INFO8006 Introduction to Artificial Intelligence

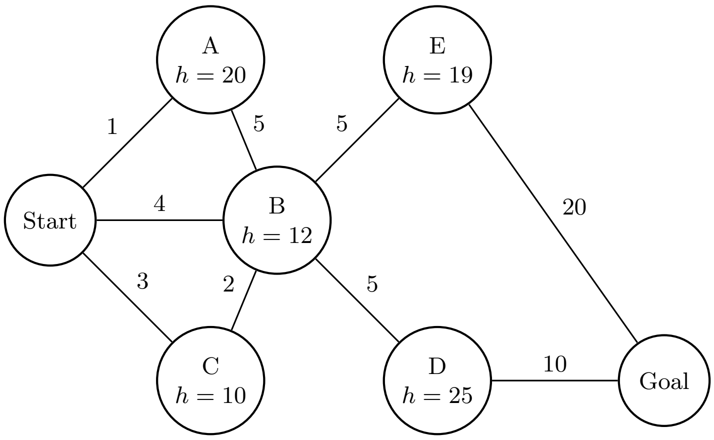
Exercises 1: Solving problems by searching

Learning outcomes

At the end of this exercise session you should be able to:

- formulate search problems rigorously.
- theoretically analyse the algorithms to perform uninformed search (depth-first, breadth-first, uniform-cost) and informed search (greedy-search, A*).
- apply each of these algorithms on search problems defined in fully observable and deterministic environments.

Exercise 1: Search algorithms

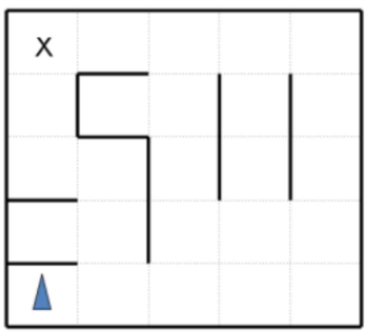


For each of the following search algorithms, give the order in which states are expanded as well as the final path returned by the algorithm. If two nodes are in competition to be expanded, the conflict is resolved by alphabetical order.

1. Depth-First search
2. Breadth-First search
3. Uniform-Cost search
4. Greedy search
5. A* (Is the heuristic admissible?)

Exercise 2: Maze Car

This exercice is taken from CS188 Spring 2014.
Consider a car event which has to exit the following maze:



At all timesteps, the agent points at direction $d \in$ (N, S, E, W). With a single action, the agent can either move forward at an adjustable velocity v or turn. The turning actions are left and right, which change the agent's direction by 90 degrees. Turning is only permitted when the velocity is zero (and leaves it at zero). The moving actions are fast and slow. Fast increments the velocity by 1 and slow decrements the velocity by 1; in both cases the agent then moves a number of squares equal to its *new* adjusted velocity. Any action that would result in a collision with a wall crashes the agent and is illegal. Any action that would reduce v below 0 or above a maximum speed V_{max} is also illegal. The agent's goal is to find a plan which parks it (stationary) on the exit square using as few actions (time steps) as possible.

As an example: if the shown agent is initially stationary, it might first turn to the east using (right), then move one square east using fast, then two more squares east using fast again. The agent will of course have to slow to turn.

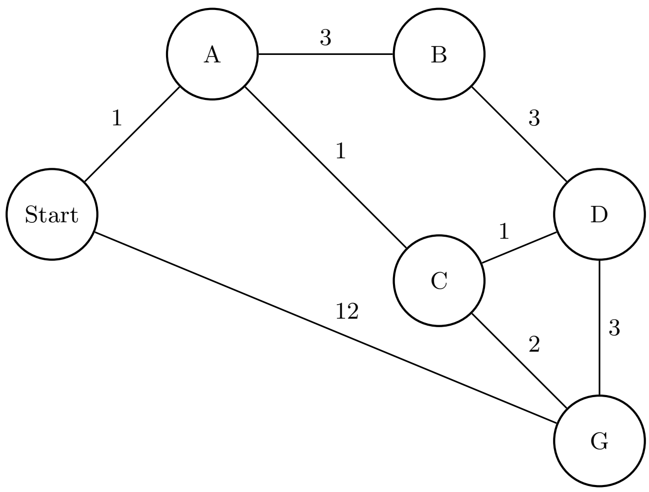
- Quiz:
  1. For a grid of size $M \times N$, what is the size of the state space? Assume that all configurations are reachable from the starting state.
  2. What is the maximum branching factor of this problem? Assume that illegal actions are simply not returned by the successor function.
  3. Is the Manhattan distance from the agent's location to the exit's location admissible?
  4. If we used an inadmissible heuristic in A* tree search, could it change the completeness of the search?
  5. If we used an inadmissible heuristic in A* tree search, could it change the optimality of the search?
- Discussion:
  1. State and motivate a non-trivial admissible heuristic for this problem.
  2. Give a general advantage that an inadmissible heuristic might have over an admissible one.

Exercise 3: Heuristic ⋆

Consider a search problem where all edges have a unit cost and the optimal solution has cost C. Let h be a heuristic which is $\max\{h^\star - k, 0\}$, where $h^\star$ is the actual cost to the closest goal and k is a non-negative constant.

1. Is h admissible?
2. Which of the following is the most reasonable description of how much more work will be done (= how many more nodes will be expanded) with heuristic h compared to $h^\star$, as a function of k?
   (a) Constant in k
   (b) Linear in k
   (c) Exponential in k
   (d) Unbounded

Exercise 4: Search algorithms ⋆



For each of the following search algorithms, give the order in which states are expanded as well as the final path returned by the algorithm. If two nodes are in competition to be expanded, the conflict is resolved by alphabetical order.

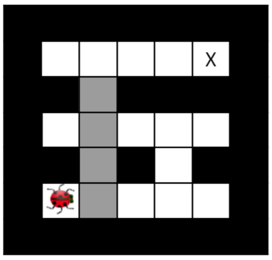
1. Depth-First search
2. Breadth-First search
3. Uniform-Cost search
4. Consider the following heuristics: which one is not admissible? Why?
5. Use the admissible heuristic to apply A* algorithm.

State	h_1	h_2
S	5	4
A	3	2
B	6	6
C	2	1
D	3	3
G	0	0

Table 1: 2 possible heuristics

Exercise 5: The hive $\star$

The hive of insects needs your help. You control an insect in a rectangular maze-like environment of size $M \times N$, as shown on the Figure below. At each time-step, the insect can move into a free adjacent cell or stay in its current location. All actions have a unit cost.
In this particular case, the insect must pass through a series of partially flooded tunnels, as illustrated by the grey cells on the map. The insect can hold its breath for A time-steps in a row. Moving into a flooded cell requires your insect to consume 1 unit of air, while moving into a free cell refills its air supply.



- Give a minimal state space for this problem (i.e., do not include extra information). You should answer for a general instance of the problem, not the specific map above.
- Give the size of your state space.

Supplementary materials

Berkeley 1

Berkeley 2

Chapter 3 of reference book