Homework 3 solutions

1. **Unification**

   (a) $\{x/A, y/B, z/B\}$

   (b) $\{x/g(u), u/f(v)\}$

   (c) Not unifiable.

   (d) $\{y/z, z/x, z/B\}$

   (e) Not unifiable.

2. **Resolution Theorem Proving**

   (a) i. That { ¬ angel(Alice) ∧ angel(Bob) ∧ ¬ angel(Chris) }

   ii. This is impossible.

   iii.

   angel(Alice) ⇔ ¬ angel(Alice) ∧ ¬ angel(Bob) ∧ ¬ angel(Chris)
   angel(Bob) ⇔ (angel(Alice) ∧ ¬ angel(Bob) ∧ ¬ angel(Chris)) ⋁
   (¬ angel(Alice) ∧ angel(Bob) ∧ ¬ angel(Chris)) ⋁
   (¬ angel(Alice) ∧ ¬ angel(Bob) ∧ angel(Chris))

   (b)

   i. ¬ angel(Alice)
   ii. angel(Alice) ∨ angel(Bob) ∨ angel(Chris)
   iii. ¬ angel(Bob) ∨ ¬ angel(Alice)
   iv. ¬ angel(Bob) ∨ ¬ angel(Chris)
   v. ¬ angel(Alice) ∨ angel(Bob) ∨ angel(Chris)
   vi. angel(Alice) ∨ angel(Bob) ∨ ¬ angel(Chris)

   (c) equivalently:

   1. ¬ angel(Alice)
   2. ¬ angel(Alice) ∨ angel(Bob) ∨ angel(Chris)
   3. ¬ angel(Bob) ∨ ¬ angel(Chris)
   4. angel(Alice) ∨ angel(Bob) ∨ ¬ angel(Chris)

   (d) And

   from 1,2 ⇒ 5. angel(Bob) ∨ angel(Chris)
   from 1,4 ⇒ 6. angel(Bob) ∨ ¬ angel(Chris)
   from 5,6 ⇒ 7. angel(Bob)
   from 6,3 ⇒ 8. ¬ angel(Chris)

   Therefore ¬ angel(Alice), angel(Bob), ¬ angel(Chris)

3. **Reasoning about action and change**

(a)

	t= 0	t= 1	t= 2
Action(t)	Action(0)=Load(..)	Action(1)=Fly(..)	
At(Sleigh, NorthPole, t)	T	?	?
At(Sleigh, AVW,t)	?	?	T
At(Machine1, NorthPole, t)	?	?	?
At(Machine1, AVW, t)	?	?	?
On(Machine1, Sleigh, t)	T	?	?
At(Machine2, NorthPole, t)	T	?	?
At(Machine2, AVW, t)	?	?	?
On(Machine2, Sleigh, t)	F	T	?

(b)

i. Things can only be in one place at a time:
At(x,NorthPole,t)$\rightarrow \neg$At(x,AVW,t)
At(x,AVW,t)$\rightarrow \neg$At(x,NorthPole,t)

ii. Whatever is on sleigh, it is also where the sleigh is located:
On(x, Sleigh, t) $\wedge$ At(sleigh,l,t)$\rightarrow$ At(x,l,t)

(c)

Moving(x,l,t)$\rightarrow$ (Flies(x) $\wedge$ Action(t)=Fly(x,l)) $\vee \exists$y(On(x,y,t) $\wedge$ Flies(y) $\wedge$ Action(t)=Fly(y,l))

(d)

Moving(x,l,t)$\rightarrow$At(x,l,t+1)
At(x,$l1$,t)$\wedge\neg\exists l2$(Moving(x,$l2$,t))$\rightarrow$At(x,$l1$,t+1)
On(x,y,t)$\rightarrow$On(x,y,t+1)

