Artificial Intelligence I 2023/2024

Week 9 Tutorial and Additional Exercises

Uninformed Search

School of Computer Science

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In this tutorial. . .

In this tutorial we will be covering

- Search problem formulation and components.
- Breadth-First Search (BFS).
- Depth-First Search (DFS).

Formulating a Search Problem

Definition 1 (Search Problem Formulation and Components)

Formulating a search problem is the process to formally define a search for a solution. A search problem has five components:

- **Initial state**, the state where the agent starts its search;
- **Action set**, the set $\mathcal{A}$ describing the actions that can be executed in any state $s_i \in \mathcal{S}$;
- **Transition model**, a mapping between states and actions, i.e., the states resulting from executing each action $a_i \in \mathcal{A}$ in every state $s_i \in \mathcal{S}$;
- **Goal test**, to determine if a state is a goal state;
- **Path cost function**, which assigns a cost to each path.

- The first three components define the **state space**.
- The state space can take the form of a graph or network.

Solution, Cost and Path

Definition 2 (Solution)

The **solution** of a search problem is the sequence of actions from the initial state to a goal state.

Definition 3 (Cost)

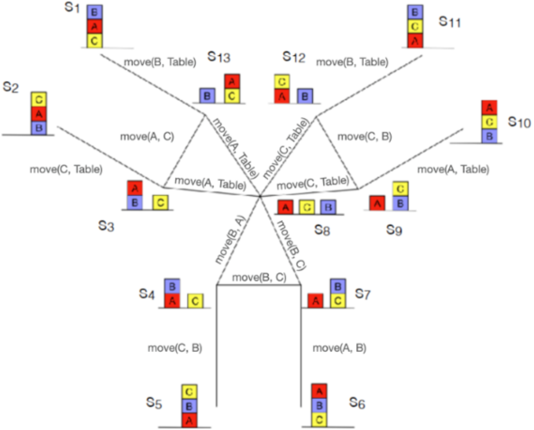
The **cost** of a solution is the sum of the cost of the actions from the initial state to the goal state.

Definition 4 (Path)

A **path** in the state space is a sequence of states connected by a sequence of actions.

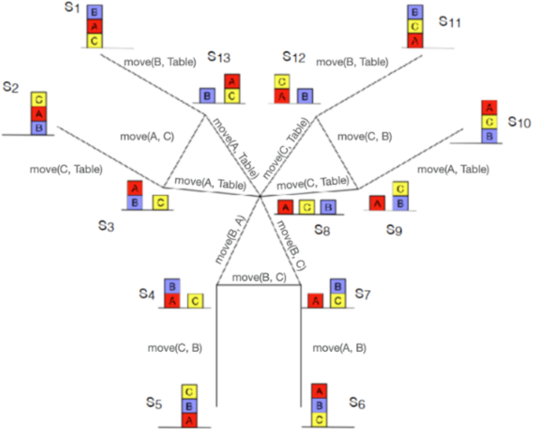
Exercise 1

- Consider the state space graph for the **three-block world**, shown to the right.
- There are three blocks and the goal is to go from one particular configuration to another.
- To do so, blocks can be placed on the table and then moved into different configurations.
- Each move costs 1.



Exercise 1 (continued)

- Provide a search problem formulation for the three-block-world.
- Identify the five components in Definition 1 for this search problem.



Uninformed Search Strategies

Definition 5 (Uninformed search)

Uninformed Search (also called **blind search**) is a term used to define the set of strategies having no additional information about the state space beyond that provided in the problem formulation.

- Uninformed search strategies can only generate successors and distinguish a goal state from a non-goal state.
- The key difference between two uninformed search strategies is the **order** in which nodes are expanded.

Breadth-First Search

- Recall the definition of Breadth-First Search.

Definition 6 (Breadth-First search)

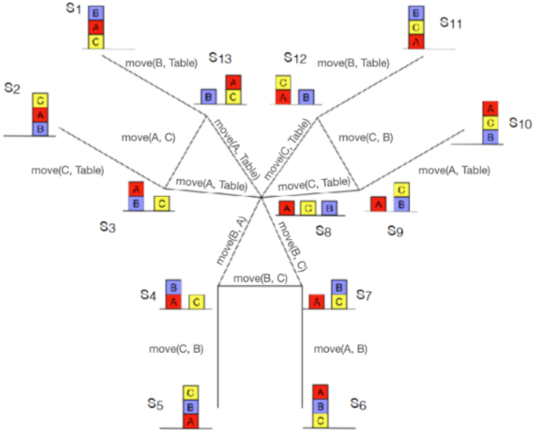
Breadth-First Search (BFS) is an uninformed search strategy in which

- the root node is expanded first;
- then, all the successors of the root node are expanded;
- then, the successors of each of these nodes are expanded;
- until the goal node is placed in the frontier.

- This is equivalent to expanding the shallowest unexpanded node in the frontier.

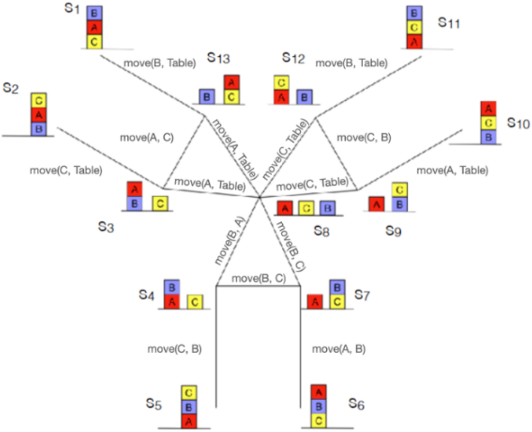
Exercise 2

- Reconsider the three-block world.
- Assume the initial state is s_{13} and the goal state is s_5.
- Use BFS from Definition 6 to solve this search problem.
- Write the BFS tree, and the sequence of nodes, in the order they are expanded.
- When multiple nodes are at the same level, expand the one with the smallest index.



