

CSE 4308 / CSE 5360 - *Artificial Intelligence I*

Homework 4- Fall 2013

Sample Solution

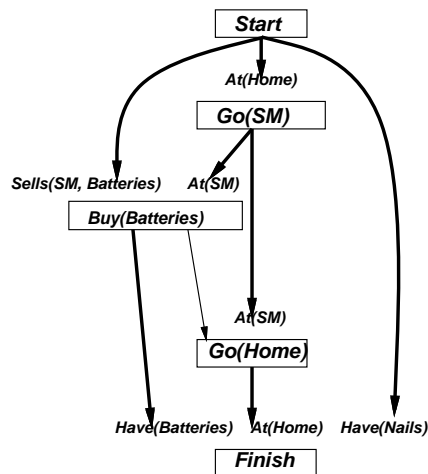
Partial-Order Plans

- For the shopping domain that we used in the class, construct a partial-order plan for the following start and goal states. The operators for this domain are:

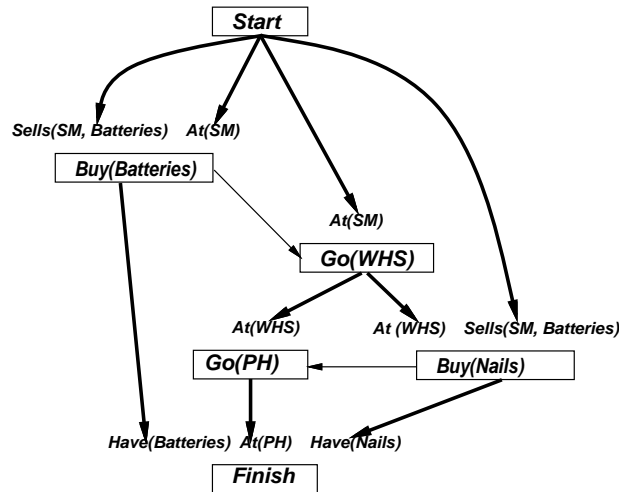
$OP(\text{ Action : } Go(y),$
 $\text{ Precond : } At(x),$
 $\text{ Effect : } At(y) \wedge \neg At(x))$

$OP(\text{ Action : } Buy(x),$
 $\text{ Precond : } At(y) \wedge Sells(y, x),$
 $\text{ Effect : } Have(x))$

- Start: $At(Home) \wedge \neg Have(Batteries) \wedge \neg Have(Tape) \wedge Have(Nails) \wedge Sells(SM, Batteries) \wedge Sells(PH, Tape)$
 Goal: $At(Home) \wedge Have(Batteries) \wedge Have(Nails)$



- b) Start: $At(SM) \wedge \neg Have(Batteries) \wedge \neg Have(Nails) \wedge Sells(SM, Batteries) \wedge Sells(PH, Tape) \wedge Sells(WHS, Nails)$
 Goal: $At(PH) \wedge Have(Nails) \wedge Have(Batteries)$



2. Extend the shopping domain from problem 1. so you can also sell items. Define the operator for selling, including all other predicates, operators, or definitions you would need (note that in order to sell something successfully you will need a customer).

Additional predicate:

$Buys(x, y)$

Additional operator:

$OP(Action : Sell(y),$

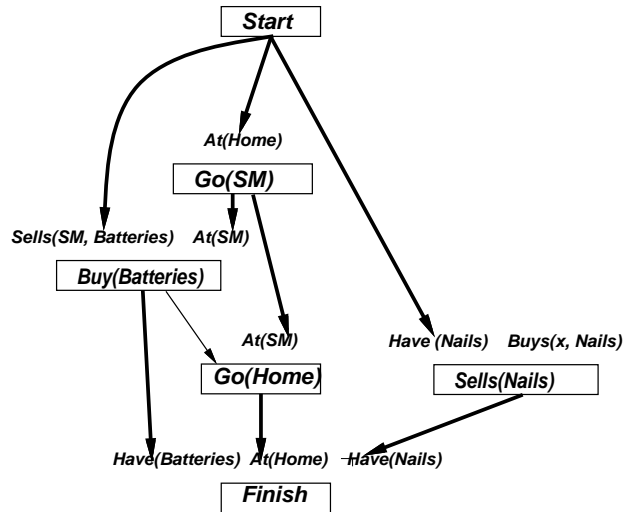
$Precond : Have(y) \wedge Buys(z, y),$

$Effect : \neg Have(y))$

Using this new operator construct a partial-order plan for the following start and goal conditions:

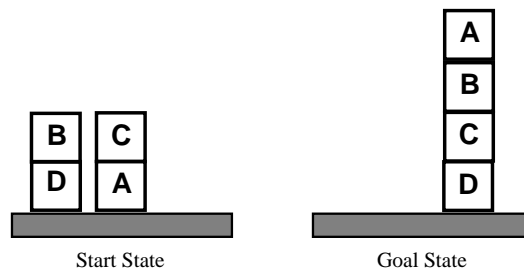
Start: $At(Home) \wedge \neg Have(Batteries) \wedge \neg Have(Tape) \wedge Have(Nails) \wedge Sells(SM, Batteries) \wedge Sells(PH, Tape)$

Goal: $At(Home) \wedge Have(Batteries) \wedge \neg Have(Nails)$



Note that this plan is not complete as the predicate $Buy(x, Nails)$ was not present in the start condition. Thus no plan is possible. alternatively a condition $Buy(A, Nails)$ could have been added to the start state and a plan could have been completed.

- Use the POP algorithm to construct a plan for the following blocks-world problem. Using the operator schemata in the book, trace the operation of the POP algorithm.



For every iteration of the algorithm show the set of plan steps, the set of ordering constraints, and the set of causal links. If necessary, resolve possible threats (i.e. threats that contain a variable) immediately with an equality constraint.

<i>Plan</i>	<i>OpenPreconditions</i>	<i>NewOperations</i>
<i>Steps</i> : $\{S_1, S_2\}$ <i>Orderings</i> : $\{S_1 \prec S_2\}$ <i>Links</i> : $\{\}$	$On(A, B), On(B, C)$ $On(C, D), On(D, Table)$	$S_1 : Start$ $S_2 : Finish$
<i>Steps</i> : $\{S_1, S_2, S_3\}$ <i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3\}$ <i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2\}$	$On(B, C), On(C, D)$ $On(D, Table), Clear(A)$ $On(A, Table), Clear(B)$	$S_3 : Move(A, Table, B)$
<i>Steps</i> : $\{S_1, S_2, S_3, S_4\}$ <i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3, S_1 \prec S_4, S_4 \prec S_2\}$ <i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2, S_4 \xrightarrow{On(B,C)} S_2\}$	$On(C, D), On(D, Table)$ $Clear(A), On(A, Table)$ $Clear(B), Clear(B)$ $On(B, Table), Clear(C)$	$S_4 : Move(B, Table, C)$
<i>Steps</i> : $\{S_1, S_2, S_3, S_4, S_5\}$ <i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3, S_1 \prec S_4, S_4 \prec S_2, S_1 \prec S_5, S_5 \prec S_2\}$ <i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2, S_4 \xrightarrow{On(B,C)} S_2, S_5 \xrightarrow{On(C,D)} S_2\}$	$On(D, Table), Clear(A)$ $On(A, Table), Clear(B)$ $Clear(B), On(B, Table)$ $Clear(C), Clear(D)$ $On(C, Table), Clear(C)$	$S_5 : Move(C, Table, D)$
<i>Steps</i> : $\{S_1, S_2, S_3, S_4, S_5\}$ <i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3, S_1 \prec S_4, S_4 \prec S_2, S_1 \prec S_5, S_5 \prec S_2\}$ <i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2, S_4 \xrightarrow{On(B,C)} S_2, S_5 \xrightarrow{On(C,D)} S_2, S_1 \xrightarrow{On(D,Table)} S_5\}$	$Clear(A), On(A, Table)$ $Clear(B), Clear(B)$ $On(B, Table), Clear(C)$ $Clear(D), On(C, Table)$ $Clear(C)$	
<i>Steps</i> : $\{S_1, S_2, S_3, S_4, S_5, S_6\}$ <i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3, S_1 \prec S_4, S_4 \prec S_2, S_1 \prec S_5, S_5 \prec S_2, S_1 \prec S_6, S_6 \prec S_2\}$ <i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2, S_4 \xrightarrow{On(B,C)} S_2, S_5 \xrightarrow{On(C,D)} S_2, S_1 \xrightarrow{On(D,Table)} S_5, S_6 \xrightarrow{Clear(A)} S_3\}$	$On(A, Table), Clear(B)$ $Clear(B), On(B, Table)$ $Clear(C), Clear(D)$ $On(C, Table), Clear(C)$ $Clear(C), On(C, A)$	$S_6 : Move(C, A, Table)$

