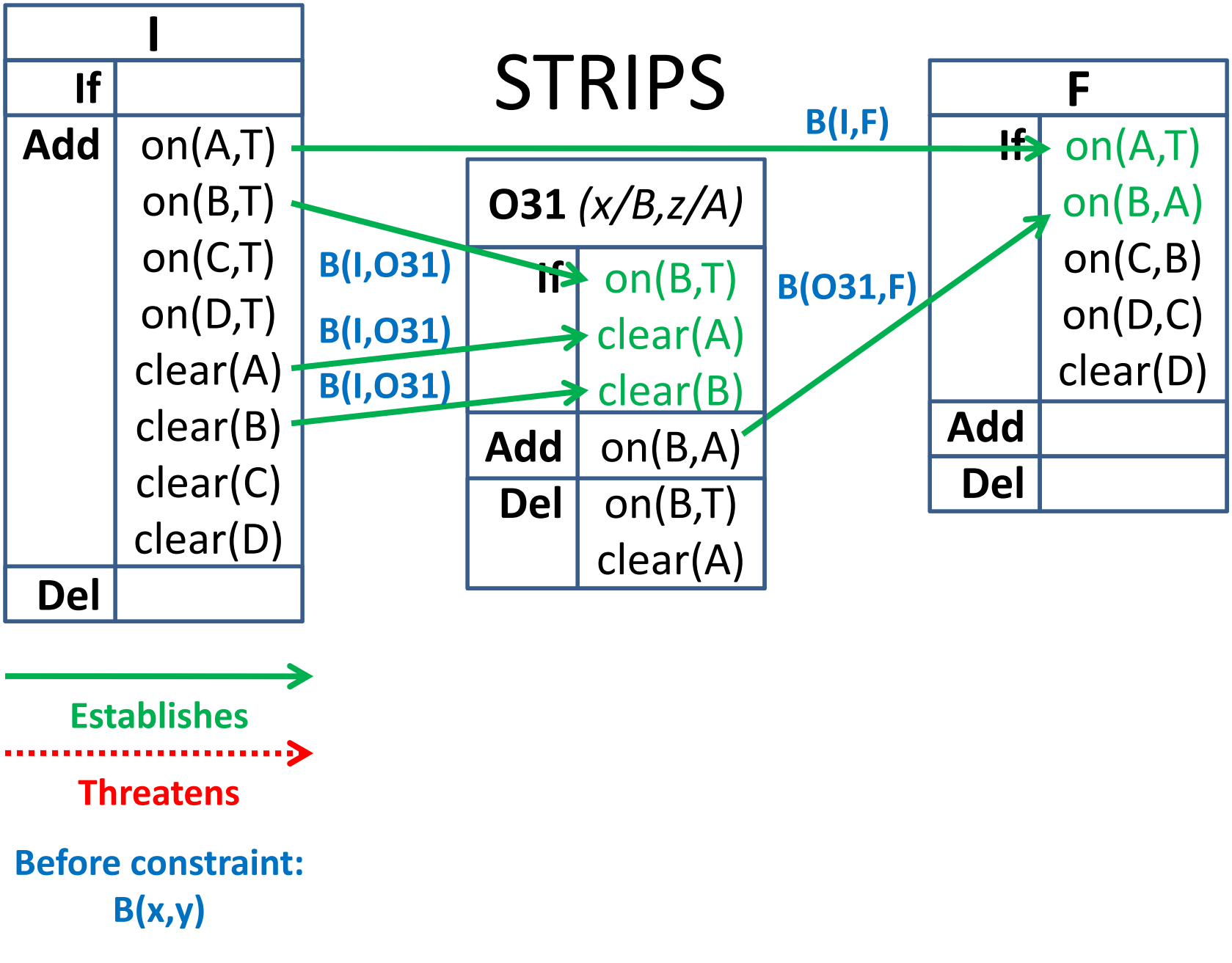
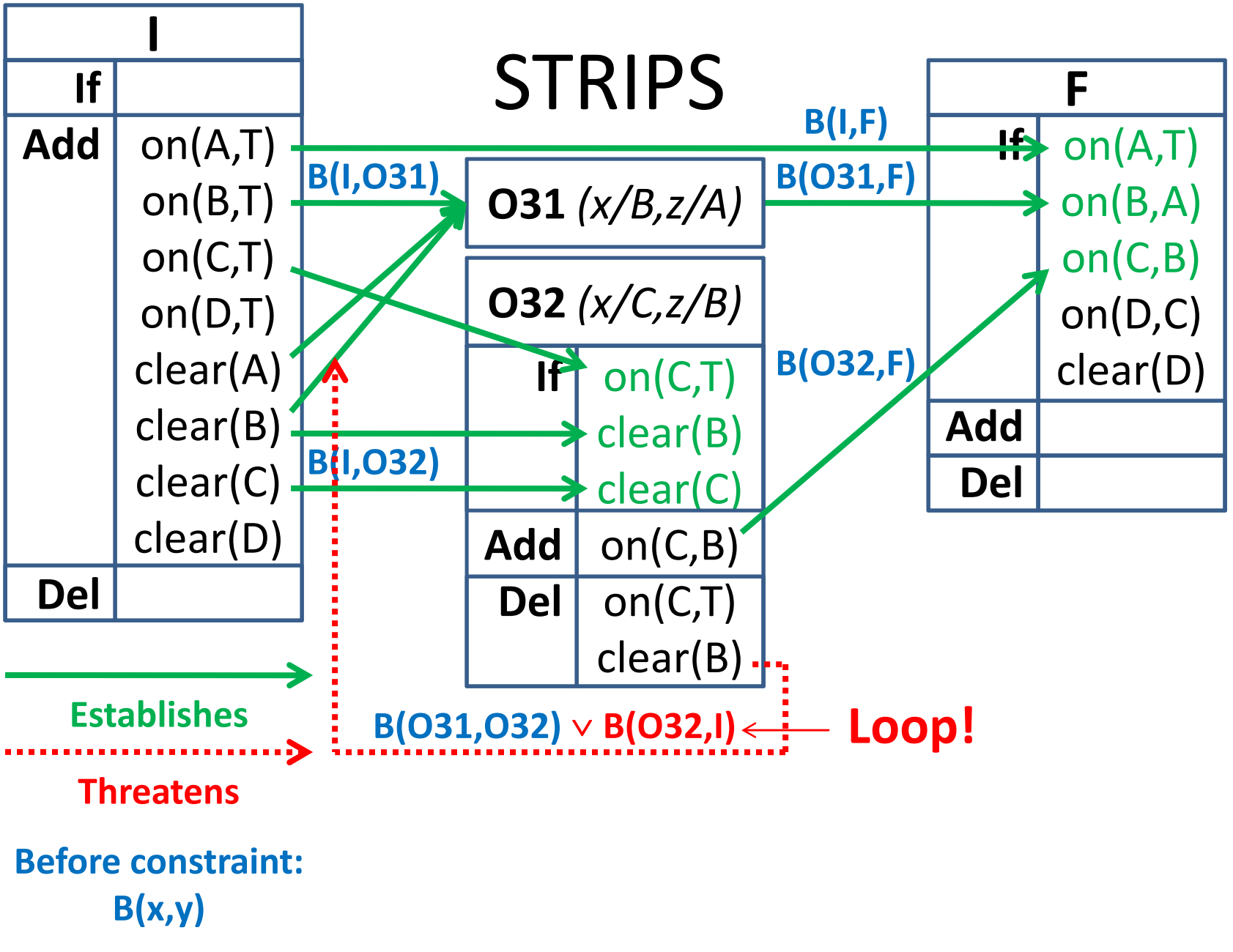
