FRL Definitions

- **State-Space**: The set of all possible states.
- **Optimal Solution**: A solution that meets certain criteria, such as minimizing cost, maximizing utility, or achieving the best possible outcome, given a specific problem and its constraints. It is the most desirable solution among all possible solutions available for a given problem.
- **Polynomial problems**: These are problems for which the time complexity of the best-known algorithm is polynomial in the size of the input. In other words, the time taken to solve these problems grows at most polynomially with the size of the input.
- **Non-polynomial problems**: These are problems for which the time complexity of the best-known algorithm is non-polynomial in the size of the input. In other words, the time taken to solve these problems grows exponentially or faster with the size of the input.
- **Heuristic**: The term **Heuristic** originates from the Greek word "heuriskein," which means "to discover" or "to find." It is a strategy that helps to efficiently navigate complex situations or tasks, often by simplifying the problem or focusing attention on relevant information.

Basics

- With Artificial Intelligence, our goal is to build machines and softare with intelligence similar to humans. These machines will be able to perform thinking, reasoning, decision-making, problem solving, natural language processing, just like humans.

- The main goals of an artificially intelligent system are:

  - Reasoning
  - Learning
  - Problem Solving
  - Perception ... like a human.

- When it comes to solving a problem, you need to represent the problem in such a way that the machine can understand it. Represent:

  - Precisely
  - In such a way that it can be analyzed

- The major branches of AI are:

  - Perceptive
  - Vision
  - Robotics
  - Expert Systems: stores knowledge, makes inferences from it
  - Learning systems

- Views of AI:

Thinking humanly	Thinking Rationally
Acting humanly	**Acting Rationally**

- Things AI Can Do:
    - **Natural Language Processing (NLP)**: AI can understand, interpret, and generate human language, enabling applications like chatbots and language translation.
    - **Image and Video Recognition**: AI can analyze and identify objects, faces, and scenes in images and videos, useful in security and medical imaging.
    - **Predictive Analytics**: AI can analyze historical data to make predictions about future events, aiding decision-making in finance and healthcare.
    - **Robotics and Automation**: AI can control robots and automate tasks, advancing manufacturing and logistics.
    - **Recommendation Systems**: AI can personalize content and product recommendations based on user behavior, enhancing experiences on e-commerce sites and streaming services.
- Categories of Artificially Intelligent Systems:
    - **Narrow AI (Weak AI)**: These are AI systems designed to handle a specific task or a narrow range of tasks. Examples include virtual assistants like Siri and Alexa, recommendation algorithms on Netflix, and image recognition systems.
    - **General AI (Strong AI)**: This is a theoretical concept where AI possesses the ability to understand, learn, and apply knowledge across a wide range of tasks, much like a human being. General AI can reason, solve problems, and make decisions autonomously in any situation.
    - **Superintelligence**: This refers to AI that surpasses human intelligence and capabilities. It can perform tasks and solve problems beyond human comprehension, potentially leading to breakthroughs in various fields. Superintelligence is still a hypothetical concept and has not been achieved yet.

Searching Techniques

- Uninformed & Informed Search
- Difference: +: Informed, -: Uninformed

```diff
+ Utilizes specific information about the problem domain to guide the search process.
- Lacks specific domain knowledge and relies solely on general search strategies. It is only aware of the start & goal state.
+ Generally more efficient in terms of time and space complexity.
- May be less efficient compared to informed search algorithms, especially for complex problems.
+ Designed to provide an optimal solution.
- May or may not provide an optimal solution.
+ Examples include A* search, heuristic search, and informed hill climbing.
- Examples include depth-first search, breadth-first search, and uniform-cost search.
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State-Space Search

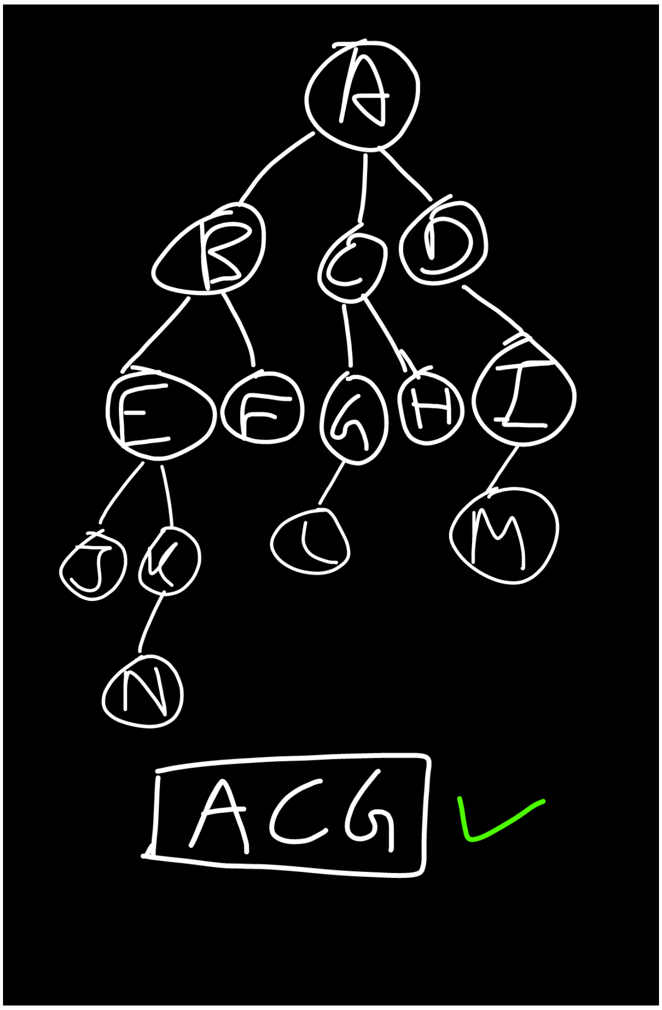
- State-Space: The set of all possible states.
- Set: {S,A,Action(s), Result(s,a), Cost(s,a)}

- S: Start, Goal
- A: The set of all possible actions.
- Action(s): The action we chose to execute.
- Result(s,a): State formed as a Result of the action.
- Cost(s,a): Cost of execute the action. The goal is to minimize the cost.

Breadth-First Search

- Type: Uninformed Search.
- Based on: FIFO (Queue).
- Time complexity: $O(b^d)$
  - b: Branch factor, maximum number of children of a node.
  - d: Depth: Maximum Level of the tree, root node is at Level 0.
- Optimal, provides the best solution, if costs of all nodes is the same.
- Complete, always provides a solution.
- Example 0 (Start: A, Goal: G):
  1. A
  2. ~~A~~BCD
  3. ~~B~~CDEF
  4. ~~C~~DEFGH
  5. ~~D~~EFGHI
  6. ~~E~~FGHIJK
  7. ~~F~~GHIJK
  8. ~~G~~HIJKL
  - G was found. Result: ACG.

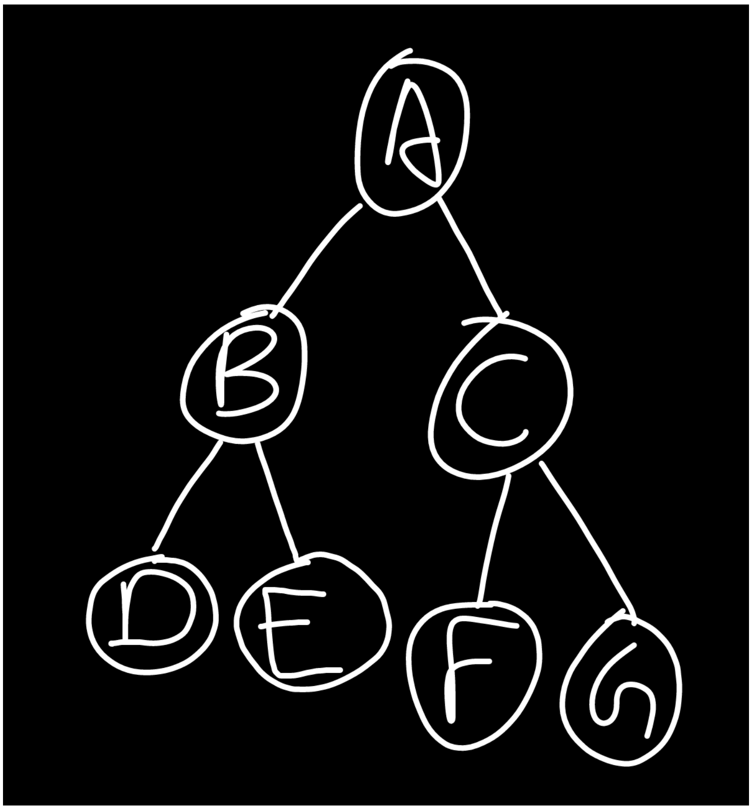
    - Note the implementation of FIFO: Elements are removed from LHS, and inserted from RHS.



Depth-First Search

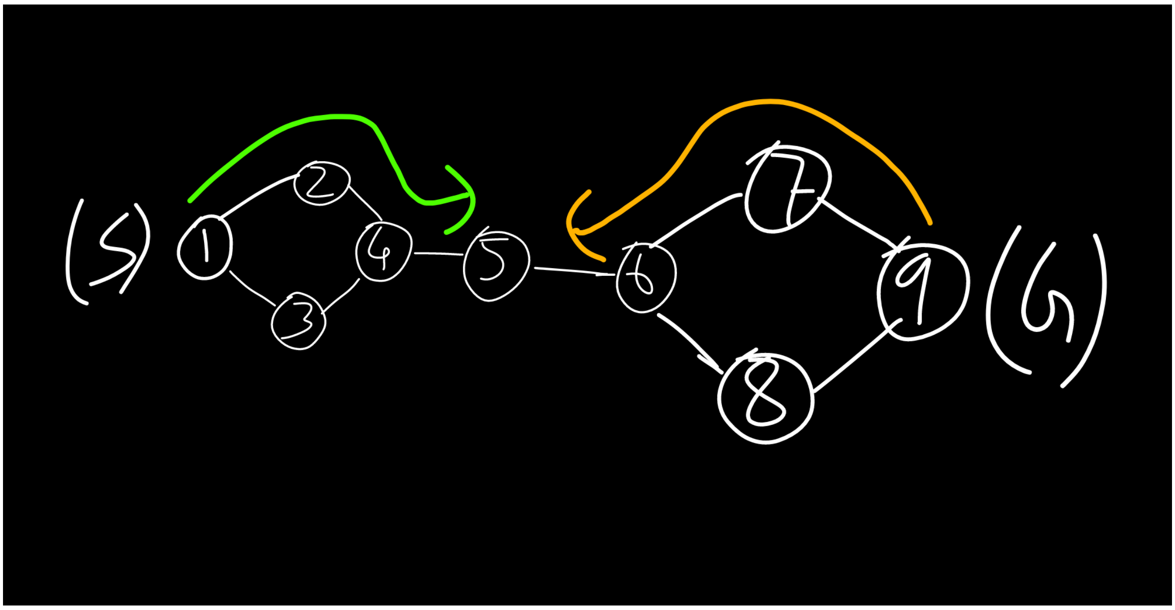
- Type: Uninformed Search.
- Based on: LIFO (Stack).
- Time complexity: $O(b^d)$
    - b: Branch factor, maximum number of children of a node.
    - d: Depth: Maximum Level of the tree, root node is at Level 0.
- Not Optimal, may not provide the best solution.
- Not Complete, may not provide a solution.
- Example 0 (Start: A, Goal: D):
    1. A
    2. ~~A~~BC
    3. B~~C~~FG
    4. BF~~G~~
    5. B~~F~~
    6. ~~B~~DE
    7. D~~E~~

8. ~~D~~
   - D was found. Result: ACG
   - Sequence: ACGFBED
   - Note the implementation of LIFO: Elements are removed from RHS, and inserted from RHS.



Bi-directional Search

- Type: Depends on algorithm used.
- 2 simultaneous search, one from initial node to goal node, another from goal node to initial node.
