Artificial Intelligence (521279S), Spring 2022
Exercise 1 : Search methods for problem solving and optimization
Deadline for reports: Wed 26.1.2022 23:59 (+1h)

This handout contains six problems related to search methods. Problems 1-5 are just exercises to support learning and answers to them are provided in **answers1p1-5.pdf**. For Problem 6, the answer is not given and you can return an answer to it as a report. So, **include in the report only the answer to Problem 6**. The answer gives max. 1 point, which is taken into account in grading. The report can also be in Finnish.

Problems 1-3 and 5: Introduction to the state space search was provided in Lectures 2.1 and 2.2 (Track 1). See also the course book Chapter 3. Problem 4: background for local search was provided in Lecture 4.1.

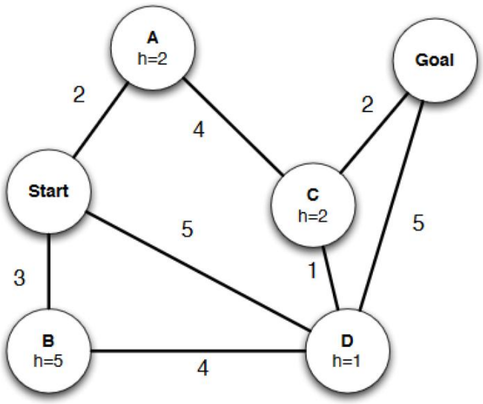
Problem 1. You are given two empty pots, whose sizes are 4 and 3 liters, and a tap is available for filling the pots with water. In addition, the water can be poured to the ground. Pots do not have any measuring markings. Consider the task of getting exactly 2 liters of water in one of the pots. When solving this problem, you want to minimize the waste of water.

(a) Formulate the problem as a state space search problem. How state can be represented? What is initial state? What is the goal test? What are the possible actions? Describe the successor function associated with the actions (next state, cost).

(b) Sketch a search tree for the problem.

(c) What is the difference between applying the graph search and tree search algorithms to this problem?

Problem 2. Consider the state space graph



where the start and goal states are indicated by naming. Work out the order in which the states are involved in node expansion, as well as the path returned by the graph search algorithm, when the search strategy is

(a) Depth-first search.

(b) Breadth-first search.

(c) Uniform cost search.

(d) Greedy search with the heuristic **h** shown on the graph.

(e) A* search with the same heuristic **h**.

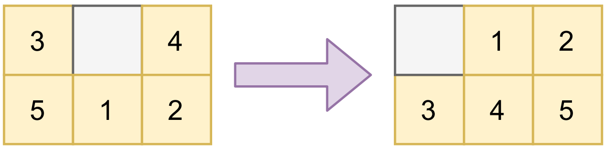
In each case, draw the tree generated by node expansions. Assume in solutions that ties resolve in such a way that states with earlier alphabetical order are expanded first. That is, use the ordering (Start, A, B, C, D, Goal).

Notes: Remember that in the graph search algorithm, a state is expanded only once. Also notice that the goal test is applied after the node is taken out from the queue (fringe) for expansion, that is, also a node referring to the Goal is put into the queue first, without checking it immediately.

Problem 3. What happens in Problem 2 if you use the tree search algorithm? Repeat each subtask (a)-(e) using this algorithm.

Problem 4. Study the article *Morris (1993) The Breakout Method for Escaping from Local Minima. Proc. AAAI-93.*[1] Explain the basic idea of the algorithm.

Problem 5. Consider the 6-puzzle problem, where starting from an initial state (an example shown on the left below) one wants to get to the goal state shown on the right. Your task is to design a state space search formulation for this problem.



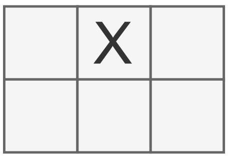
(a) How large is the state space of this problem? Justify.

(b) Define a list of actions for this problem.

(c) For each action, provide conditions for the state space for the applicability of the action.

(d) For each action, specify the associated state space transition.

(e) For each action, specify the cost of action. The cost must take into account that there is extra friction for sliding the tile from/to square X shown below. Therefore, cost of such an action is 3. Other actions have cost equal to 1.



(f) Propose a good heuristic function for this state space search problem.

[1]Downloadable from https:// www.aaai.org/Library/AAAI/1993/aaai93-007.php.

***Problem 6** [1p]. You have three jugs, measuring 12 dl (deciliter), 8 dl, and 5 dl, and a water faucet. You can fill the jugs up or empty them out from one to another or onto the ground. Initially the jugs are empty, and you need to measure out exactly 1 dl.

(a) Give a state space search formulation for this problem. For the actions in your formulation, specify action costs when

1. you just want to minimize the number of actions.
2. you just want to minimize the time for achieving the target. Assume that an action takes at least 2.0 s (seconds). In addition, the water faucet can give water at the rate of 0.2 dl/s, and you can pour water from one jug to another or onto the ground with the rate of 0.3 dl/s.

(b) Draw a search tree, which shows all states resulting from the first two actions. What is the average branching factor for this tree?

(c) Provide a solution to the problem. Use uniform cost search with the action cost for minimizing the time you determined in subproblem (a) case 2. Note: it may be a useful exercise to write a program for search in this subtask.