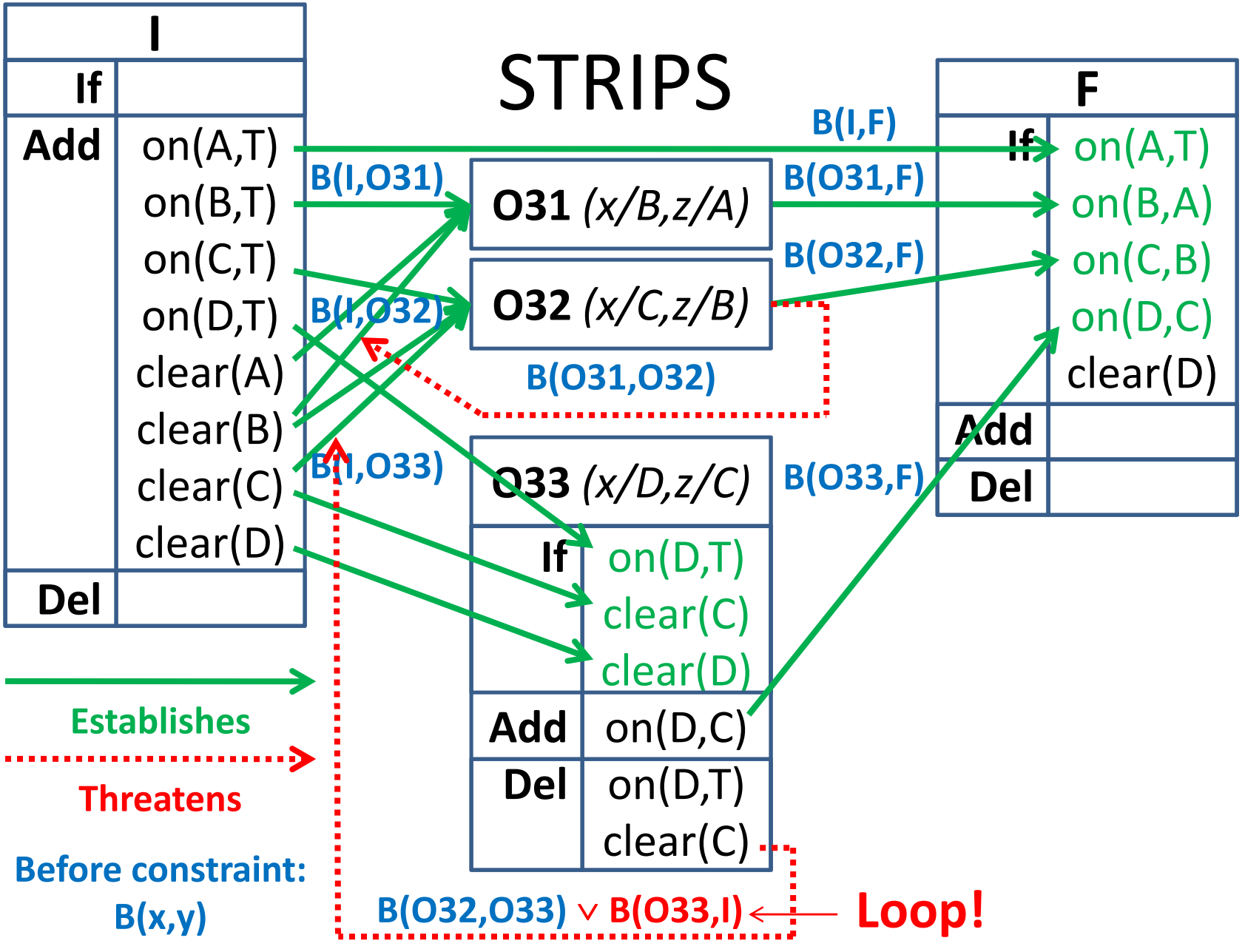
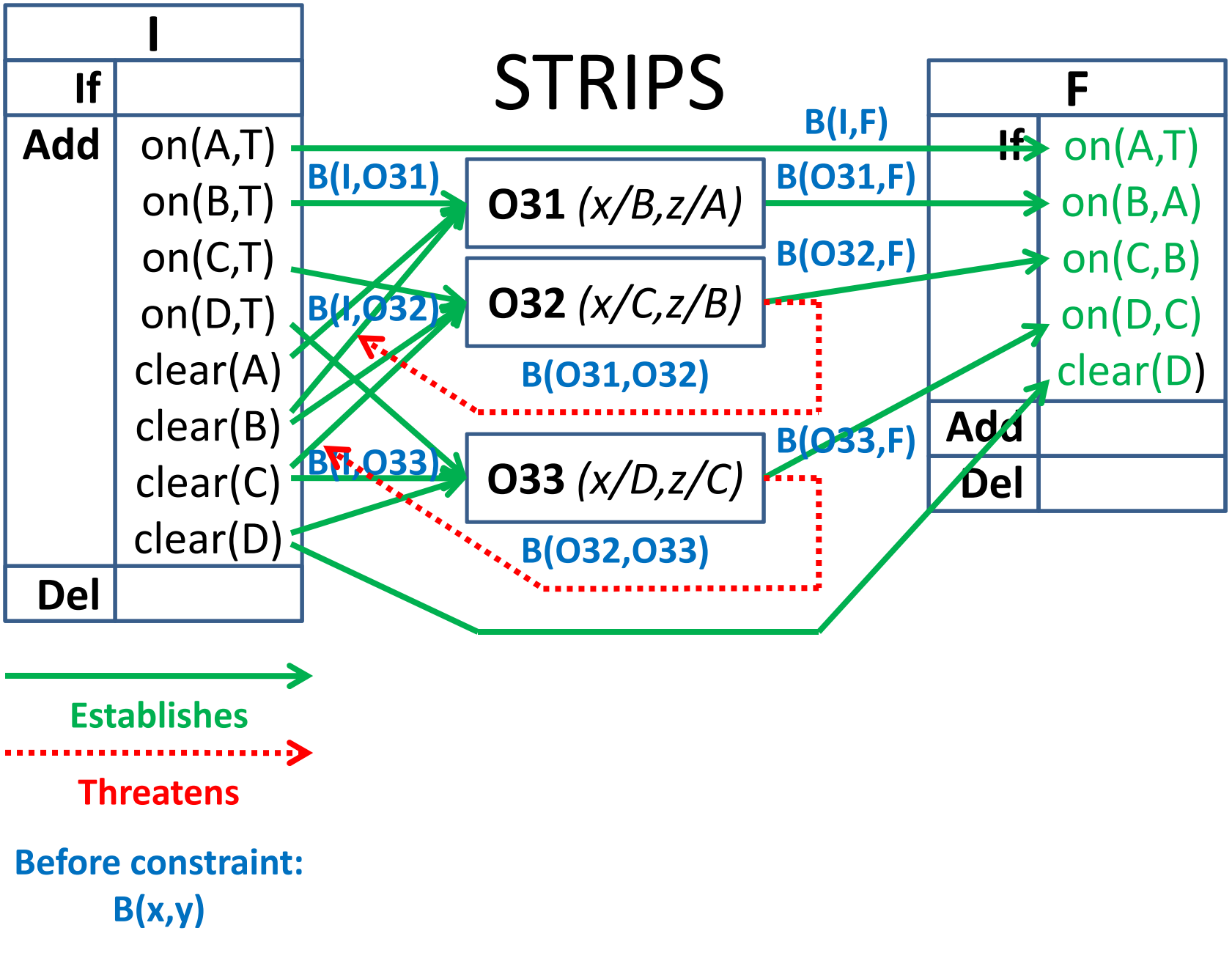
Exercises: Artificial Intelligence

