.

Problems, and Problem Spaces in AI

For example, in a game of chess, the problem is to find a sequence of moves that lead to checkmate, while in route planning, the problem is to find the shortest path between two locations on a map.

In other words, the problem space defines all the possible configurations or arrangements of elements involved in the problem and the set of valid moves or actions that can be taken at each state. Each state in the problem space represents a specific configuration, and each action represents a possible move or step from one state to another.

Problems in AI

- In the realm of AI, problems refer to specific tasks or goals that researchers and practitioners aim to address using artificial intelligence techniques.
- These problems can range from simple to complex and may involve tasks such as image recognition, natural language understanding, decision-making, game playing, and more.
- Solving these problems often requires the development and application of algorithms, models, and systems that can perform intelligent tasks.

Problem Spaces in AI

- A problem space in AI is the abstract, conceptual framework that encompasses all possible states and transitions of a particular problem.
- It defines the scope of a problem, including the set of possible inputs, the rules or constraints governing the problem, and the range of potential solutions.
- Problem spaces help in understanding the structure of a problem and designing algorithms or approaches to navigate through or solve the problem effectively

Case Studies and Scenario (1/6)

- **Data Quality and Quantity:**

- **Problem:** AI algorithms heavily rely on large and high-quality datasets. In many cases, obtaining sufficient and relevant data can be challenging.
- **Problem Space:** Data preprocessing techniques, data augmentation, and the development of methods to handle noisy or incomplete data.

Case Studies and Scenario (2/6)

Bias and Fairness:

Problem: AI systems can inherit biases present in training data, leading to unfair or discriminatory outcomes.

Problem Space: Researchers are working on developing algorithms and frameworks that address bias and promote fairness in AI systems.

Case Studies and Scenario (3/6)

Interpretability and Explainability:

Problem: Many AI models, especially complex ones like deep neural networks, lack interpretability, making it challenging to understand their decision-making processes.

Problem Space: Research focuses on developing interpretable models and methods for explaining the decisions of black-box models.

Case Studies and Scenario (4/6)

Scalability:

Problem: Scaling AI models to handle large amounts of data and complex tasks can be computationally expensive and resource-intensive.

Problem Space: Efficient algorithms, distributed computing, and advancements in hardware (e.g., GPUs and TPUs) contribute to addressing scalability challenges.

Case Studies and Scenario (5/6)

Robustness and Security:

Problem: AI systems may be vulnerable to adversarial attacks, where subtle modifications to input data can lead to incorrect outputs.

Problem Space: Research in adversarial machine learning focuses on making AI models more robust and secure against malicious manipulations.

Case Studies and Scenario (6/6)

Human-AI Collaboration:

Problem: Integrating AI systems into human workflows requires addressing challenges related to user interaction, trust, and the effective collaboration between humans and machines.

Problem Space: Designing AI systems with user-friendly interfaces, promoting transparency, and considering human factors in AI development.

Problem, Problem Space → Search

For example, in the problem of route planning, the problem space includes all possible locations on the map as states and all valid roads or paths between them as actions.

Search: Search is the process of exploring the problem space to find a sequence of actions or moves that lead to the goal state or a satisfactory solution. In AI, search algorithms are used to systematically navigate through the problem space and discover paths or solutions that satisfy the problem's constraints and objectives.

Problem, Problem Space → Search

In summary, a problem is a task or challenge that requires a solution, the problem space represents all possible configurations and actions related to the problem, and search involves exploring the problem space to find a sequence of actions leading to the desired goal or solution.

Efficient search algorithms are essential in AI problem-solving to effectively navigate large and complex problem spaces and find optimal or near-optimal solutions.

Problem, Problem Space → Search

The search process involves starting from the initial state and exploring possible actions to generate new states. These states are then evaluated based on certain criteria **(e.g., distance to the goal, cost, or utility)** to determine the most promising states to explore further. **The process continues iteratively until the goal state is reached or a satisfactory solution is found.**

Problem, Problem Space → Search

There are various search algorithms used in AI, such as **depth-first search**, **breadth-first search**, **A* search**, **and heuristic search.** Each algorithm has its strengths and weaknesses, and the choice of search algorithm depends on the problem's characteristics, size of the problem space, and the resources available.

