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Theoretical Exercise Sheet 8

Deadline Friday, June 24, 23:59

About the submission of this sheet.

- You might submit the solutions to exercises in groups of up to 3 students.
- All students of a group need to be in the same tutorial.
- Write the names of **all** students of your group on your solution.
- Hand in the solution **in CMS** and use "Team Groupings".
  - Go to your personal page in CMS. Here you find the entry "Teams".
  - When you click "Create team", you get an invite code.
  - Please share this with your team mates, who need to click on "Join team" and enter the code.

1. (50 points) Consider the following problem. Some bulbs hang out of reach from the ceiling. A robot needs to repair them. The room also contains a box. Pushing that box into the correct position and climbing onto the box will bring a bulb into reach for the robot.

   The exercise is to model this problem as a STRIPS planning task. In doing so, assume the following framework: There is a 4x4 grid (from position 1-1 to 4-4), the robot is initially at position 1-1, there are two fused bulbs at positions 2-2 and 3-3, and a box initially at the position 3-3. The robot and box are at the same height "Low", the fused bulbs are at height "High". The goal is to repair both bulbs. There are the following actions available to the robot:

   1. "*Climb-up*": If the robot is at a location adjacent to the position of the box, the robot can climb onto the box. By doing so, the robot changes its position from "Low" to "High" and moves into the location of the box.
   2. "*Climb-down*": If the robot is on the box, it can climb-down by moving to any location adjacent to the box and changing from "High" to "Low".
   3. "*Move*" from one cell to an adjacent cell, which is only possible if the robot is "Low" and the cell is clear (does not contain the box).
   4. "*Push*" the box one cell (only possible if the robot is adjacent to the box and both are "Low"). Both the robot and the box change their location. The robot is in the location where the box was and the box gets pushed to the next cell (e.g., if the robot is at 1-1 and the box is at 1-2, after executing push the robot will be at 1-2 and the box at 1-3).
   5. "*Repair*" simultaneously fixes all bulbs in the position of the robot and all adjacent positions. For this, the robot must be "High".

Your task is to encode the problem above as a STRIPS planning task. You must specify the set of facts, the initial state, goal, and define the aforementioned actions. When specifying the task, please try to be as concise as possible, i.e., use parametrization such as "$at(x, y)$ for every $x, y \in \{1, \dots 4\}$".

2. (25 points) In the following, mark all statements that are true (and only those):

   - ◯ PolyPlanLen, the problem of deciding whether there exists a plan of polynomial length, is NP-Hard.
   - ◯ For every STRIPS planning task $\Pi = (P, A, I, G)$ the number of states in the state space is exponential in $|A|$.
   - ◯ For every STRIPS planning task $\Pi = (P, A, I, G)$ the number of **reachable** states is exponential in $|P|$.
   - ◯ For every STRIPS planning task $\Pi = (P, A, I, G)$ such that $I \cap G = \emptyset$ it holds that the plan must have at least $|G|$ actions.
   - ◯ For every STRIPS planning task $\Pi = (P, A, I, G)$ such that $del_a = \emptyset$ for every $a \in A$ it holds that an optimal plan can have at most $|A|$ actions.