<i>Plan</i>	<i>OpenPreconditions</i>	<i>NewOperations</i>
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<i>Plan</i>	<i>OpenPreconditions</i>	<i>NewOperations</i>
<p><i>Steps</i> : $\{S_1, S_2, S_3, S_4, S_5, S_6, S_7\}$</p> <p><i>Orderings</i> : $\{S_1 \prec S_2, S_3 \prec S_2, S_1 \prec S_3,$ $S_1 \prec S_4, S_4 \prec S_2, S_1 \prec S_5, S_5 \prec S_2,$ $S_1 \prec S_6, S_6 \prec S_2, S_4 \prec S_3, S_1 \prec S_7,$ $S_7 \prec S_2\}$</p> <p><i>Links</i> : $\{S_3 \xrightarrow{On(A,B)} S_2, S_4 \xrightarrow{On(B,C)} S_2,$ $S_5 \xrightarrow{On(C,D)} S_2, S_1 \xrightarrow{On(D,Table)} S_5,$ $S_6 \xrightarrow{Clear(A)} S_3, S_1 \xrightarrow{On(A,Table)} S_3,$ $S_1 \xrightarrow{Clear(B)} S_3, S_1 \xrightarrow{Clear(B)} S_4$ $S_7 \xrightarrow{On(B,Table)} S_4\}$</p>	<p><i>Clear(C), Clear(D)</i></p> <p><i>On(C, Table), Clear(C)</i></p> <p><i>Clear(C), On(C, A)</i></p> <p><i>Clear(B), On(B, D)</i></p>	<p><i>S₇ : Move(B, D, Table)</i></p>
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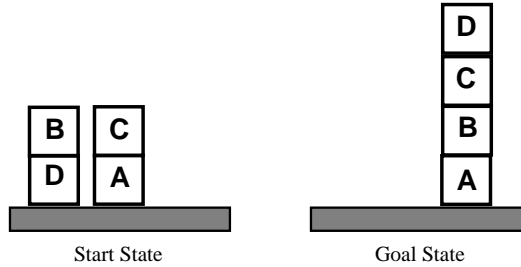
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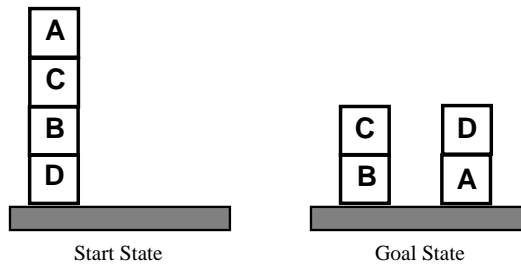
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4. Solve the following Blocks-world problems using Sensory GraphPlan (SGP). SGP is a partial order planner written in Lisp (omega has a Lisp interpreter called clisp in which you can run the program. If you want to run it on your computer you will need to install a Lisp interpreter, e.g. <http://www.clisp.org/>). You can find instructions on how to use SGP in the README file. There are also two example files, gripper.pddl and blocks.pddl. blocks.pddl is a definition of the operator for the blocks world problem and contains the Sussman anomaly as an example scenario. Your task is to modify the blocks.pddl file such as to solve the following blocks world problems. For each of the problems you are to hand in a printout of your *.pddl file and a printout of the solution the planner found.

a)



b)



Knowledge Engineering for Planning

- 5.* Consider the following robot cleaning scenario. A cleaning robot works in a house with a number of different rooms that are connected by doors that can either be open or closed. The robot can always only clean one room at a time and sometimes certain rooms are not supposed to be cleaned. To move between rooms, the robot has to sometimes open doors.

Give the initial state description (in predicate calculus) and STRIPS-style definitions for the actions (at least a clean, a moveto, and a door open action - but there could be more) in this problem. Each action schema has to contain at least the obvious preconditions and effects.

Initial State example:

$$Open(A, B) \wedge Open(B, A) \wedge \neg Open(B, C) \wedge \neg Open(C, B) \wedge ToBeCleaned(B) \wedge \neg Clean(B)$$

Operations:

$$OP(\text{ Action : } Moveto(x),$$

$$\text{ Precond : } At(y) \wedge Open(x, y),$$

$$\text{ Effect : } At(x) \wedge \neg At(y))$$

$OP(\text{ Action : } DoorOpen(x, y),$
 $\text{ Precond : } At(x) \wedge \neg Open(x, y),$
 $\text{ Effect : } Open(x, y) \wedge Open(y, x))$

$OP(\text{ Action : } Clean(x),$
 $\text{ Precond : } At(x) \wedge \neg Clean(x) \wedge ToBoCleaned(x),$
 $\text{ Effect : } Clean(x))$