To solve the problem of building an AI system

1. **Define the problem accurately** including detailed specifications and what constitutes a suitable solution.

2. **Scrutinize the problem carefully**, for some features may have a central effect on the chosen method of solution.

3. **Segregate and represent** the background knowledge needed in the solution of the problem.

4. **Choose the best solving techniques** for the problem to solve a solution

Characteristics of a Problem in AI

Complexity: AI problems often involve intricate relationships and intricate patterns that require advanced algorithms to decipher.

Ambiguity: Many AI problems have unclear or incomplete information, making it challenging to precisely define the problem or its solution.

Dynamic Nature: Real-world problems evolve over time, necessitating AI systems to adapt and learn continuously to remain effective.

Data Dependence: AI heavily relies on data, and the quality, quantity, and relevance of the data significantly impact the performance and accuracy of the solution.

Characteristics of a Problem in AI

Resource Intensiveness: Developing and solving AI problems often demands substantial computational resources, both in terms of processing power and memory.

Uncertainty: AI systems often operate in environments with inherent uncertainty, requiring them to make decisions or predictions based on incomplete or probabilistic information.

Interdisciplinary Complexity: AI problems often require expertise from various domains, combining knowledge from computer science, mathematics, and specific application areas for effective solutions.

Ethical Considerations: As AI systems influence decision-making, ethical concerns such as bias, fairness, and privacy become crucial aspects of problem-solving.

Characteristics of a Problem in AI

Scalability: The ability of an AI solution to handle increasing amounts of data, users, or complexity is a significant consideration in many problems.

Interpretability: Understanding and interpreting the decisions or outputs of AI systems is essential for trust and accountability, especially in sensitive applications like healthcare or finance.

Problem solving techniques in AI

Search Algorithms: Search algorithms, such as depth-first search, breadth-first search, and A* search, are fundamental techniques used in problems where the solution can be represented as a path through a state space.

Heuristic Methods: Heuristics involve using rules of thumb or guiding strategies to speed up the search for solutions. They are often applied in optimization problems to quickly reach near-optimal solutions.

Knowledge Representation and Reasoning: Representing knowledge in a structured manner and using logical reasoning to draw inferences is crucial for problem-solving. This involves creating knowledge bases.

Problem solving techniques in AI

Machine Learning: Leveraging machine learning techniques, such as supervised learning, unsupervised learning, and reinforcement learning, allows AI systems to learn from data and improve their performance over time.

Constraint Satisfaction: Constraint satisfaction involves finding a solution that satisfies a set of constraints. This approach is commonly used in scheduling, planning, and optimization problems.

Search techniques in AI

Uninformed Search:

Approach: Blindly explores the problem space without considering any additional information about the state or the goal.

Examples: Depth-First Search (DFS), Breadth-First Search (BFS), Uniform-Cost Search (UCS).

Informed Search:

Approach: Utilizes heuristic information to guide the search more intelligently, considering estimates of the remaining cost to the goal.

Examples: A* Search Algorithm, Greedy Best-First Search, Hill Climbing, Simulated Annealing.

Search techniques in AI

Informed search methods use heuristics to make more informed decisions about which paths to explore, potentially leading to more efficient solutions.

Uninformed search, on the other hand, explores the search space without utilizing additional knowledge about the problem.

Search techniques in AI

Informed search	Uninformed search
Also known as Heuristic search	Also known as Blind search
Requires information to perform search	Do not require information to perform search.
Quick solution to problem.	May be time comsuming.
Cost is low.	Comparitively high in cost.
It can be both complete and incomplete.	It is always bound to complete.
The AI gets suggestions regarding how and where to find a solution to any problem.	The AI does not get any suggestions regarding what solution to find and where to find it. Whatever knowledge it gets is out of the information provided.
Eg. Greedy Search A* Search AO* Search Hill Climbing Algorithm	Eg. Depth First Search (DFS) Breadth First Search (BFS) Branch and Bound

Search techniques in AI

Uninformed versus Informed (cont)

Uninformed search	Informed search
➢ look for solutions by **systematically** generating new states and checking each of them against the goal. 1. It is very **inefficient** in most cases. 2. Most successor states are “obviously” a bad choice. 3. Such strategies do not use problem-specific knowledge	1. They are almost always **more efficient** than uninformed strategies. 2. May reduce time and space complexities. 3. Evaluation function f(n) measures distance to the goal. 4. Order nodes in **Frontier** according to f(n) and decide which node to expand next.

