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Principles of AI Planning

Exercise Sheet 7

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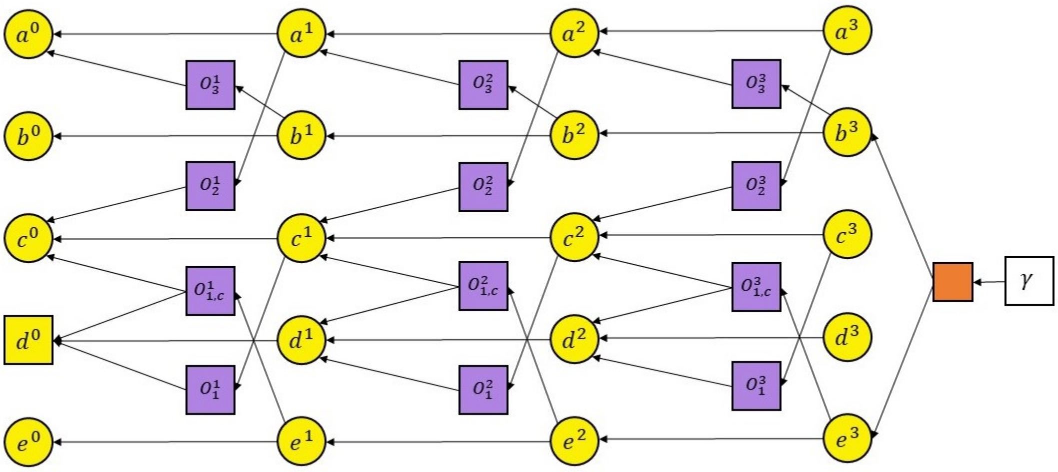
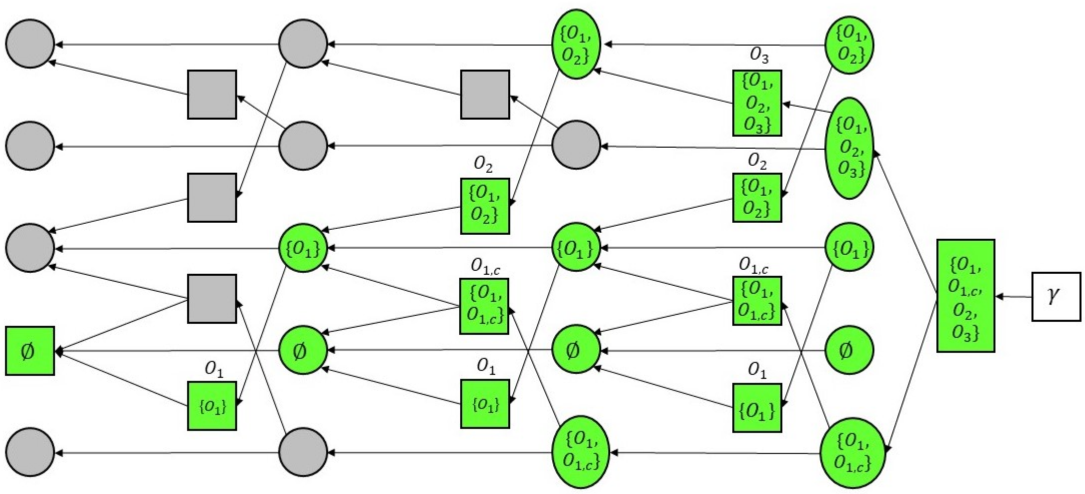
Exercise 8.1 - Relaxed planning graph and heuristics

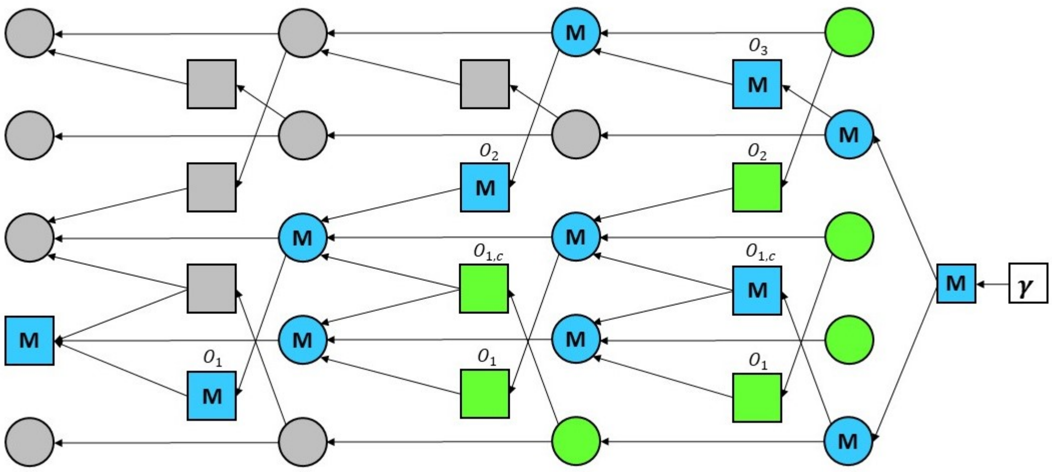
Consider the relaxed planning task Π^+ with variables $A = \{a, b, c, d, e\}$, operators $O = \{o_1, o_2, o_3\}$, $o_1 = \langle d, c \wedge (c \rhd e)\rangle$, $o_2 = \langle c, a\rangle$, $o_3 = \langle a, b\rangle$, goal $\gamma = b \wedge e$ and initial states $s = \{a \mapsto 0, b \mapsto 0, c \mapsto 0, d \mapsto 1, e \mapsto 0\}$. Solve the following by drawing the relaxed planning graph for the lowest depth k that is necessary to extract a solution



(a) **Calculate $h_{sa}(s)$ for Π^+**
The heuristic value for the initial state is 4.



