Unit 2: Advanced Search Methods & Knowledge Representation

1. Heuristic Search Methods

1.1 Definition

A **heuristic search** is an informed search strategy that uses a **heuristic function** to estimate the best path to the goal. It improves search efficiency by guiding the search towards promising paths.

1.2 Characteristics

- Uses **domain-specific knowledge** to make decisions.
- Reduces the number of states to explore.
- Often faster than uninformed search methods.

1.3 Examples of Heuristic Functions

- **Manhattan Distance** in pathfinding problems.
- **Hamming Distance** in text comparison.

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2. Generate and Test

2.1 Definition

A brute-force approach where **possible solutions are generated and tested** against the goal criteria.

2.2 Steps

1. Generate a potential solution.
2. Test whether it satisfies the goal.
3. If successful, return the solution; otherwise, repeat.

2.3 Example

Solving a **Sudoku puzzle** by trying different numbers and checking constraints.

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3. Hill Climbing

3.1 Definition

A local search technique that **continuously moves in the direction of increasing value** (closer to the goal).

3.2 Steps

1. Start from an initial state.
2. Evaluate the neighboring states.
3. Move to the neighbor with the highest value.
4. Repeat until a peak (local maximum) is reached.

3.3 Disadvantages

- **Gets stuck in local maxima** (suboptimal solutions).
- May suffer from **plateaus and ridges** (flat regions where progress is slow).

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4. Best-First Search

4.1 Definition

An informed search strategy that expands the **most promising node first**, using a heuristic function.

4.2 Algorithm

1. Place the starting node in a priority queue.
2. Expand the node with the lowest heuristic cost.
3. Continue until the goal node is reached.

4.3 Example

- **A* Algorithm**, which uses both the cost so far (**g(n)**) and the estimated cost to goal (**h(n)**).

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5. Graph Search

5.1 Definition

A search technique that operates on a **graph-based problem representation**. It ensures efficient exploration by maintaining a record of visited nodes.

5.2 Types

- **Depth-First Search (DFS)**
- **Breadth-First Search (BFS)**
- **A* Algorithm**

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6. AND-OR Search Methods

6.1 Definition

A search method used in **decision-making problems** where **AND** represents multiple conditions that must be met, and **OR** represents alternative choices.

6.2 Example

- **Game playing AI**, where a move may have multiple outcomes (OR) and some conditions must be satisfied together (AND).

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7. Constraint Satisfaction Problems (CSP)

7.1 Definition

A problem-solving approach where solutions must satisfy a **set of constraints**.

7.2 Components

1. **Variables**: Elements to be assigned values.
2. **Domain**: Possible values for each variable.
3. **Constraints**: Rules that must be satisfied.

7.3 Example

- **Solving a Sudoku puzzle** with number placement constraints.

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8. Backtracking

8.1 Definition

A search technique that **explores all possible solutions recursively** and **abandons paths** that violate constraints.

8.2 Steps

1. Pick a possible solution.
2. If constraints are violated, backtrack to the previous step.
3. Repeat until a valid solution is found.

8.3 Example

- **Solving N-Queens problem** by placing queens row by row and backtracking when a conflict arises.

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9. List and String Processing

9.1 Lists

- Ordered collection of elements.
- Used in AI to store sequences of operations.

9.2 String Processing

- Manipulation of character sequences (e.g., **pattern matching, text recognition**).

9.3 Applications

- **Natural Language Processing (NLP)**.
- **Search algorithms** that process textual data.

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10. Concept of Knowledge

10.1 Definition

Knowledge represents **facts, rules, and heuristics** used by AI systems for decision-making.

10.2 Types of Knowledge

1. **Declarative Knowledge**: Facts and relationships.
2. **Procedural Knowledge**: Steps and rules to solve problems.

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11. Logic in AI

11.1 Definition

Logic is the **mathematical foundation** that allows AI to **reason and make decisions**.

11.2 Types of Logic

1. **Propositional Logic**: Deals with simple true/false statements.
2. **Predicate Logic**: Uses variables and quantifiers for complex reasoning.

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12. Propositional and Predicate Calculus

12.1 Propositional Calculus

- Uses **propositions** (statements that are true or false).
- Example:

```
A: "It is raining."
B: "I will take an umbrella."
(A → B) means "If it is raining, I will take an umbrella."
```

12.2 Predicate Calculus

- Extends propositional logic by using **variables and quantifiers**.

- Example:

```
∀x (Student(x) → Studies(x))
("For all x, if x is a student, then x studies.")
```

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13. Resolution in AI

13.1 Definition

Resolution is a **rule-based method** for logical inference in AI. It simplifies complex logical expressions into **simpler clauses**.

13.2 Example

1. Given:

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P ∨ Q (P OR Q)
¬P (NOT P)
```

2. Resolution:

```
Q (Only Q remains)
```
