SAARLAND UNIVERSITY ARTIFICIAL INTELLIGENCE
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Theoretical Exercise Sheet 9

Deadline Friday, July 1, 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.

For the following questions, consider the following STRIPS planning task Π with a set of facts P, initial state I, goal G, and a set of actions A:

- Facts P:
  - $At(x, y)$: To indicate that object $x \in \{Box, Bulb, Robot\}$ is at position $y \in \{A, B, C\}$.
  - $Height(x, y)$: To indicate that object $x \in \{Box, Bulb, Robot\}$ is at height $y \in \{Low, High\}$.
  - $Pushable(x)$: To indicate that object $x \in \{Box, Bulb, Robot\}$ can be pushed.
  - $Climbable(x)$: To indicate that the robot can climb on object $x \in \{Box, Bulb, Robot\}$.
  - $RepairedBulb$: To indicate that object $Bulb$ is repaired.
- Initial state I:

$$\begin{aligned} I \;=\; & \{At(Robot, A), At(Bulb, B), At(Box, C), \\ & Height(Robot, Low), Height(Box, Low), Height(Bulb, High), \\ & Pushable(Box), Climbable(Box)\} \end{aligned}$$

- Goal $G = \{RepairedBulb, At(Robot, A)\}$

- Actions A:
  - $Go(x, y) =$

$$\begin{aligned} &pre: \{At(Robot, x), Height(Robot, Low)\} \\ &add: \{At(Robot, y)\} \\ &del: \{At(Robot, x)\} \end{aligned}$$

    for all $x, y \in \{A, B, C\}$ such that $x \neq y$.
  - $Push(x, y, z) =$

$$\begin{aligned} &pre: \{At(Robot, y), Pushable(x), At(x, y), Height(Robot, Low), Height(x, Low)\} \\ &add: \{At(x, z), At(Robot, z)\} \\ &del: \{At(x, y), At(Robot, y)\} \end{aligned}$$

    for all $x \in \{Box, Bulb, Robot\}$, $y, z \in \{A, B, C\}$ such that $y \neq z$.
  - $ClimbUp(x, y) =$

$$\begin{aligned} &pre: \{At(Robot, y), At(x, y), Climbable(x), Height(Robot, Low), Height(x, Low)\} \\ &add: \{Height(Robot, High)\} \\ &del: \{Height(Robot, Low)\} \end{aligned}$$

    for all $x \in \{Box, Bulb, Robot\}$, $y \in \{A, B, C\}$.
  - $ClimbDown() =$

$$\begin{aligned} &pre: \{Height(Robot, High)\} \\ &add: \{Height(Robot, Low)\} \\ &del: \{Height(Robot, High)\} \end{aligned}$$

  - $RepairBlub(y, z) =$

$$\begin{aligned} &pre: \{At(Robot, y), At(Bulb, y), Height(Robot, z), Height(Bulb, z)\} \\ &add: \{RepairedBulb\} \\ &del: \{\} \end{aligned}$$

    for all $x \in \{Box, Bulb, Robot\}$, $y \in \{A, B, C\}$, $z \in \{High, Low\}$.

1. (10 points) Write down an optimal plan for Π. What is the value of $h^\star(I)$?
2. (10 points) Write down an optimal relaxed plan for Π. What is the value of $h^+(I)$?
3. (10 points) Write down all states that are reachable from I by the action Go. Mark each state with $s_1, \ldots, s_n$ (where n is the number of distinct states reachable from I by the action Go).
4. (10 points) For each s_i from the previous question, write down $h^+(s_i)$.

5. (10 points) Fill the following table with the Relaxed Planning Graph for the initial state I:

F_0	$\{At(Robot, A), At(Bulb, B), At(Box, C),$ $Height(Robot, Low), Height(Box, Low), Height(Bulb, High),$ $Pushable(Box), Climbable(Box)\}$
A_0	
F_1	$F_0 \cup$
A_1	$A_0 \cup$
F_2	$F_1 \cup$
A_2	$A_1 \cup$
F_3	$F_2 \cup$

6. (15 points) Compute $h^{FF}(I)$ using the table from the previous question. And also describe the steps of the algorithm from slide 48 (Chapter 13) it the following way:

- In the table from the previous question, underline every goal fact $g \in G$ at $level(g)$ (i.e., in the row $F_{level(g)}$).
- In the table from the previous question, circle all selected actions at the level they were selected (cf. line 8 of the algorithm), as well as the facts from their preconditions added as subgoals (cf. line 9).