Planning & Logic: Blocks world

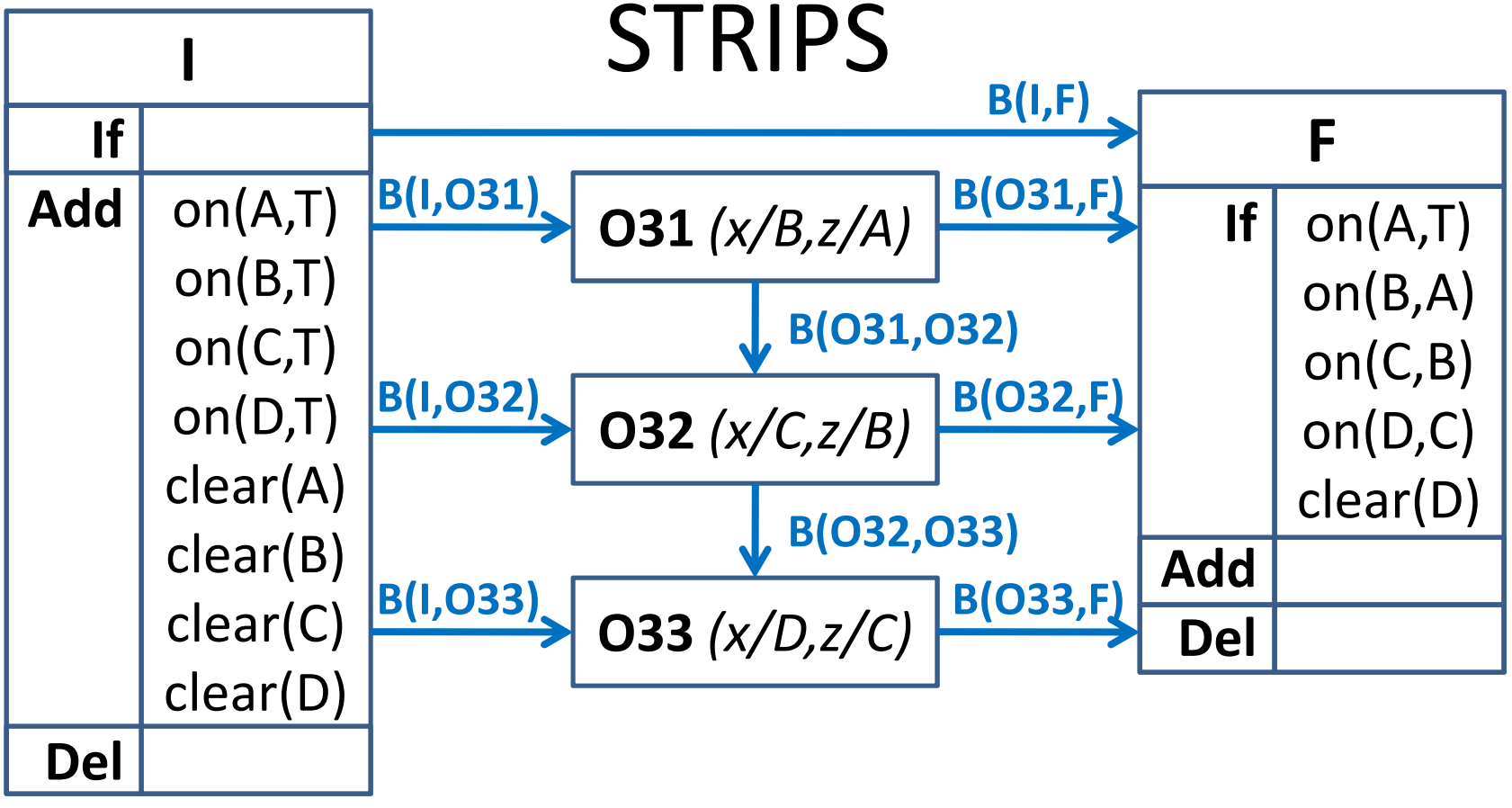

I
If
Add
on(A,T)
on(B,T)
on(C,T)
on(D,T)
clear(A)
clear(B)
clear(C)
clear(D)
Del
STRIPS
B(I,F)
O31 (x/B,z/A)
If
on(B,T)
clear(A)
clear(B)
Add
on(B,A)
Del
on(B,T)
clear(A)
B(I,O31)
B(I,O31)
B(I,O31)
B(O31,F)
F
If
on(A,T)
on(B,A)
on(C,B)
on(D,C)
clear(D)
Add
Del
Establishes
Threatens
Before constraint:
B(x,y)


I
If
Add
on(A,T)
on(B,T)
on(C,T)
on(D,T)
clear(A)
clear(B)
clear(C)
clear(D)
Del
STRIPS
B(I,F)
B(I,O31)
O31 (x/B,z/A)
B(O31,F)
O32 (x/C,z/B)
If
on(C,T)
clear(B)
clear(C)
B(O32,F)
B(I,O32)
Add
on(C,B)
Del
on(C,T)
clear(B)
F
If
on(A,T)
on(B,A)
on(C,B)
on(D,C)
clear(D)
Add
Del
Establishes
Threatens
B(O31,O32) ∨ B(O32,I)
Loop!
Before constraint:
B(x,y)


I
If
Add
on(A,T)
on(B,T)
on(C,T)
on(D,T)
clear(A)
clear(B)
clear(C)
clear(D)
Del
STRIPS
B(I,F)
B(I,O31)
B(I,O32)
B(I,O33)
O31 (x/B,z/A)
O32 (x/C,z/B)
O33 (x/D,z/C)
B(O31,F)
B(O32,F)
B(O33,F)
B(O31,O32)
F
If
on(A,T)
on(B,A)
on(C,B)
on(D,C)
clear(D)
Add
Del
If
on(D,T)
clear(C)
clear(D)
Add
on(D,C)
Del
on(D,T)
clear(C)
Establishes
Threatens
Before constraint:
B(x,y)
B(O32,O33) ∨ B(O33,I)
Loop!


I
If
Add
on(A,T)
on(B,T)
on(C,T)
on(D,T)
clear(A)
clear(B)
clear(C)
clear(D)
Del
STRIPS
B(I,F)
B(I,O31)
O31 (x/B,z/A)
B(O31,F)
B(O32,F)
B(I,O32)
O32 (x/C,z/B)
B(O31,O32)
B(O33,F)
B(I,O33)
O33 (x/D,z/C)
B(O32,O33)
F
If
on(A,T)
on(B,A)
on(C,B)
on(D,C)
clear(D)
Add
Del
Establishes
Threatens
Before constraint:
B(x,y)

STRIPS



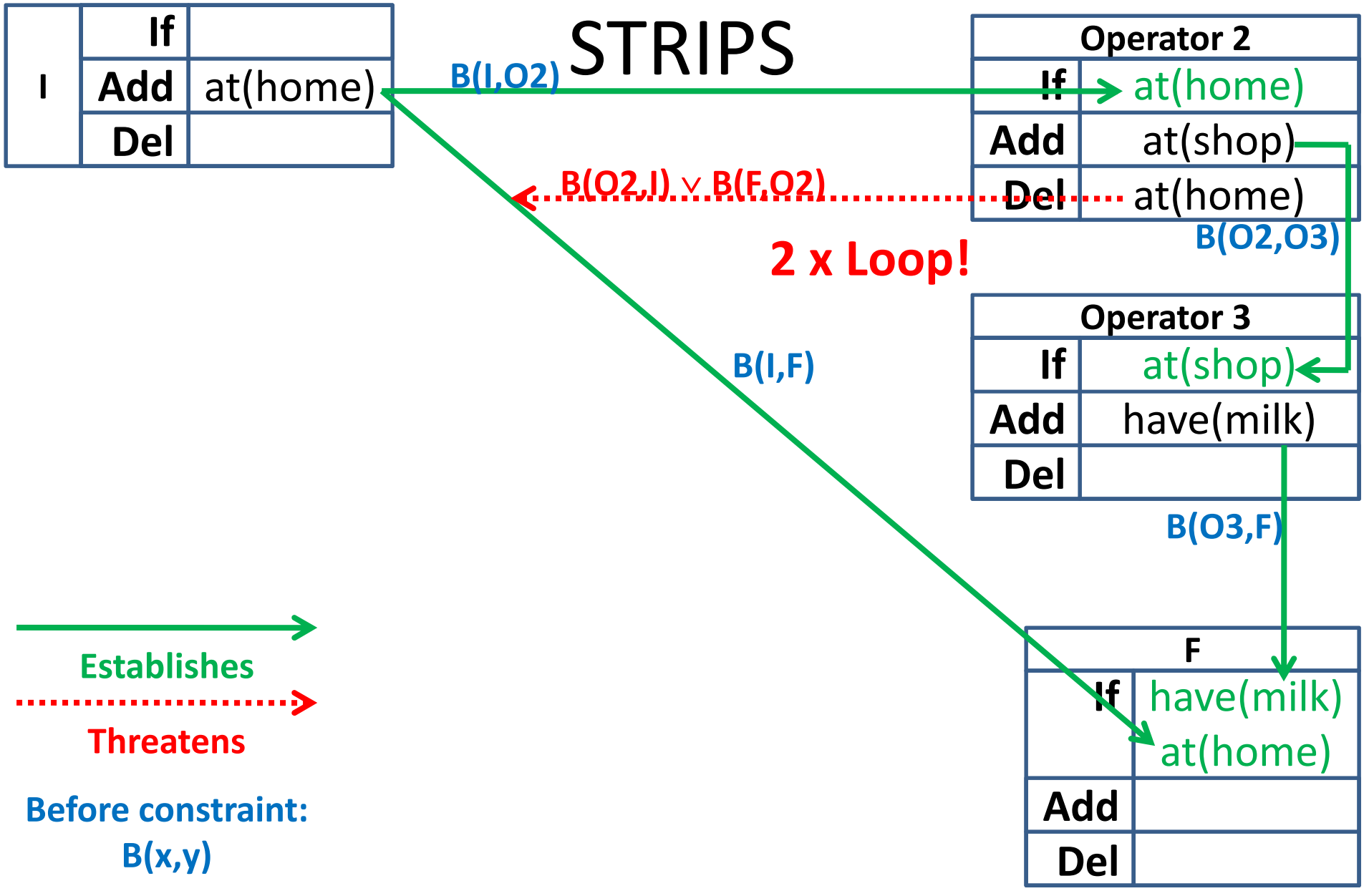
Are the before constraints satisfiable?

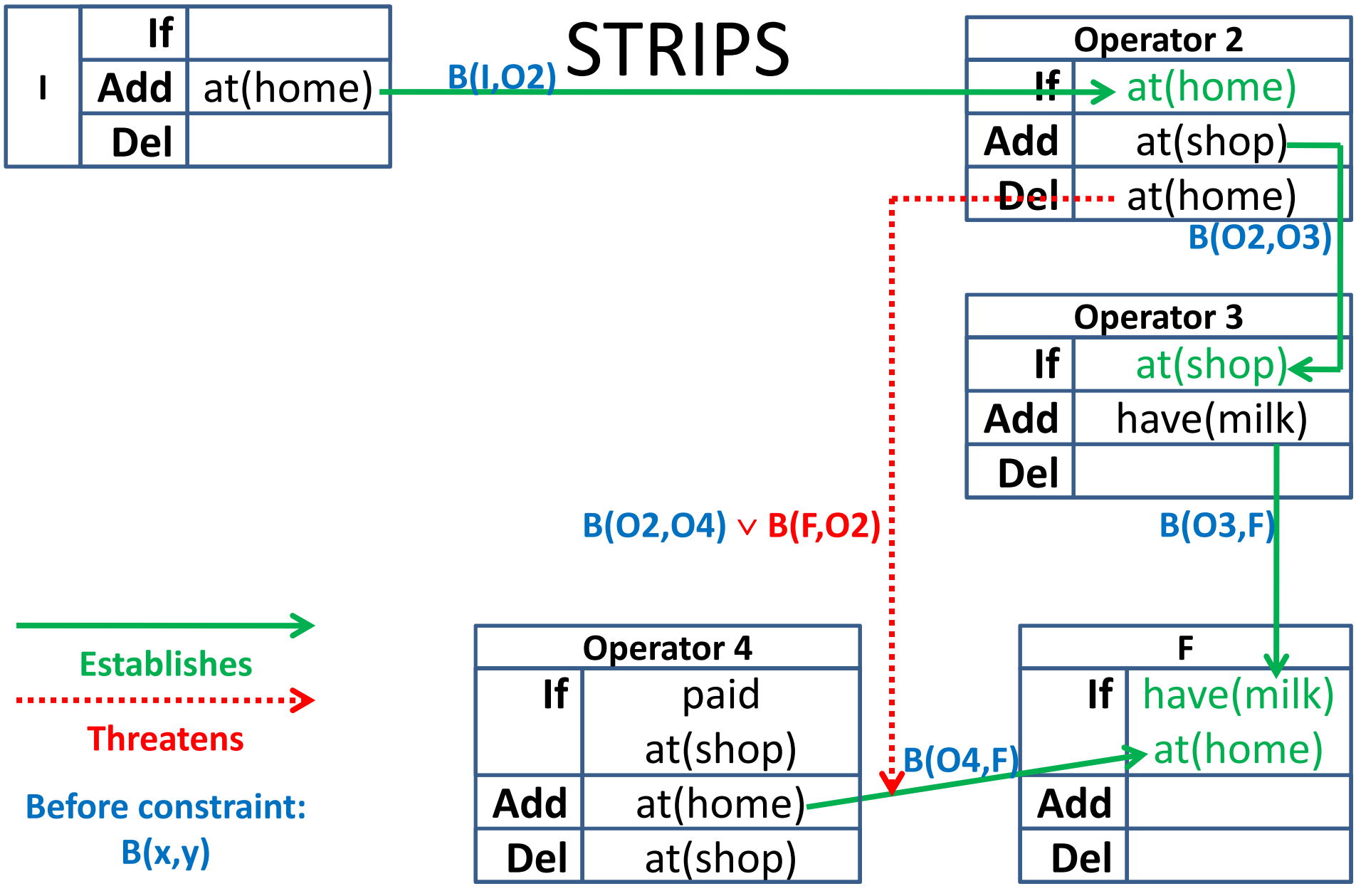
YES:

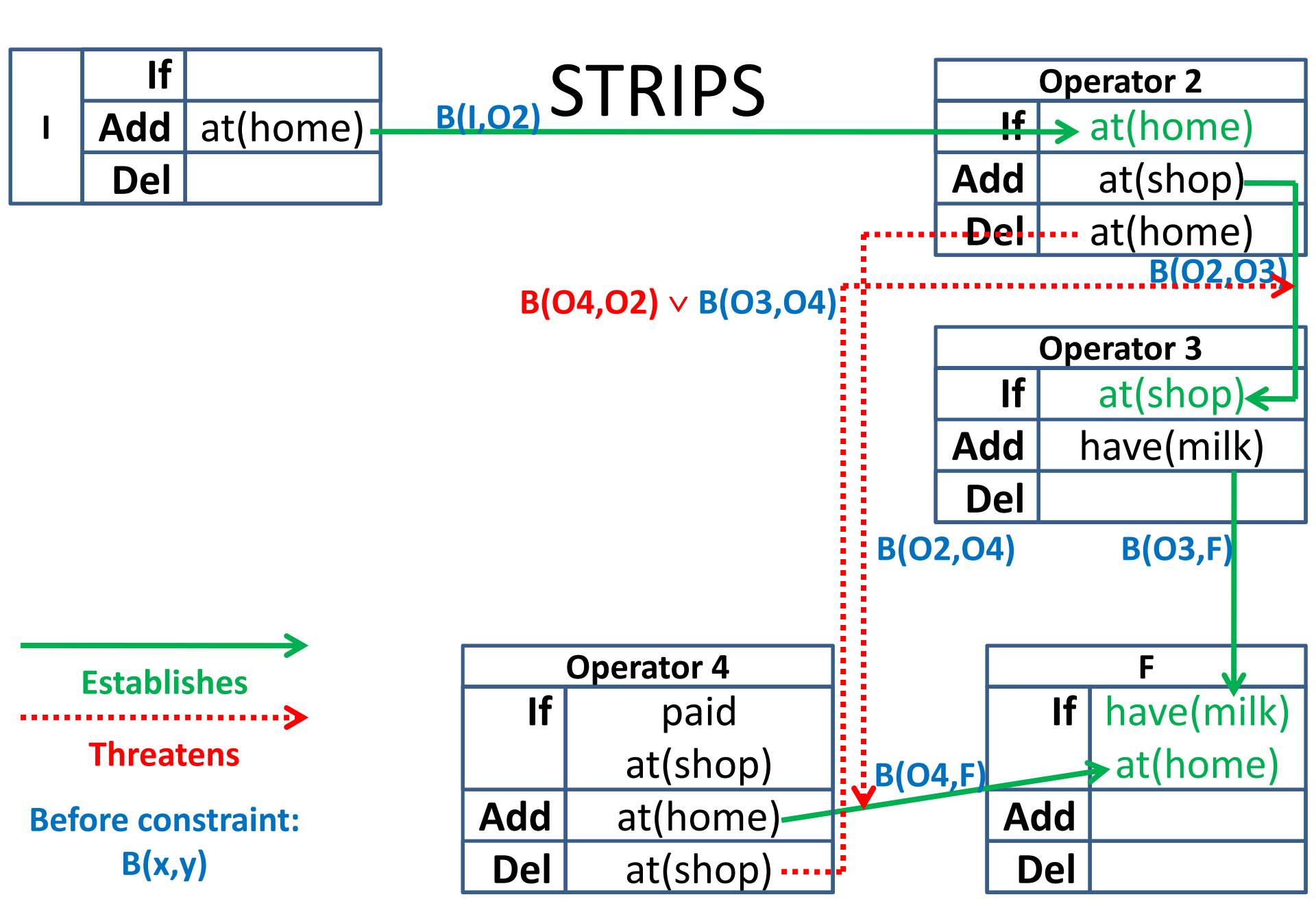
⟶ O31 ⟶ O32 ⟶ O33 ⟶

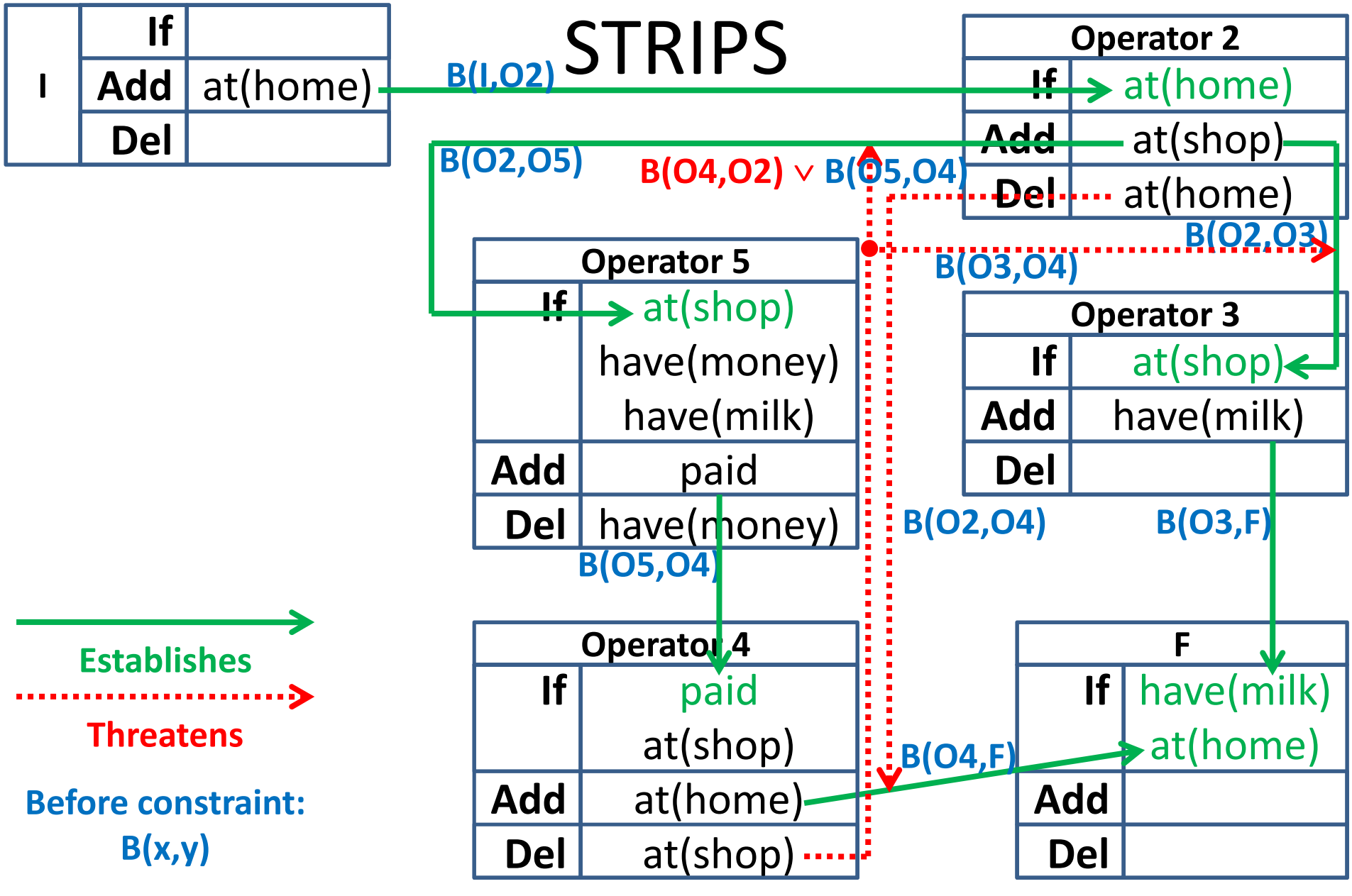
Exercises: Artificial Intelligence

Planning & Logic: Buying milk

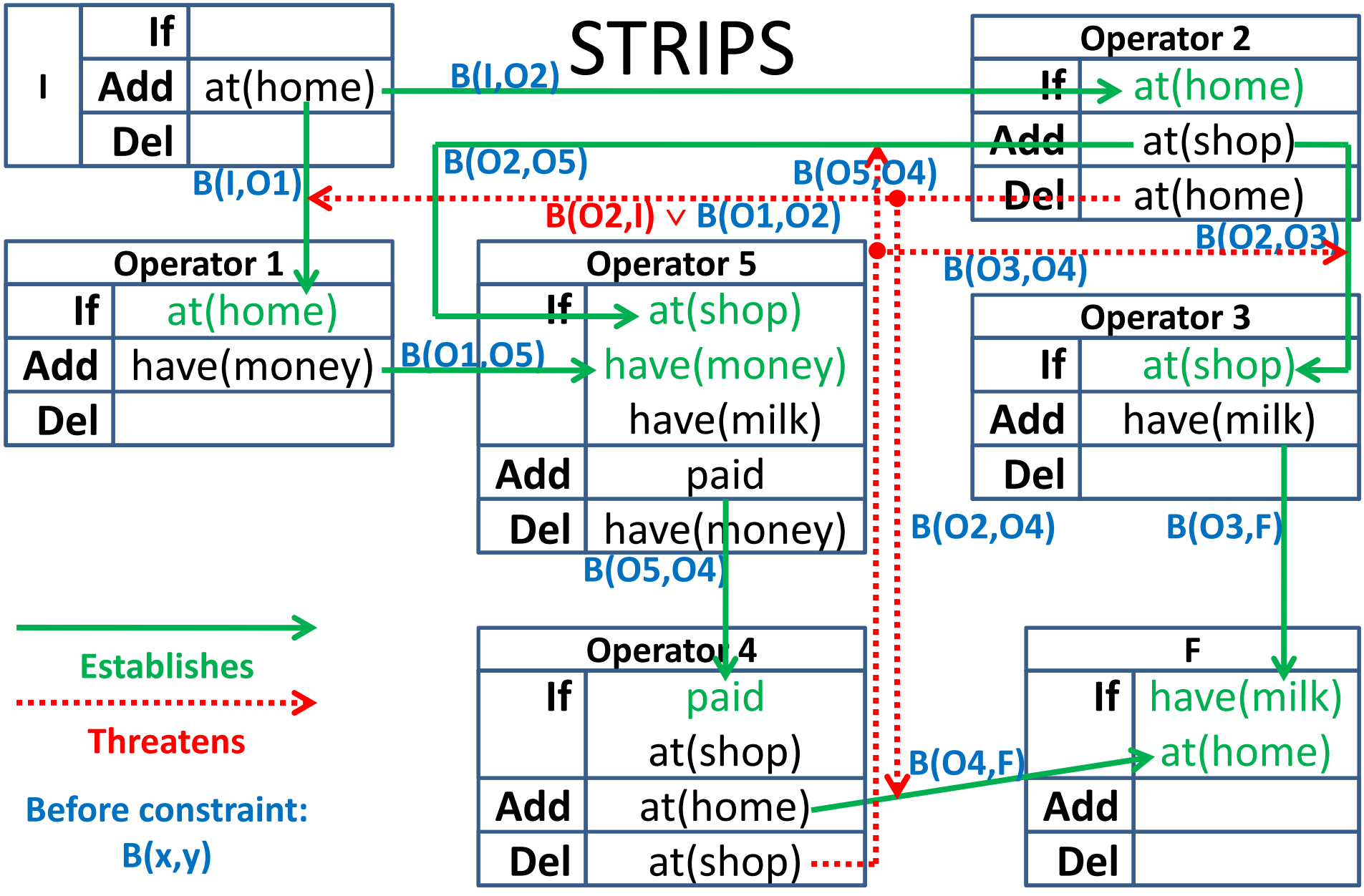

STRIPS
I
If
Add
at(home)
Del
B(I,O2)
Operator 2
If
at(home)
Add
at(shop)
Del
at(home)
B(O2,I) ∨ B(F,O2)
B(O2,O3)
2 x Loop!
Operator 3
If
at(shop)
Add
have(milk)
Del
B(I,F)
B(O3,F)
F
If
have(milk)
at(home)
Add
Del
Establishes
Threatens
Before constraint:
B(x,y)

