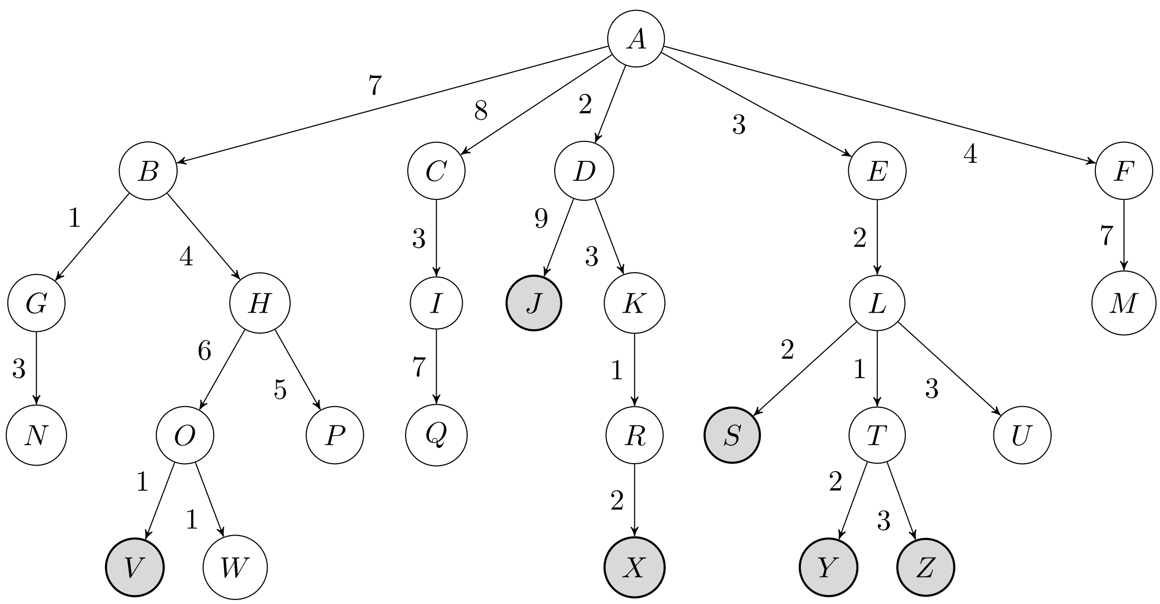
Einführung in Künstliche Intelligenz SS 2014, 2.0 VU, 184.735

Exercise Sheet 1 – Agents and Search

For the presentation part of this exercise, mark your solved exercises in **TUWEL** until **Monday, April 13, 13:00 CET**. Be sure that you tick only those exercises that you can solve and explain in detail with the necessary theoretical background! In particular note that ticking exercises which you do not understand can result in the denial of **all exercises** of this sheet!

Please ask questions in the **TISS** Forum or visit our tutors during the tutor hours (see **TUWEL**).

Exercise 1 (2 pts.): Consider the following search tree (the grey nodes are goal nodes):



Determine for the following search strategies the order in which the nodes are expanded and the corresponding goal node. In case you can expand several nodes and the search strategy does not specify the order, choose the nodes in alphabetic sequence. In addition, compute for each search strategy the set of nodes that is actually kept in memory when the goal node is found (node A has depth zero).

- Breadth First Search
- Uniform-Cost Search
- Depth First Search
- Depth-Limited Search (use a limit of 3)
- Iterative Deepening Search

Exercise 2 (2 pts.): In this exercise, we will see that some agents which have rich enough capabilities of *self-consciousness* cannot exist in principle. To this end, we define the notion of a *Gödelian agent*[1]

[1] The self-referential character of this agent is very similar to the self-referential techniques used on the proofs of Gödel's seminal incompleteness results. Do not get scared, to solve this exercise you do not need to know anything about these.

as follows. Imagine such an agent to be a device which is able to tell us statements of a specific form. The statements the agent can tell us are build up using the following symbols:

$$\neg, T, N, (,)$$

We call all the statements which we can form using these symbols the *language* of our agent. For example, the statement $\neg T(T)$ is in the agent's language. The *norm* of a statement X is the statement $X(X)$. Not all statements in this language are meaningful. A *sentence* is a statement if it is of one of the following forms:

1. $T(X)$,
2. $\neg T(X)$,
3. $TN(X)$,
4. $\neg TN(X)$.