Search techniques in AI

Uninformed vs. Informed Search

- **Uninformed Search Strategies**
  - Breadth-First search
  - Depth-First search
  - Uniform-Cost search
  - Depth-First Iterative Deepening search
- **Informed Search Strategies**
  - Hill climbing
  - Best-first search
  - Greedy Search
  - Beam search
  - Algorithm A
  - Algorithm A*

Heuristic Search techniques in AI

Heuristics

- To solve larger problems, domain-specific knowledge must be provided to improve the search efficiency
- Heuristic
  – Any advice that is often effective but is not always guaranteed to work
- Heuristic Evaluation Function
  – Estimates cost of an optimal path between two states
  – Must be inexpensive to calculate
  – $h(n)$

Heuristic Search techniques in AI

Admissible Heuristic

- Let $h^*(N)$ be the cost of the optimal path from N to a goal node
- The heuristic function $h(N)$ is admissible if:

$$0 \le h(N) \le h^*(N)$$

- An admissible heuristic function is always optimistic !

G is a goal node $\rightarrow$ $h(G) = 0$

Heuristic Search techniques in AI

Searching and AI

- Searching falls under Artificial Intelligence (AI).
- A major goal of AI is to give computers the ability to think, or in other words, mimic human behavior.
- The problem is, unfortunately, computers don't function in the same way our minds do.
- They require a series of ***well-reasoned out*** steps before finding a solution.

Heuristic Search techniques in AI

Searching and AI

- Your goal, then, is to take a complicated task and convert it into simpler steps that your computer can handle.
- That conversion from something complex to something simple which computer can easily solve.

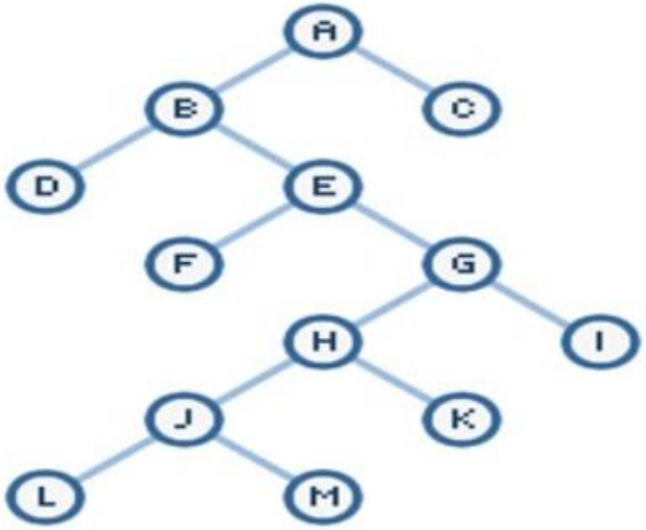
Heuristic Search techniques in AI

Searching and AI

- Let's first learn how we humans would solve a search problem.
  - First, we need a representation of how our search problem will exist.
  - We normally use search tree for representation of how search problem will exist.
- It is a series of interconnected nodes that we will be searching through
- Let us see diagram below

Heuristic Search techniques in AI

Searching and AI



- In our above graph, the path connections are not two-way. All paths go only from top to bottom. In other words, A has a path to B and C, but B and C do not have a path to A.

