Planning: Heuristics and CSP Planning

Computer Science cpsc322, Lecture 18

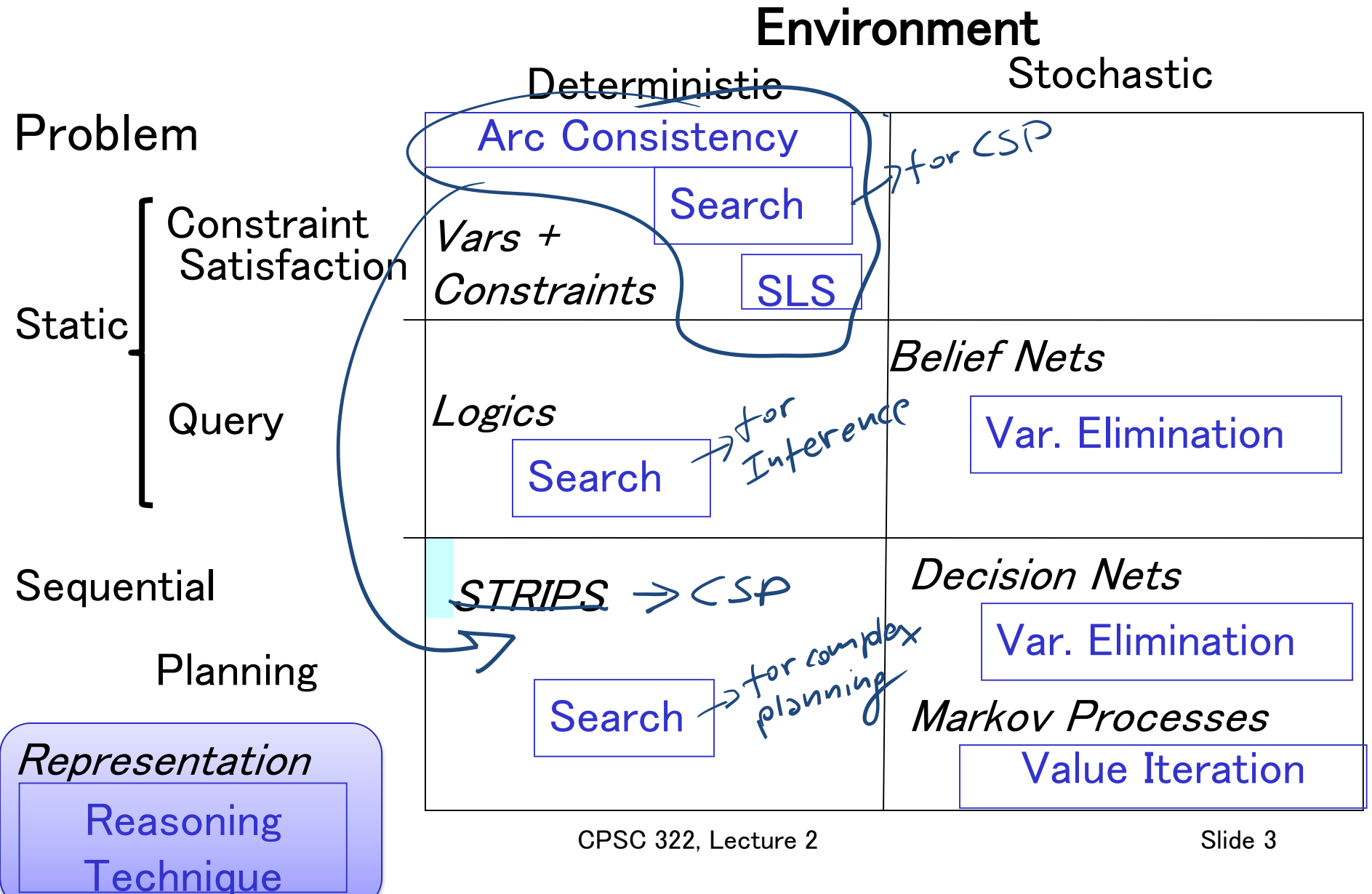
(Textbook Chpt 8)

June, 1, 2017

Lecture Overview

- **Recap: Planning Representation and Forward algorithm**
- Heuristics
- CSP Planning

Modules we'll cover in this course: R&Rsys



Standard Search vs. Specific R&R systems

Constraint Satisfaction (Problems):

- State: assignments of values to a subset of the variables
- Successor function: assign values to a "free" variable
- Goal test: set of constraints
- Solution: possible world that satisfies the constraints
- Heuristic function: *none (all solutions at the same distance from start)*

Planning :

- State? A. Full assignment B. Partial assignment
- Successor function?
- Goal test? A. Full assignment B. Partial assignment
- Solution?
- Heuristic function….