(Here, X is an arbitrary statement.) We now assign *truth values* to sentences as follows:

1. $T(X)$ is true iff X can be told by the agent;
2. $\neg T(X)$ is true iff X cannot be told by the agent;
3. $TN(X)$ is true iff the norm of X can be told by the agent;
4. $\neg TN(X)$ is true iff the norm of X cannot be told by the agent.

We assume our agent to be trustworthy, i.e., we assume that whenever the agents tells us a sentence, then it is true. Now your task is to show that, under this assumption, the opposite does not hold, i.e., prove that there is a true statement which cannot be told by our trustworthy agent. *Hint:* find a statement which is true iff *the statement itself* cannot be told by the agent. Use then the assumption of trustworthiness to conclude that your statement cannot be told. Think about why your statement cannot be told and discuss the reason(s) with your teacher in class.

Exercise 3 (3 pts.):

(a) Prove that every consistent heuristic (with $h(G) = 0$ for each goal node) is admissible. **(2 pts.)**

(b) Show that there exists an admissible heuristic which is not consistent. **(1 pt.)**

Exercise 4 (2 pts.): Let h_1 and h_2 both be admissible heuristics. Check whether the following heuristics $h(h_1, h_2)$, which are combinations of h_1 and h_2, are also admissible. If $h(h_1, h_2)$ is not admissible, then estimate intervals for which admissibility is given.

(a) $h(h_1, h_2) = \frac{h_1+h_2}{c^2-h_1 \cdot h_2}$ $\qquad \forall n\colon c > h_1(n), c > h_2(n)$ **(1 pt.)**

(b) $h(h_1, h_2) = h_1 \cdot h_2$ **(1 pt.)**

Exercise 5 (2 pts.): Consider again the 8-Puzzle discussed in the lecture. Consider the discussed heuristics

- $h_1(n)$: number of misplaced tiles;

- $h_2(n)$: Manhattan distance.

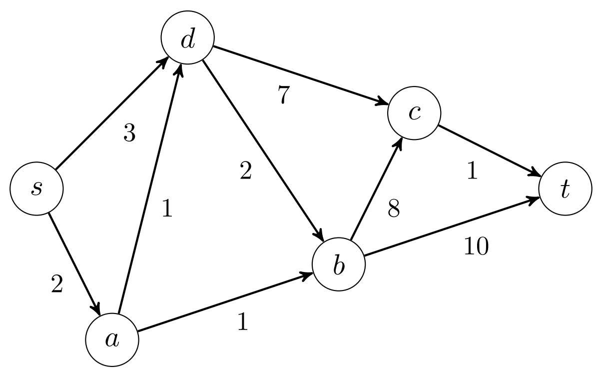
Argue whether the two suggested heuristics are admissible and/or consistent.

Exercise 6 (2 pts.): Let $f(n) = c \cdot g(n) + d \cdot h(n)$ be an evaluation function, where c and d are constants.

1. Define c, d, $h(\cdot)$, $g(\cdot)$ such that A* with this evaluation function is breadth first search.
2. Define c, d, $h(\cdot)$, $g(\cdot)$ such that A* with this evaluation function is depth first search.

Exercise 7 (2 pts.):

(a) Perform the A* algorithm using the given heuristic function h on the following graph in order to find a shortest path from s to t. In which order are the nodes expanded? Show the contents of the priority queue at each iteration.



$$h(s) = 10, h(a) = 3, h(b) = 2, h(c) = 1, h(d) = 7, h(t) = 0$$

(1 pt.)

(b) Which of the following statements are true and which are false? Explain your answers.

1. Depth First Search always expands at least as many nodes as A* search with an admissible heuristic.
2. 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 figures. Manhattan distance is an admissible heuristic for the problem of moving the rook from square A to square B with the smallest number of moves.
3. Breadth First Search is a special case of uniform-cost search.

(1 pt.)