ICS 271
Fall 2016
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Homework Assignment 7
Due Tuesday, 11/22

1. PDDL operator schemata

$$Init(LeftShoe(SH1) \wedge RightShoe(SH2) \wedge Sock(SK1) \wedge Sock(SK2) \wedge Hat(H) \wedge Shirt(ST) \wedge Human(Me) \\ \wedge \neg On(SH1, Me) \wedge \neg On(SH2, Me) \wedge \neg On(SK2, Me) \wedge \neg On(SK2, Me) \wedge \neg On(H, Me) \wedge \neg On(ST, Me))$$

$$Goal(On(SH1, Me) \wedge On(SH2, Me) \wedge On(SK2, Me) \wedge On(SK2, Me) \wedge On(H, Me) \wedge On(ST, Me))$$

$Action(PutOnShoesHat(s, a),$
$\quad$ PRECOND : $\neg On(s, a),$
$\quad$ EFFECT : $On(s, a))$

$Action(PutOnLeftSocks(s, a),$
$\quad$ PRECOND : $\neg On(s, a) \wedge \neg On(SH1, a),$
$\quad$ EFFECT : $On(s, a))$

$Action(PutOnRightSocks(s, a),$
$\quad$ PRECOND : $\neg On(s, a) \wedge \neg On(SH2, a),$
$\quad$ EFFECT : $On(s, a))$

$Action(PutOnShirt(s, a),$
$\quad$ PRECOND : $\neg On(s, a) \wedge \neg On(H, a),$
$\quad$ EFFECT : $On(s, a))$

2. The PDDL representation was designed to make it easy to regress actions. If a domain can be expressed in PDDL, then we can do regression search on it. Given a ground goal description g and a ground action a, the regression from g over a gives us a state description g' defined by

$$g' = (g - \text{ADD}(a)) \cup Precond(a)$$

Regressively, we can find the solution from *Goal* to *Init*.

3. (a) Initial State:

$$Init(At(Monkey, A) \wedge At(Bananas, B) \wedge At(Box, C) \\ \wedge Height(Monkey, Low) \wedge Height(Box, Low) \wedge Height(Bananas, High))$$

(b) Actions:

$Action(Go(x, y),$
$\quad$ PRECOND : $At(Monkey, x),$
$\quad$ EFFECT : $At(Monkey, y) \wedge \neg At(Monkey, x))$

$Action(Push(b, x, y),$
$\quad$ PRECOND : $At(Monkey, x) \wedge At(b, x),$
$\quad$ EFFECT : $At(b, y) \wedge At(Monkey, y) \wedge \neg At(b, x) \wedge \neg At(Monkey, x))$

$Action(ClimbUp(b, x),$
$\quad$ PRECOND : $At(Monkey, x) \wedge At(b, x) \wedge Height(Monkey, low),$
$\quad$ EFFECT : $On(Monkey, b) \wedge \neg Height(Monkey, Low) \wedge Height(Monkey, High))$

$Action(ClimbDown(b),$
$\quad$ PRECOND : $On(Monkey, b) \wedge Height(Monkey, High),$
$\quad$ EFFECT : $\neg On(Monkey, b) \wedge \neg Height(Monkey, High) \wedge Height(Monkey, Low)$

$Action(Grasp(b),$
$\quad$ PRECOND : $Height(Monkey, h) \wedge Height(b, h) \wedge At(Monkey, x) \wedge At(b, x),$
$\quad$ EFFECT : $Have(Monkey, b))$

$Action(UnGrasp(b),$
$\quad$ PRECOND : $Have(Monkey, b),$
$\quad$ EFFECT : $\neg Have(Monkey, b))$

(c) Goal:
$Goal(Have(Monkey, Bananas) \land At(Box, C))$

(d) Add $Pushable$ in above solution, $Init$ and $Action(Push)$ will be change to:
$Init(At(Monkey, A) \land At(Bananas, B) \land At(Box, C) \land Height(Monkey, Low)$
$\quad \land Height(Box, Low) \land Height(Bananas, High) \land Pushable(Box))$
$Action(Push(b, x, y),$
$\quad$ PRECOND : $At(Monkey, x) \land At(b, x) \land Pushable(b),$
$\quad$ EFFECT : $At(b, y) \land At(Monkey, y) \land \neg At(b, x) \land \neg At(Monkey, x))$

4. See Figure 1

5. SATPlanning Problem (Ignore $Block(A)$,$Block(B)$,$Block(C)$)

$Init^0 = On(A, Table)^0 \land On(B, Table)^0 \land On(C, Table)^0$
$\quad \land \neg On(A, B)^0 \land \neg On(A, C)^0 \land \neg On(B, A)^0 \land \neg On(B, C)^0 \land \neg On(C, A)^0 \land \neg On(C, B)^0$
$\quad \land Clear(A)^0 \land Clear(B)^0 \land Clear(C)^0$