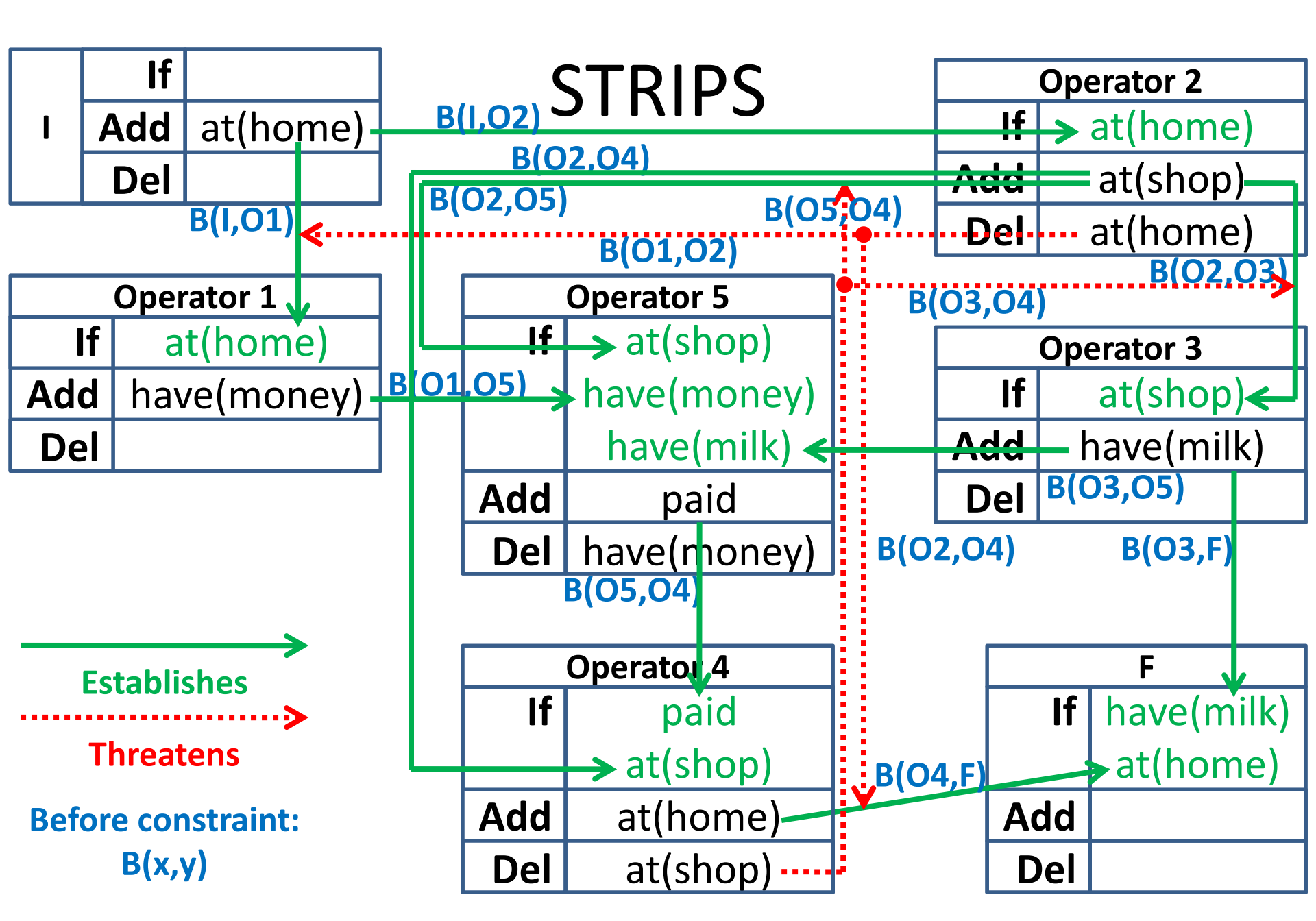

I
If
Add
at(home)
Del
STRIPS
B(I,O2)
Operator 2
If
at(home)
Add
at(shop)
Del
at(home)
B(O2,O3)
Operator 3
If
at(shop)
Add
have(milk)
Del
B(O2,O4) ∨ B(F,O2)
B(O3,F)
Establishes
Threatens
Before constraint:
B(x,y)
Operator 4
If
paid
at(shop)
Add
at(home)
Del
at(shop)
B(O4,F)
F
If
have(milk)
at(home)
Add
Del


I
If
Add at(home)
Del
STRIPS
B(I,O2)
Operator 2
If at(home)
Add at(shop)
Del at(home)
B(O2,O3)
B(O4,O2) ∨ B(O3,O4)
Operator 3
If at(shop)
Add have(milk)
Del
B(O2,O4)
B(O3,F)
Establishes
Threatens
Before constraint:
B(x,y)
Operator 4
If paid
at(shop)
Add at(home)
Del at(shop)
B(O4,F)
F
If have(milk)
at(home)
Add
Del

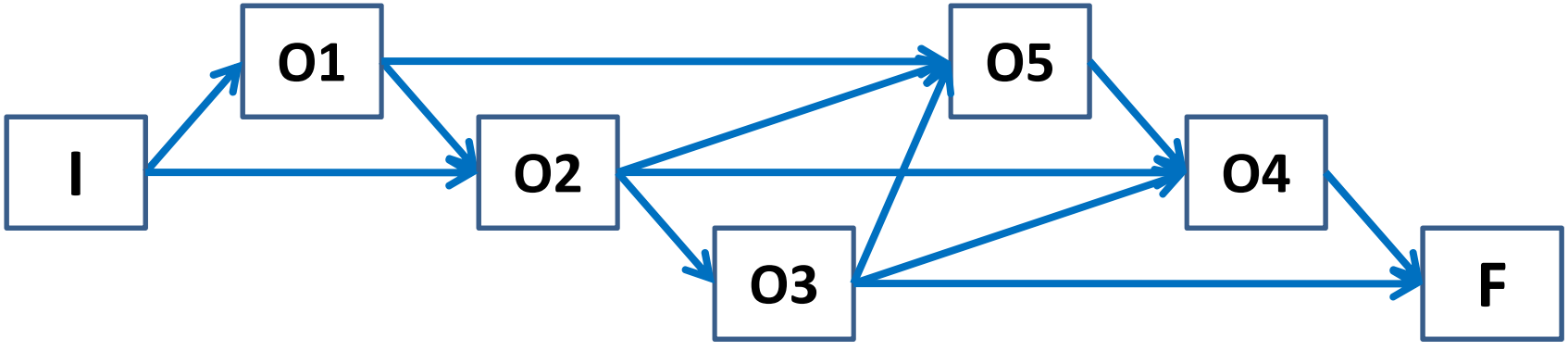

STRIPS
I
If
Add
Del
at(home)
B(I,O2)
Operator 2
If
Add
Del
at(home)
at(shop)
at(home)
B(O2,O5)
B(O4,O2) ∨ B(O5,O4)
B(O2,O3)
B(O3,O4)
Operator 5
If
Add
Del
at(shop)
have(money)
have(milk)
paid
have(money)
Operator 3
If
Add
Del
at(shop)
have(milk)
B(O2,O4)
B(O3,F)
B(O5,O4)
Operator 4
If
Add
Del
paid
at(shop)
at(home)
at(shop)
F
If
Add
Del
have(milk)
at(home)
B(O4,F)
Establishes
Threatens
Before constraint:
B(x,y)

STRIPS


I
If
Add at(home)
Del
B(I,O2)
Operator 2
If at(home)
Add at(shop)
Del at(home)
B(O2,O5)
B(O5,O4)
B(I,O1)
B(O2,I) ∨ B(O1,O2)
B(O2,O3)
B(O3,O4)
Operator 1
If at(home)
Add have(money)
Del
B(O1,O5)
Operator 5
If at(shop)
have(money)
have(milk)
Add paid
Del have(money)
Operator 3
If at(shop)
Add have(milk)
Del
B(O2,O4)
B(O3,F)
B(O5,O4)
Operator 4
If paid
at(shop)
Add at(home)
Del at(shop)
B(O4,F)
F
If have(milk)
at(home)
Add
Del
Establishes
Threatens
Before constraint:
B(x,y)


STRIPS
I
If
Add at(home)
Del
Operator 2
If at(home)
Add at(shop)
Del at(home)
Operator 1
If at(home)
Add have(money)
Del
Operator 5
If at(shop)
have(money)
have(milk)
Add paid
Del have(money)
Operator 3
If at(shop)
Add have(milk)
Del
Operator 4
If paid
at(shop)
Add at(home)
Del at(shop)
F
If have(milk)
at(home)
Add
Del
B(I,O2)
B(O2,O4)
B(O2,O5)
B(I,O1)
B(O1,O2)
B(O5,O4)
B(O2,O3)
B(O3,O4)
B(O1,O5)
B(O3,O5)
B(O2,O4)
B(O3,F)
B(O5,O4)
B(O4,F)
Establishes
Threatens
Before constraint:
B(x,y)

STRIPS



Are the before constraints satisfiable?

YES:

⟶ O1 ⟶ O2 ⟶ O3 ⟶ O5 ⟶ O4 ⟶

Exercises: Artificial Intelligence

Planning & Logic: English to Logic

Problem & Solution

- *Not all students take both history and biology*

$$\neg\forall x\,[\text{student}(x) \Rightarrow \text{takes}(x,\text{hist}) \wedge \text{takes}(x,\text{bio})]$$

$$\Leftrightarrow [A \Rightarrow B \Leftrightarrow \neg A \vee B]$$

$$\neg\forall x\,[\neg[\text{student}(x)] \vee [\text{takes}(x,\text{hist}) \wedge \text{takes}(x,\text{bio})]]$$

$$\Leftrightarrow [\neg\forall x\,(F) \Leftrightarrow \exists x\,(\neg F)]$$

$$\exists x\,\neg[\neg[\text{student}(x)] \vee [\text{takes}(x,\text{hist}) \wedge \text{takes}(x,\text{bio})]]$$

$$\Leftrightarrow [\neg(A \vee B) \Leftrightarrow \neg A \wedge \neg B],[\neg(A \wedge B) \Leftrightarrow \neg A \vee \neg B]$$

$$\exists x\,[\text{student}(x) \wedge [\neg\text{takes}(x,\text{hist}) \vee \neg\text{takes}(x,\text{bio})]]$$

Problem & Solution

- *No person likes a smart vegetarian*

$$\forall x\ \forall y\ [person(x) \wedge vegetarian(y) \wedge smart(y) \Rightarrow \neg likes(x,y)]$$

$$\Leftrightarrow [A \Rightarrow B \Leftrightarrow \neg A \ \vee B]$$

$$\forall x\ \forall y\ [\neg[person(x) \wedge vegetarian(y) \wedge smart(y)] \vee \neg likes(x,y)]$$

$$\Leftrightarrow [\neg A \ \vee \neg B \Leftrightarrow \neg(A \wedge B)]$$

$$\forall x\ \forall y\ \neg[person(x) \wedge vegetarian(y) \wedge smart(y) \wedge likes(x,y)]$$

$$\Leftrightarrow [\forall x\ \neg(F) \Leftrightarrow \neg\exists x\ (F)]$$

$$\neg\ \exists x\ \exists y\ [person(x) \wedge vegetarian(y) \wedge smart(y) \wedge likes(x,y)]$$

Problem & Solution

- *There is a woman who likes all men who are not vegetarians.*

$$\exists x[\text{woman}(x) \wedge [\forall y\ [\text{man}(y) \wedge \neg \text{vegetarian}(y) \Rightarrow \text{likes}(x,y)]]]$$

Problem & Solution

- *The best score in history was better than the best score in biology.*

  $\forall x \, \forall y \, [\text{bestscore}(\text{hist},x) \wedge \text{bestscore}(\text{bio},y) \Rightarrow \text{better}(x,y)]$

Problem & Solution

- *Every person who dislikes all vegetarians is smart.*

$$\forall x[\ \text{person}(x) \wedge [\forall y\ [\text{vegetarian}(y) \Rightarrow \neg \text{likes}(x,y)]] \Rightarrow \text{smart}(x)]$$

Problem & Solution

- *There is a barber who shaves all men in town who do not shave themselves.*

$$\exists x\,[\text{barber}(x) \wedge [\forall y\,[\text{townsman}(y) \wedge \neg \text{shaves}(y,y) \Rightarrow \text{shaves}(x,y)]]]$$

$$\Leftrightarrow$$

$$\exists x\,[\text{barber}(x) \wedge [\forall y\,[\neg[\text{townsman}(y) \wedge \neg \text{shaves}(y,y)] \vee \text{shaves}(x,y)]]]$$

$$\Leftrightarrow$$

$$\exists x\,[\text{barber}(x) \wedge [\forall y\,\neg[\text{townsman}(y) \wedge \neg \text{shaves}(y,y) \wedge \neg \text{shaves}(x,y)]]]$$

$$\Leftrightarrow$$

$$\exists x\,[\text{barber}(x) \wedge [\neg\,\exists y\,[\text{townsman}(y) \wedge \neg \text{shaves}(y,y) \wedge \neg \text{shaves}(x,y)]]]$$

Problem & Solution

- *No person likes a professor unless the professor is smart.*

$$\forall x\, \forall y\, [\text{person}(x) \wedge \text{professor}(y) \Rightarrow [\text{likes}(x,y) \Rightarrow \text{smart}(y)]] \Leftrightarrow$$
$$\forall x\, \forall y\, [\text{person}(x) \wedge \text{professor}(y) \Rightarrow [\neg\text{likes}(x,y) \vee \text{smart}(y)]] \Leftrightarrow$$
$$\forall x\, \forall y\, [\neg[\text{person}(x) \wedge \text{professor}(y)] \vee [\neg\text{likes}(x,y) \vee \text{smart}(y)]] \Leftrightarrow$$
$$\forall x\, \forall y\, [\neg[\text{person}(x) \wedge \text{professor}(y)] \vee \neg[\text{likes}(x,y) \wedge \neg\text{smart}(y)]] \Leftrightarrow$$
$$\forall x\, \forall y\, \neg[\text{person}(x) \wedge \text{professor}(y) \wedge \text{likes}(x,y) \wedge \neg\text{smart}(y)] \Leftrightarrow$$
$$\neg\, \exists x\, \exists y\, [\text{person}(x) \wedge \text{professor}(y) \wedge \text{likes}(x,y) \wedge \neg\text{smart}(y)]$$

Problem & Solution

- *Only one person failed both history and biology.*

$$\exists!x\ \text{student}(x) \wedge \text{failed}(x,\text{hist}) \wedge \text{failed}(x,\text{bio})$$

Note that: $\exists!x\ p(x) \Leftrightarrow \exists x\ p(x) \wedge [\forall y\ [p(y) \Rightarrow x=y]]$

Problem & Solution

- *Politicians can fool some of the people all the time, and they can fool all of the people some of the time, but they can't fool all the people all of the time.*

$$\forall x\ [\text{politician}(x) \Rightarrow [\exists y\ \text{people}(y) \wedge [\forall t\ \text{time}(t) \Rightarrow \text{fool}(x,y,t)]]]$$

$$\forall x\ [\text{politician}(x) \Rightarrow [\exists t\ \text{time}(t) \wedge [\forall y\ \text{people}(y) \Rightarrow \text{fool}(x,y,t)]]]$$

$$\forall x\ [\text{politician}(x) \Rightarrow \neg[\forall y\ \forall t\ [\text{people}(y) \wedge \text{time}(t)] \Rightarrow \text{fool}(x,y,t)]]$$

Exercises: Artificial Intelligence

Planning & Logic: And-Or-If

Problem & Solution

- *One more outburst like that and you are in contempt of court.*

$$\text{outburst} \Rightarrow \text{court}$$

NOT: $\text{outburst} \wedge \text{court}$

Problem & Solution

- *Either the Red Sox win or I'm out ten dollars.*

$$\text{redSoxWin} \Leftrightarrow \neg\text{outTenDollars}$$

NOT: $\text{redSoxWin} \vee \text{outTenDollars}$

Problem & Solution

- *Maybe I'll come to the party and maybe I won't.*

$$\text{maybeComeToParty} \vee \neg\text{maybeComeToParty}$$

NOT: $\text{maybeComeToParty} \wedge \neg\text{maybeComeToParty}$

Exercises: Artificial Intelligence

Planning & Logic: Weird Logic

Problem & Solution

- *I don't jump off the Empire State Building implies if I jump off the Empire State Building, then I float safely to the ground.*
  - *Translating the meaning of the sentence is not possible*

$$\neg \text{jumpESB} \Rightarrow [\text{jumpESB} \Rightarrow \text{floatTTGround}] \Leftrightarrow$$
$$\neg \text{jumpESB} \Rightarrow [\neg \text{jumpESB} \vee \text{floatTTGround}] \Leftrightarrow$$
$$\text{jumpESB} \vee \neg \text{jumpESB} \vee \text{floatTTGround}$$

Problem & Solution

- *It is not the case that if you attempt this exercise you will get an F. Therefore, you will attempt this exercise.*
  - *Translating the meaning of the sentence is not possible*

$$\neg[\text{attempt} \Rightarrow \text{getF}] \Rightarrow \text{attempt} \Leftrightarrow$$

$$\neg[\neg\text{attempt} \vee \text{getF}] \Rightarrow \text{attempt} \Leftrightarrow$$

$$\neg\text{attempt} \vee \text{getF} \vee \text{attempt}$$