(b) **Calculate $h_{FF}(s)$ for Π^+**
The heuristic value for the initial state is 4.



Exercise 8.1 - Finite domain representation

(a)Specify a planning taskt Π' that is equivalent to Π in a finite-domain representation.

FDR planning task $\Pi' = \langle V, I', O', \gamma' \rangle$

$$V = \{above - a, above - b, above - c, below - a, below - b, below - c\}$$

$$\mathcal{D}_{above\text{-}a} = \{b, c, nothing\} \qquad \mathcal{D}_{below\text{-}a} = \{b, c, table\}$$
$$\mathcal{D}_{above\text{-}b} = \{a, c, nothing\} \qquad \mathcal{D}_{below\text{-}b} = \{a, c, table\}$$
$$\mathcal{D}_{above\text{-}c} = \{a, b, nothing\} \qquad \mathcal{D}_{below\text{-}c} = \{a, b, table\}$$

$$\begin{aligned} I = \{above\text{-}a &\mapsto nothing, \\ above\text{-}b &\mapsto a, \\ above\text{-}c &\mapsto nothing, \\ below\text{-}a &\mapsto b, \\ below\text{-}b &\mapsto table, \\ below\text{-}c &\mapsto table\} \end{aligned}$$

$$O = \{move\text{-}x\text{-}y\text{-}z, move\text{-}x\text{-}table\text{-}z, move\text{-}x\text{-}y\text{-}table\}$$

$$\begin{aligned} move\text{-}x\text{-}y\text{-}z = \langle &above\text{-}y = x \wedge above\text{-}x = nothing \wedge above\text{-}z = nothing, \\ &below\text{-}x := z \wedge above\text{-}y := nothing \wedge above\text{-}z := x\rangle \end{aligned}$$

$$\begin{aligned} move\text{-}x\text{-}table\text{-}z = \langle &above\text{-}x = nothing \wedge below\text{-}x = table \wedge above\text{-}z = nothing, \\ &below\text{-}x := z \wedge above\text{-}z := x\rangle \end{aligned}$$

$$\begin{aligned} \textit{move-x-y-table} = \langle & \textit{above-y} = x \wedge \textit{above-x} = \textit{nothing}, \\ & \textit{below-x} := \textit{table} \wedge \textit{above-y} := \textit{nothing} \rangle \end{aligned}$$

for pair-wise distinct $x, y, z \in a, b, c$

$$\gamma = \textit{above-c} = b \wedge \textit{above-a} = c$$

(b) Specify the propositional planning taskt Π'' that is induced by Π'

In the induced propositional planning task $\Pi'' = \langle A, I, O'', \gamma \rangle$ the goal, initial state and propositional variables remain the same as in Π.

$$I(a) = 1 \text{ for } a \in \{\textit{A-clear}, \textit{A-on-B}, \textit{C-clear}, \textit{C-on-T}, \textit{B-on-T}\}$$
$$I(a) = 0, \text{ else.}$$

$$O'' = \{\textit{move-X-Y-Z}', \textit{move-X-Table-Z}', \textit{move-X-Y-Table}'\}$$

$$\begin{aligned} \textit{move-X-Y-Z}' = \langle & \textit{X-on-Y} \wedge \textit{X-clear} \wedge \textit{Z-clear}, \\ & \textit{X-on-Z} \wedge \neg \textit{X-on-T} \wedge \neg \textit{X-on-Y} \wedge \textit{Y-clear} \wedge \neg \textit{Z-on-Y} \wedge \neg \textit{Y-on-Z} \wedge \neg \textit{Z-clear} \rangle \end{aligned}$$

$$\begin{aligned} \textit{move-X-Table-Z}' = \langle & \textit{X-clear} \wedge \textit{X-on-T} \wedge \textit{Z-clear}, \\ & \textit{X-on-Z} \wedge \neg \textit{X-on-T} \wedge \neg \textit{X-on-Y} \wedge \neg \textit{Y-on-Z} \wedge \neg \textit{Z-clear} \rangle \end{aligned}$$

$$\begin{aligned} \textit{move-X-Y-Table}' = \langle & \textit{X-on-Y} \wedge \textit{X-clear}, \\ & \textit{X-on-T} \wedge \neg \textit{X-on-Z} \wedge \neg \textit{X-on-Y} \wedge \textit{Y-clear} \wedge \neg \textit{X-on-Y} \wedge \neg \textit{Z-on-Y} \rangle \end{aligned}$$

$$\gamma = \textit{B-on-C} \wedge \textit{C-on-A}$$

(c) How are both planning tasks Π and Π'' related? Is a plan for Π always a plan for Π'' and vice versa?

Let's analyze the operators as are the only things that changes from the original planning task Π and the induced planning task Π''

Taking as example we see *move-X-Y-Z* and *move-X-Y-Z′* They both have the same precondition but different effects, the effects of *move-X-Y-Z′* includes all the atomic effects of *move-X-Y-Z* and the following ones:

$$\neg \textit{X-on-T} \wedge \neg \textit{Z-on-Y} \wedge \neg \textit{Y-on-Z}$$

But if we analyze this, one precondition is *X-on-Y* and it is part of the same mutex group as *X-on-T*, meaning the last one is already false. Similarly *X-on-Y* is part of the same mutex group as *Z-on-Y* and then the last one is already false too. Finally with the precondition is *Z-clear* we know *Y-on-Z* is already false.

Therefore we can see that these additional effects don't change the outcome of using this operator if the given mutex groups are in fact mutually exclusive.

We can make an analogous analysis in the other 3 operators therefore we can conclude a plan for Π is always a plan for Π'' and viceversa, if the given mutex groups are correct.