$Goal^t = On(A, B)^t \land On(B, C)^t$

$Move(A, Table, B):$
$\quad$ PRECOND : $On(A, Table) \land Clear(A) \land Clear(B)$
$\quad$ EFFECT : $On(A, B) \land Clear(Table) \land \neg On(A, Table) \land \neg Clear(B)$

$Move(A, Table, C):$
$\quad$ PRECOND : $On(A, Table) \land Clear(A) \land Clear(C)$
$\quad$ EFFECT : $On(A, C) \land Clear(Table) \land \neg On(A, Table) \land \neg Clear(C)$

$Move(B, Table, A):$
$\quad$ PRECOND : $On(B, Table) \land Clear(B) \land Clear(A)$
$\quad$ EFFECT : $On(B, A) \land Clear(Table) \land \neg On(B, Table) \land \neg Clear(A)$

$Move(B, Table, C):$
$\quad$ PRECOND : $On(B, Table) \land Clear(B) \land Clear(C)$
$\quad$ EFFECT : $On(B, C) \land Clear(Table) \land \neg On(B, Table) \land \neg Clear(C)$

$Move(C, Table, A):$
$\quad$ PRECOND : $On(C, Table) \land Clear(C) \land Clear(A)$
$\quad$ EFFECT : $On(C, A) \land Clear(Table) \land \neg On(C, Table) \land \neg Clear(A)$

$Move(C, Table, B):$
$\quad$ PRECOND : $On(C, Table) \land Clear(C) \land Clear(B)$
$\quad$ EFFECT : $On(C, B) \land Clear(Table) \land \neg On(C, Table) \land \neg Clear(B)$

$Move(A, B, C):$
$\quad$ PRECOND : $On(A, B) \land Clear(A) \land Clear(C)$
$\quad$ EFFECT : $On(A, C) \land Clear(B) \land \neg On(A, B) \land \neg Clear(C)$

$Move(A, C, B):$
$\quad$ PRECOND : $On(A, C) \land Clear(A) \land Clear(B)$
$\quad$ EFFECT : $On(A, B) \land Clear(C) \land \neg On(A, C) \land \neg Clear(B)$

$Move(B, A, C):$
$\quad$ PRECOND : $On(B, A) \land Clear(B) \land Clear(C)$
$\quad$ EFFECT : $On(B, C) \land Clear(A) \land \neg On(B, A) \land \neg Clear(C)$

$Move(B, C, A):$
$\quad$ PRECOND : $On(B, C) \land Clear(B) \land Clear(A)$
$\quad$ EFFECT : $On(B, A) \land Clear(C) \land \neg On(B, C) \land \neg Clear(A)$

$Move(C, A, B)$:
  PRECOND : $On(C, A) \wedge Clear(C) \wedge Clear(B)$
  EFFECT : $On(C, B) \wedge Clear(A) \wedge \neg On(C, A) \wedge \neg Clear(B)$

$Move(C, B, A)$:
  PRECOND : $On(C, B) \wedge Clear(C) \wedge Clear(A)$
  EFFECT : $On(C, A) \wedge Clear(B) \wedge \neg On(C, B) \wedge \neg Clear(A)$

$MoveToTable(A, B)$:
  PRECOND : $On(A, B) \wedge Clear(A)$
  EFFECT : $On(A, Table) \wedge Clear(B) \wedge \neg On(A, B)$

$MoveToTable(A, C)$:
  PRECOND : $On(A, C) \wedge Clear(A)$
  EFFECT : $On(A, Table) \wedge Clear(C) \wedge \neg On(A, C)$

$MoveToTable(B, A)$:
  PRECOND : $On(B, A) \wedge Clear(B)$
  EFFECT : $On(B, Table) \wedge Clear(A) \wedge \neg On(B, A)$

$MoveToTable(B, C)$:
  PRECOND : $On(B, C) \wedge Clear(B)$
  EFFECT : $On(B, Table) \wedge Clear(C) \wedge \neg On(B, C)$

$MoveToTable(C, A)$:
  PRECOND : $On(C, A) \wedge Clear(C)$
  EFFECT : $On(C, Table) \wedge Clear(A) \wedge \neg On(C, A)$

$MoveToTable(C, B)$:
  PRECOND : $On(C, B) \wedge Clear(C)$
  EFFECT : $On(C, Table) \wedge Clear(B) \wedge \neg On(C, B)$

Successor state axioms:
  $F^{t+1} \Leftrightarrow ActionCausesF^t \vee (F^t \wedge \neg ActionCausesNotF^t)$

Precondition axioms:

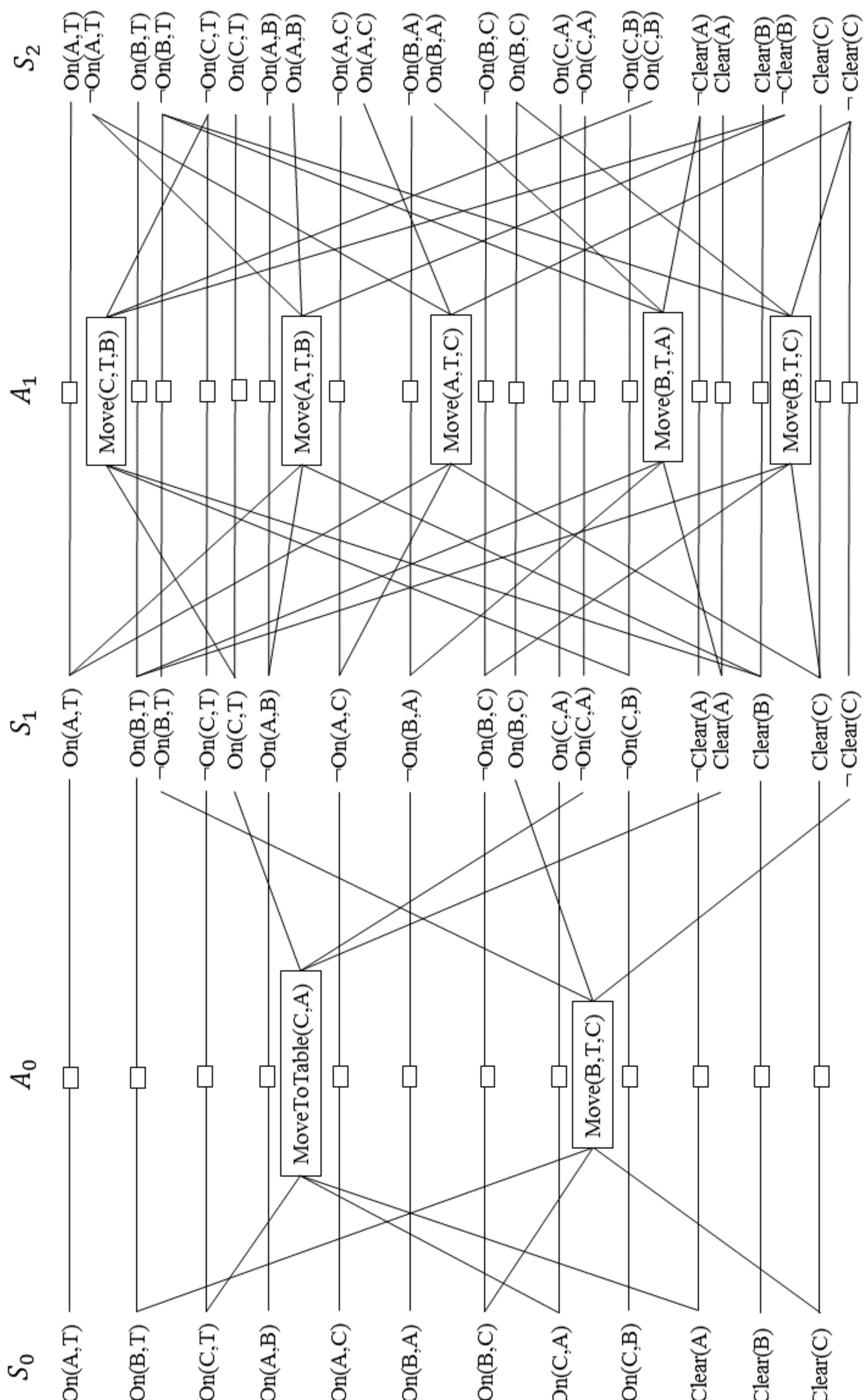
$$Move^0(A, Table, B) \Rightarrow (On(A, Table)^0 \wedge Clear(A)^0 \wedge Clear(B)^0)$$

$$\ldots$$

Action exclusion axioms: ($Action_i$ is one of the $Action$s above)

$$\bigwedge_{i \neq j} (\neg Action_i^0 \vee \neg Action_j^0)$$

$$\ldots$$



S_0
On(A,T)
On(B,T)
¬On(C,T)
¬On(A,B)
¬On(A,C)
¬On(B,A)
¬On(B,C)
On(C,A)
¬On(C,B)
¬Clear(A)
Clear(B)
Clear(C)
A_0
MoveToTable(C,A)
Move(B,T,C)
S_1
On(A,T)
On(B,T)
¬On(B,T)
¬On(C,T)
On(C,T)
¬On(A,B)
¬On(A,C)
¬On(B,A)
¬On(B,C)
On(B,C)
On(C,A)
¬On(C,A)
¬On(C,B)
¬Clear(A)
Clear(A)
Clear(B)
Clear(C)
¬ Clear(C)
A_1
Move(C,T,B)
Move(A,T,B)
Move(A,T,C)
Move(B,T,A)
Move(B,T,C)
S_2
On(A,T)
¬On(A,T)
On(B,T)
¬On(B,T)
¬On(C,T)
On(C,T)
¬On(A,B)
On(A,B)
¬On(A,C)
On(A,C)
¬On(B,A)
On(B,A)
¬On(B,C)
On(B,C)
On(C,A)
¬On(C,A)
¬On(C,B)
On(C,B)
¬Clear(A)
Clear(A)
Clear(B)
¬Clear(B)
Clear(C)
¬ Clear(C)

Figure 1: