Foundations of Artificial Intelligence

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Exercise Sheet 10

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Exercise 10.1 (Problem formalization and FF)

On the exercise web page you can find the FF planning system and the description of two planning instances. The domain description `truck-domain.pddl` specifies the set of used predicates and the actions of the domain. Concrete instances for this domain are given in the files `trucks-problem-1.pddl` and `trucks-problem-2.pddl`: the problem description in these files states the existing objects, the initial state and the goal formula.
In the given planning domain there are several cities in which trucks can drive to transport packages from their origin to their destination location. Within one city a truck can arbitrarily drive between the locations and there is no restriction on the number of packages loaded. Furthermore, a truck cannot drive between cities. The possible actions of this domain are the loading and unloading of packages and driving the truck from one location to another.

(a) Have a closer look to the planning task defined in `trucks-problem-1.pddl` and depict it (draw the locations and the positions of the trucks and the packages. Make clear, where the trucks can drive and where the packages should be delivered to.)

(b) Solve this planning instance with the FF planning system by calling it as follows:

```
./ff -o trucks-domain.pddl -f trucks-problem-1.pddl
```

State the plan that is found by the system. Is it optimal, i.e. is there no shorter plan for this planning instance? Justify your answer.

(c) If you try to solve the second planning instance with FF, it will inform you that the instance is unsolvable. Is this really the case? Why?

Modify the domain descrition in such a way that one can use not only the trucks but also airplanes. These should be able to fly between airports, also if these are located in different cities. Since the trucks should be able to drive to the airports, the airports are also normal locations.

Modify the planning task in `trucks-problem-2.pddl` in such a way that `loc-1-4` and `loc-2-1` are airports and that there is an airplane that is initially located at `loc-2-1`.

Use the FF system to solve the modified planning instance (for the new domain). State the plan found by FF and send the modified domain and instance description files by e-mail to your tutor.

Exercise 10.2 (Complexity of monotonic planning)

Assume "propositional STRIPS planning". "Propositional STRIPS planning" is planning in which an initial state is a finite set of ground atoms, specifying exactly the atoms that are initially true (i.e. all other ground atoms are initially false). The preconditions of operators are conjunctions of ground atoms and the effects conjunctions of ground literals. Hence, operators in this model do not have any variables. The goal is specified as a set of ground atoms. *Monotonic* planning considers operators having only positive effects.

In the lecture, we have stated that the decision problem for monotonic planning, i.e. to determine the existence of a solution is solvable in polynomial time.

- Specify an algorithm with polynomial time complexity in the size of operators solving the decision problem for monotonic, propositional STRIPS planning. Justify why your algorithm is correct.

To describe the computational complexity of an optimization problem, it is converted into the decision problem determining whether a given bound can be achieved.

- Show that it is NP-hard to determine the existence of a solution of $k \in \mathbb{N}$ operators or less for monotonic, propositional STRIPS planning, where k is given as part of the input.

Exercise 10.3 (Value iteration algorithm)

Consider the following grid world. The u values specify the utilities after convergence of the value iteration and r is the reward associated with a state. Assume that $\gamma = 1$ and that an agent can perform four possible actions: **North**, **South**, **East** und **West**. With probability 0.7 the agent reaches the intended state, with probability 0.2 it moves to the right of the intended direction, and with probability 0.1 to the left.

$u = 8$	$u = 15$	$u = 9$
$u = 2$	$r = 2$	$u = 7$
$u = 4$	$u = 16$	$u = 11$

Which is the best action an agent can execute if he is currently in the center state of the grid world? Justify your answer. Which utility does the center state have?

If you are beyond this exercise interested into getting a feeling for the behaviour of the value iteration algorithm (especially for the influence of the discount rate and the initial values of the fields), you can try out our applet at
`http://www.informatik.uni-freiburg.de/~burgard/vi/vi.html`.

Exercise 10.4 (Policy iteration algorithm)

Let $\gamma = 0.5$ and let there be only the actions **East** and **West**. With probability 0.9 the agent reaches the intended state (or stays where he was, if the action would move him out of the grid), and with probability 0.1 he moves in the opposite direction. The reward in the three western states is -0.05 each.

s_0	s_1	s_2	s_3
$\longleftarrow$	$\longleftarrow$	$\longleftarrow$	$r = +1$

Perform one step of the policy iteration algorithm. The initial policy is given by the arrows in the states. Give the linear system of equations for the first policy evaluation, a solution to the system as well as the first improved policy π_1.

The exercise sheets may and should be handed in and be worked on in groups of three (3) students. Please fill the cover sheet[1] and attach it to your solution.

[1] http://www.informatik.uni-freiburg.de/~ki/teaching/ss09/gki/coverSheet-english.pdf