Supervision Assignments in AI
Easter Term 2019
Set 1: Problem Solving by Search

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1. (*Time dependence of performance measure, AIMA2.1*) Suppose that the performance measure of an agent's behaviour is concerned with just the first T time steps of the environment and ignores everything thereafter. Show that a rational agents action may depend not just on the state of the environment but also on the time step it has reached.

2. (*Robot navigation out of maze, AIMA3.2*) Your goal is to navigate a robot out of a maze. The robot starts in the center of the maze facing north. You can turn the robot to face north, east, south, or west. You can direct the robot to move forward a certain distance, although it will stop before hitting a wall.

    a. Formulate this problem. How large is the state space?

    b. In navigating a maze, the only place we need to turn is at the intersection of two or more corridors. Reformulate this problem using this observation. How large is the state space now?

    c. From each point in the maze, we can move in any of the four directions until we reach a turning point, and this is the only action we need to do. Reformulate the problem using these actions. Do we need to keep track of the robots orientation now?

    d. In our initial description of the problem we already abstracted from the real world, restricting actions and removing details. List three such simplifications we made.

3. (*Friends meeting, AIMA3.3*) Suppose two friends live in different cities on a map, such as the Romania map shown below. On every turn, we can simultaneously move each friend to a neighboring city on the map. The amount of time needed to move from city i to neighbor j is equal to the road distance $d(i, j)$ between the cities, but on each turn the friend that arrives first must wait until the other one arrives (and calls the first

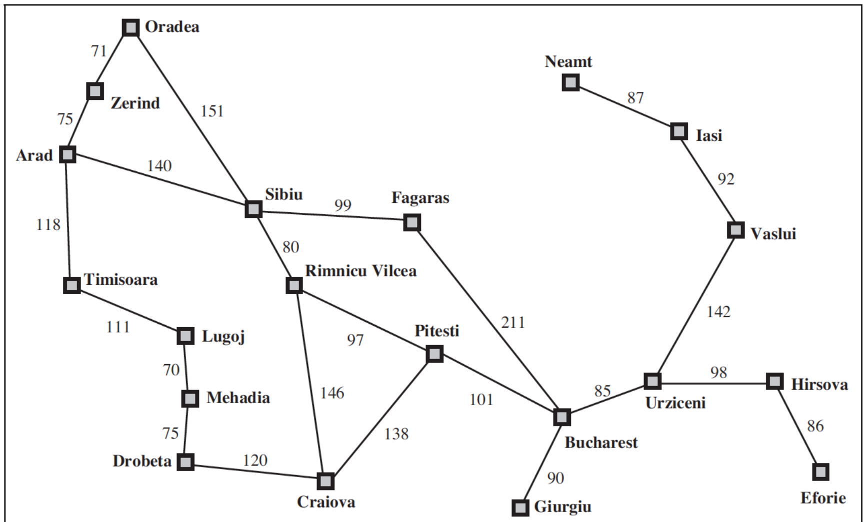

Figure 3.2 A simplified road map of part of Romania.

on his/her cell phone) before the next turn can begin. We want the two friends to meet as quickly as possible.

a. Write a detailed formulation for this search problem. (You will find it helpful to define some formal notation here.)

b. Let $D(i, j)$ be the straight-line distance between cities i and j. Which of the following heuristic functions are admissible?

  (i) $D(i, j)$

  (ii) $2D(i, j)$

  (iii) $D(i, j)/2$.

c. Are there completely connected maps for which no solution exists?

d. Are there maps in which all solutions require one friend to visit the same city twice?

4. (*True/False, 3.14*) Which of the following are true and which are false? Explain your answers.

a. Depth-first search always expands at least as many nodes as A^* search with an admissible heuristic.

b. $h(n) = 0$ is an admissible heuristic for the 8-puzzle.

c. A^* is of no use in robotics because percepts, states, and actions are continuous.

d. Breadth-first search is complete even if zero step costs are allowed.

e. Assume that a rook can move on a chessboard any number of squares in a straight line, vertically or horizontally, but cannot jump over other pieces. Manhattan distance is an admissible heuristic for the problem of moving the rook from square A to square B in the smallest number of moves.

5. (*Iterative deepening, AIMA3.18*) Describe a state space in which iterative deepening search performs much worse than depth-first search (for example, $O(n^2)$ vs. $O(n)$).

6. (*BFS/DFS/Uniform-cost, AIMA3.21*) Prove each of the following statements, or give a counterexample:

   a. Breadth-first search is a special case of uniform-cost search.

   b. Depth-first search is a special case of best-first tree search.

   c. Uniform-cost search is a special case of A^* search.

7. (*n-queens, AIMA4.4*) Generate a large number of 8-puzzle and 8-queens instances and solve them (where possible) by hill climbing (steepest-ascent and first-choice variants), hill climbing with random restart, and simulated annealing. Measure the search cost and percentage of solved problems and graph these against the optimal solution cost. Comment on your results.

8. (*n-queens, AIMA3.5*) An efficient incremental formulation of n-queens problem is as follows:

   - States: All possible arrangements of n queens ($0 \leq n \leq 8$), one per column in the leftmost n columns, with no queen attacking another.
   - Actions: Add a queen to any square in the leftmost empty column such that it is not attacked by any other queen.

   Explain why the state space has at least $\sqrt[3]{n!}$ states and estimate the largest n for which exhaustive exploration is feasible. (Hint: Derive a lower bound on the branching factor by considering the maximum number of squares that a queen can attack in any column.)

9. *(A^*, AIMA3.23)* Trace the operation of A^* search applied to the problem of getting to Bucharest from Lugoj using the straight-line distance heuristic. That is, show the sequence of nodes that the algorithm will consider and the f, g, and h score for each node.

10. *(Consistent/admissible heuristics, AIMA3.29)* Prove that if a heuristic is consistent, it must be admissible. Construct an admissible heuristic that is not consistent.

11. (*Online-DFS, AIMA4.14*) Like DFS, online DFS is incomplete for reversible state spaces with infinite paths. For example, suppose that states are points on the infinite two-dimensional grid and actions are unit vectors $(1, 0)$, $(0, 1)$, $(1, 0)$, $(0, 1)$, tried in that order. Show that online DFS

starting at $(0,0)$ will not reach $(1,1)$. Suppose the agent can observe, in addition to its current state, all successor states and the actions that would lead to them. Write an algorithm that is complete even for bidirected state spaces with infinite paths. What states does it visit in reaching $(1,1)$?

12. (*AIMA4.1*) Give the name of the algorithm that results from each of the following special cases:

    a. Local beam search with $k = 1$.

    b. Local beam search with one initial state and no limit on the number of states retained.

    c. Simulated annealing with $T = 0$ at all times (and omitting the termination test).

    d. Simulated annealing with $T = \infty$ at all times.