Exercise 3

- Reconsider the three-block world.
- Assume the initial state is s_{13} and the goal state is s_5.
- From what we found in Exercise 2 using BFS, write the solution from Definition 2, and the corresponding cost from Definition 3.
- Also write down the path corresponding to that solution, from Definition 4.

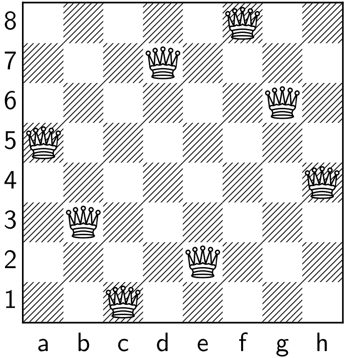


Exercise 4

- In this exercise, we consider the well-known **8 queen puzzle**.
- We start with an empty 8×8 chessboard, and the goal is to place 8 queens on the chessboard, so that there are no conflicts (no two queens attack each other).
- Recall that a queen can move any number of squares, either vertically, horizontally, or diagonally, in one move.
- Placing a queen on an empty square costs 1.
- Provide a search problem formulation for the 8 queen puzzle.
- Identify the five components in Definition 1 for this search problem.

Exercise 5

- Reconsider the 8 queen puzzle.
- Discuss how you can apply BFS to find one possible solution.
- Draw the BFS tree for the formulation you propose.
- One such solution is shown below.



Measuring Performance

- Recall some quantities for graphs, that are used to measure the performance in a search problem.

Definition 7 (Branching factor)

The **branching factor** of a graph is the maximum number of successors among its nodes.

Definition 8 (Depth)

The **depth** of a graph is the minimum level among its goal nodes.

Definition 9 (Maximum length)

The **maximum length** of a graph is the maximum level among its nodes.

Exercise 6

- Reconsider the 8 queen puzzle, and the graph formulation we gave in Exercise 5.
- Find the branching factor from Definition 7, the depth from Definition 8, and maximum length from Definition 9, of this graph.

Depth-First Search

- Recall the definition of Depth-First Search.

Definition 10 (Depth-First search)

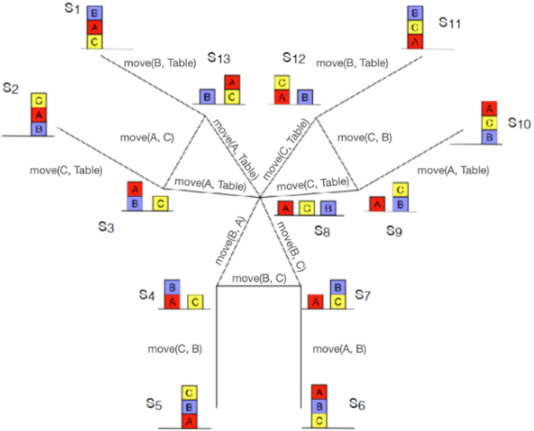
Depth-First Search (DFS) is an uninformed search strategy in which

- the root node is expanded first;
- then, the first (or one at random) successor of the root node is expanded;
- then, the deepest node in the current frontier is expanded
- until the goal node is visited.

- This is equivalent to expanding the deepest unexpanded node in the frontier.
- Note that for a DFS to terminate, the goal node must be visited, not just appear in the frontier, unlike BFS.

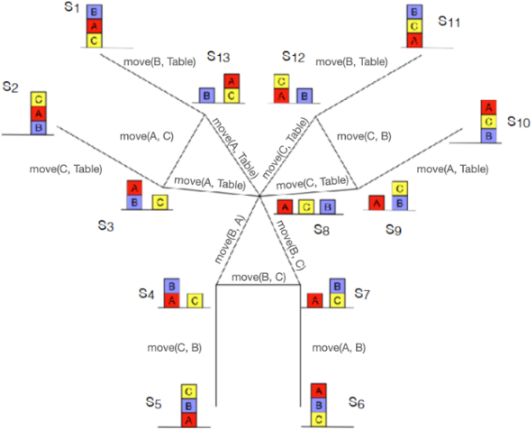
Exercise 7

- Reconsider the three-block world.
- Assume the initial state is s_1 and the goal state is s_6.
- Use DFS from Definition 10 to solve this search problem.
- Write the DFS tree, and the sequence of nodes, in the order they are expanded.
- When multiple nodes are at the same level, expand the one with the smallest index.



Exercise 8

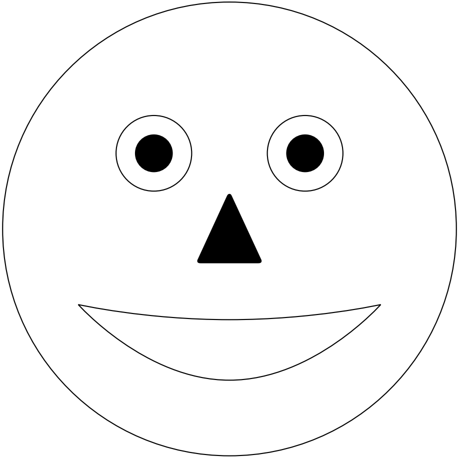
- Reconsider the three-block world.
- Assume the initial state is s_1 and the goal state is s_{13}.
- From what we found in Exercise 7 using DFS, write the solution from Definition 2, and the corresponding cost from Definition 3.
- Also write down the path corresponding to that solution, from Definition 4.



Q&A

Any questions?

Until the next time...



Thank you for your attention!