Inference

- State
- Successor function
- Goal test
- Solution
- Heuristic function

Lecture Overview

- Recap: Planning Representation and Forward algorithm
- Heuristics for forward planning 
- CSP Planning

Heuristics for Forward Planning

Heuristic function: estimate of the distance form a state to the goal

In planning this is the # actions

Two simplifications in the representation:

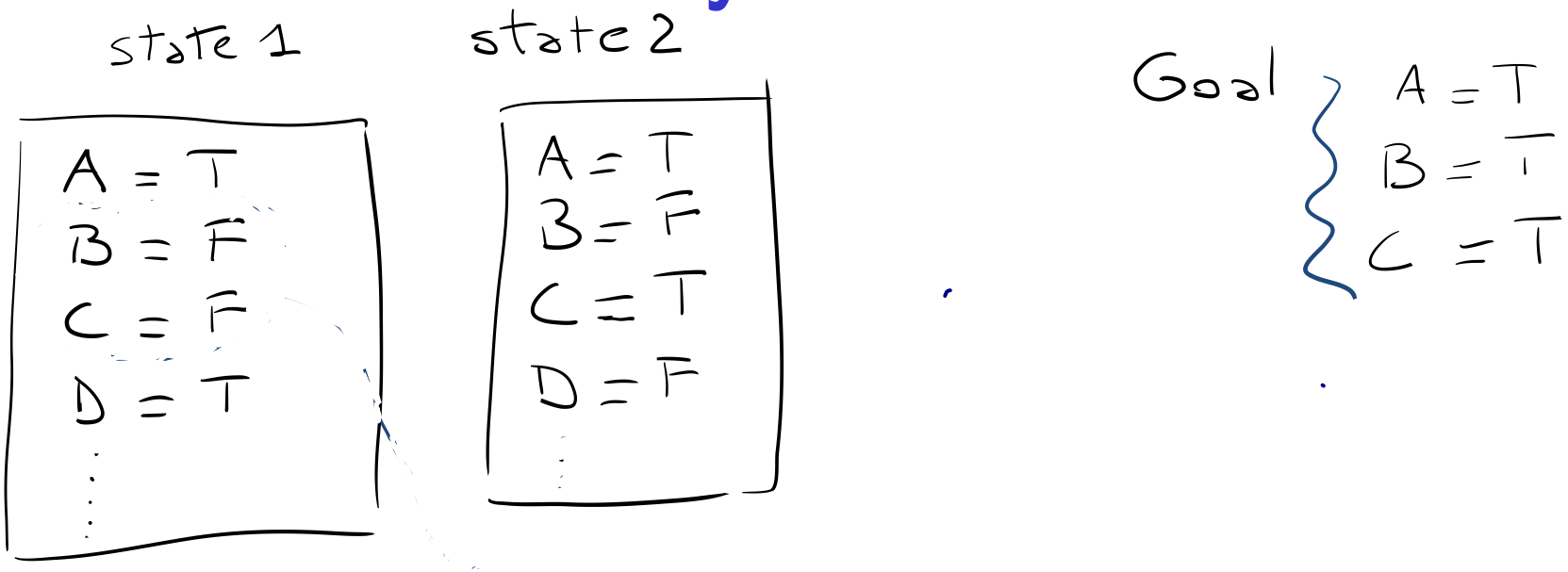
- All features are binary: T / F
- Goals and preconditions can only be assignments to T

And a Def. a subgoal is a particular assignment in the goal

e.g., if the goal is <A=T, B=T, C=T> then..

subgoal A=T subgoal B=T subgoal C=T

Heuristics for Forward Planning: Any ideas?