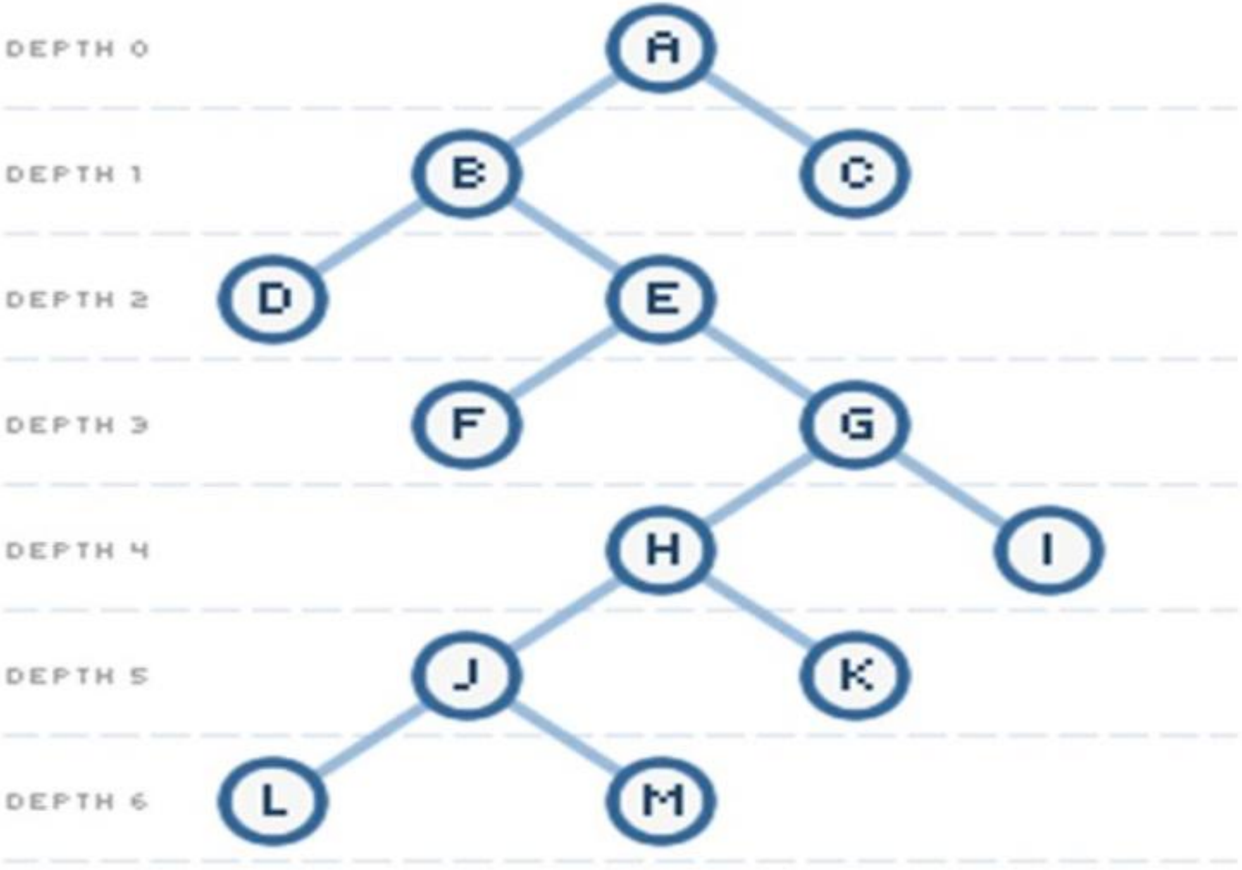
Heuristic Search techniques in AI

Searching and AI

- Each lettered circle in our graph is a node.
- A node can be connected to other via our edge/path, and those nodes that its connects to are called neighbors.
- B and C are neighbors of A. E and D are neighbors of B, and B is not a neighbors of D or E because B cannot be reached using either D or E.
- Our search graph also contains depth:

Heuristic Search techniques in AI

Searching and AI



Heuristic Search techniques in AI

Searching and AI

- We now have a way of describing location in our graph.
- We know how the various nodes (the lettered circles) are related to each other (neighbors), and we have a way of characterizing the depth each belongs in.

Heuristic Search techniques in AI

State space search
Problem = Searching for a goal state

It is a process in which successive configurations or states of an instance are considered , with the goal of finding a goal state with a desired property

. State space- a set of states that a problem can be in.

- The group consisting of all the attainable states of a problem

ex: Customers in a line would have state space {0,1,2….}

Heuristic Search techniques in AI

Search Problem

S: the full set of states

S_0 :the initial state

A:S→S set of operators

G : the set of final states.

G is subset of S

Search problem:

Find a sequence of actions which transforms the agent from the initial state to goal state.