4. STRIPS Planning

(a)

action: clean(refrigerator)
pre: dirty(refrigerator)
effect: cleaned(refrigerator), exists(garbage), dirty(counters), dirty(floor) $\neg$dirty(refrigerator), $\neg$noexists(garbage), $\neg$cleaned(counters), $\neg$cleaned(floor)

action:clean(stove)
pre: dirty(stove)
effect: cleaned(stove), dirty(floor), $\neg$dirty(stove), $\neg$cleaned(floor)

action: cover(drip_pans)
pre: cleaned(stove), uncovered(drip_pans)
effect: covered(drip_pans), $\neg$uncovered(drip_pans)

action: wash(floor)
pre: dirty(floor)
effect: cleaned(floor), dirty(sink), $\neg$dirty(floor), $\neg$cleaned(sink)

action: wash(counters)
pre: dirty(counters)
effect: cleaned(counters), dirty(sink) ¬dirty(counters), ¬cleaned(sink)

action: wash(sink)
pre: dirty(sink)
effect: cleaned(sink), ¬dirty(sink)

action: take_out(garbage)
pre: exists(garbage)
effect: noexists(garbage), ¬exists(garbage)

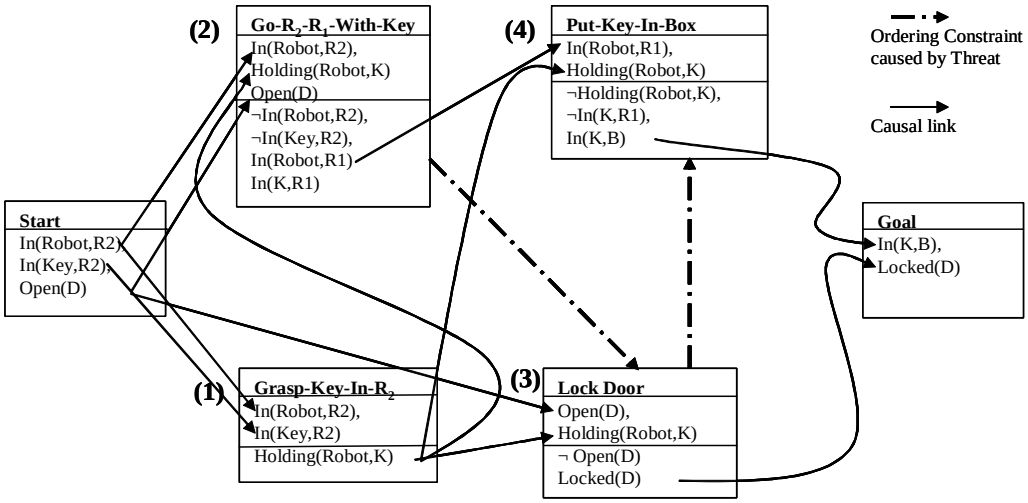
Initial state: dirty(stove), dirty(refrigerator), dirty(counters), dirty(floors), cleaned(sink), noexists(garbage)

Final state: cleaned(stove), cleaned(refrigerator), cleaned(sink), cleaned(floor), cleaned(counters), covered(drip_pans), noexists(garbage).

5. **STRIPS Planning**

Operator	Preconditions	Add effects	Delete effects
Go(x,y)	At(Monkey,x)	At(Monkey,y)	At(Monkey,x)
Push(b,x,y)	At(Monkey,x) At(b,x) Pushable(b)	At(b,y) At(Monkey,y)	At(b,x) At(Monkey,x)
ClimbUp(b,x)	At(Monkey,x) At(b,x) Climbable(b)	On(Monkey,b) Height(Monkey,High)	Height(Monkey,Low)
ClimbDown(b, x)	On(Monkey, b) Climbable(b) At(b, x)	At(Monkey, x) Height(Monkey, Low)	Height(Monkey, High)
Grasp(o,h,x)	Height(Monkey,h) Height(o,h) At(Monkey,x) At(o,x)	Have(Monkey,o)	At(o, x) Height(o, h)
UnGrasp(o, h, x)	Have(Monkey, o) At(Monkey, x) Height(o, h)	At(o, x) Height(o, h)	Have(Monkey, o)

6. **POP**



7. **Graph Plan**

All mutually exclusive pairs of actions and propositions are listed for every phase. Mutually exclusive actions that were detected as such using mutex propagation are marked with (*) (the rest are interfering actions).