- Time complexity: $O(b^d+b^d)=O(2b^{d/2})$
  - b: Branch factor, maximum number of children of a node.
  - d: Depth: Maximum Level of the tree, root node is at Level 0.
- Complete only in case of Breadth-First Search.



8-Puzzle Problem without Heuristic

- Type: Blind / Uninformed Search.
- Based on: Breadth-First Search
- Time complexity: $O(b^d)$
  - b: Branch factor, maximum number of children of a node.
  - d: Depth: Maximum Level of the tree.
- Example 0:
  - Actions (A): UP (⬆), DOWN (⬇), LEFT (⬅), RIGHT (➡)
  - Start | End:

	S				**G**	
1	2	3	..	1	2	3
	4	6		4	5	6
7	5	8		7	8	

1. Step 1:

	0		**->**		**⬆**				**➡**				**⬇**	
1	2	3	->		2	3	..	1	2	3	..	1	2	3
	4	6	->	1	4	6		4		6		7	4	6
7	5	8	->	7	5	8		7	5	8			5	8

2. Step 2 (from puzzle ➡):

	0		**->**		**⬆**				**⬇**				**⬅**				**➡**	
1	2	3	->	1		3	..	1	2	3	..	1	2	3	..	1	2	3
4		6	->	4	2	6		4	5	6			4	6		4	6	
7	5	8	->	7	5	8		7		8		7	5	8		7	5	8

3. Step 3 (from puzzle ⬇):

	0		**->**		**⬅**				**⬆**				**➡**	
1	2	3	->	1	2	3	..	1	2	3	..	1	2	3
4	5	6	->	4	5	6		4		6		4	5	6
7		8	->		7	8		7	5	8		7	8	

4. Step 4: Puzzle **3** is the Goal State.
  - At every step, all valid moves are executed for all states, and all resultant states are determined.

Heuristic in Artificial Intelligence

- The term "heuristic" originates from the Greek word "heuriskein," which means "to discover" or "to find." It is a strategy that helps to efficiently navigate complex situations or tasks, often by simplifying the problem or focusing attention on relevant information.
- We use heuristic functions when we want to convert non-polynomial problems to polynomial problems (NP➡P).

    - **Polynomial problems**: These are problems for which the time complexity of the best-known algorithm is polynomial in the size of the input. In other words, the time taken to solve these problems grows at most polynomially with the size of the input.
    - **Non-polynomial problems**: These are problems for which the time complexity of the best-known algorithm is non-polynomial in the size of the input. In other words, the time taken to solve these problems grows exponentially or faster with the size of the input.
- It provides a good solution but **not an optimal solution**. This is because there may be other obstacles (like an infinite loop) in the path the algorithm has chosen. But in most cases, it provides a more efficient approach to brute-forcing our way to the solution.
- Examples of some functions:
    - **Eucledian Distance**: $\sqrt {(x_2-x_1)^2+(y_2-y_1)^2}$, using this we can find the shortest path from point a to point b.
    - **Manhattan Distance**:

	S		**->**		**G**	
1	3	2	->	1	2	3
6	5	4	->	4	5	6
	8	7	->	7	8	

        - Manhattan Distance: $0+1+1+2+0+2+2+0=8$
        - The distance is calculated by the number of steps each number needs to be moved, to reach the Goal state (G) from the Current state.

Searching Techniques

8-Puzzle Problem with Heuristic

- Type: Informed Search.
- Based on: Number of misplaced tiles
- Example 0:
    - Actions (A): UP (⬆), DOWN (⬇), LEFT (⬅), RIGHT (➡)
    - Start | End:

	S				**G**	
1	2	3	..	1	2	3
	4	6		4	5	6
7	5	8		7	8	

        - Number of misplaced tiles, $h=3$

    1. Step 1:

	0		**->**		**⬆**				**➡**				**⬇**	
1	2	3	->		2	3	..	1	2	3	..	1	2	3
	4	6	->	1	4	6		4		6		7	4	6
7	5	8	->	7	5	8		7	5	8			5	8

        - Number of misplaced tiles, $h=4,2,4$

- We will move forward with the lowest heuristic value.

2. Step 2 (from puzzle ➡):

	0		->		⬆				⬇				⬅				➡	
1	2	3	->	1		3	..	1	2	3	..	1	2	3	..	1	2	3
4		6	->	4	2	6		4	5	6			4	6		4	6	
7	5	8	->	7	5	8		7		8		7	5	8		7	5	8

- Number of misplaced tiles, $h=3,1,3,3$

3. Step 3 (from puzzle ⬇):

	0		->		⬅				⬆				➡	
1	2	3	->	1	2	3	..	1	2	3	..	1	2	3
4	5	6	->	4	5	6		4		6		4	5	6
7		8	->		7	8		7	5	8		7	8	

- Number of misplaced tiles, $h=2,2,0$

4. Step 4: For Puzzle ➡, $h=0$, and it is the Goal State.
5. We had to traverse through a lot less states to reach the Goal state (G), compared to a typical Uninformed Search Technique.

Generate and Test

1. Generate a possible solution.
2. Test to see if this is an actual solution.
3. If a solution is found, otherwise repeat.

- Properties of Good Generators:
  - **Complete**
  - **Non-redundant**: They must not provide solutions which have already been generated in the past.
  - **Informed**: The Generator must have atleast some basic idea which it can use to generate an efficient solution.

Machine Learning

- Artificial Intelligence: Aimed at enabling computers to perform human-like tasks and simulate human behaviour.
- Machine Learning: Tries to solve a specific problem, and makes predictions using data.
- Data Science: Attempts to find patterns and find insights from data.

Types of Machine Learning

- Supervised: Learning where the model is trained on labeled data (all tuples have a class label associated with them) and learns to make predictions based on examples.
- Unsupervised: Learning from data without labeled responses, finding patterns and relationships on its own.

- Reinforcemend: Learning through trial and error, where an agent learns to make decisions by interacting with an environment and receiving feedback (either positive/reward or negative/penalty).