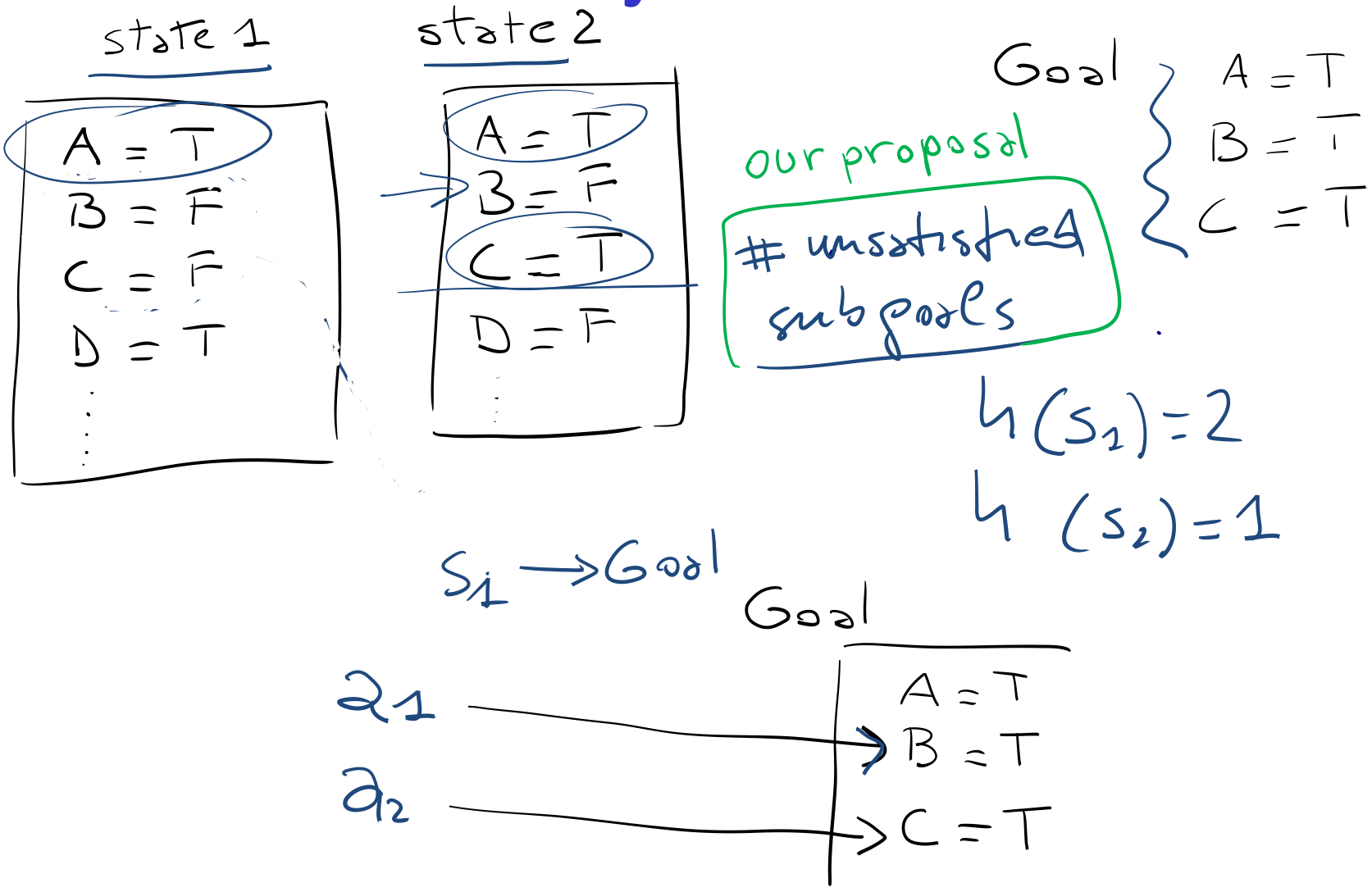


A. Number of satisfied sub-goals

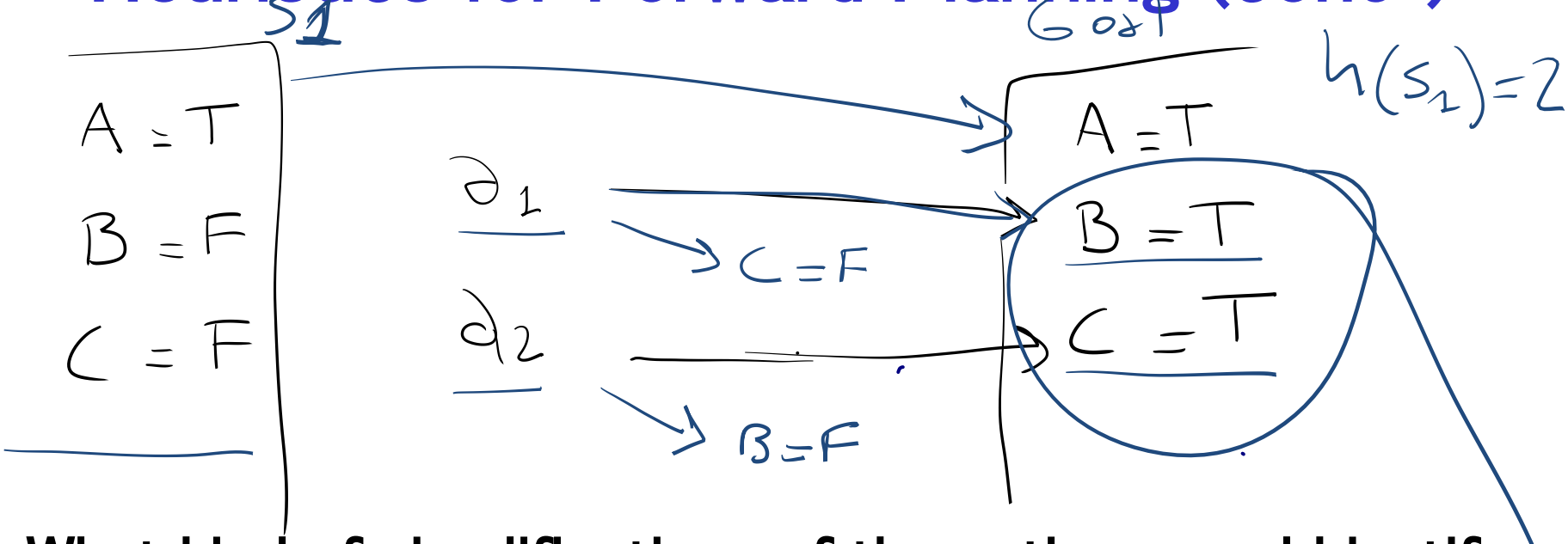
B. Number of unsatisfied sub-goals

C. None of the above

Heuristics for Forward Planning: Any ideas?



Heuristics for Forward Planning (cont')



What kind of simplifications of the actions would justify our proposal for h?

a) We have removed all ..... preconditions (too strong! VERY STRONG)

b) We have removed all ..... "negative" effects

c) We assume no action can achieve ..... both ..... (INADMISSIBLE)

Heuristics for Forward Planning: empty-delete-list

- **We only relax the problem according to (……)**

i.e., we remove all the effects that make a variable F

Action *a* effects (B=*F*, C=*T*)

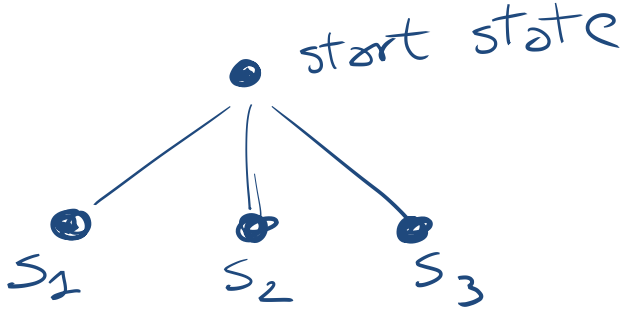
- **But then how do we compute the heuristic?**

solve a simplified planning prob.

This is often fast enough to be worthwhile

- **empty-delete-list heuristics** with **forward planning** is currently considered a very successful strategy

Empty-delete in practice



$h(s_1)$

to compute $h(s_i)$, run forward planner with s_i as start state, with the same goal as the original problem
but with all the actions with the negative effects removed.

So to compute h (for a given state) we need to solve a planning problem (but a simpler one!)
You may need to do this MANY times

Final Comment

- You should view **(informed) Forward Planning** as one of the basic planning techniques
- By itself, it cannot go far, but it can work very well in combination with other techniques, for specific domains
  - See, for instance, descriptions of competing planners in the presentation of results for the **2008 planning competition** (posted in the class schedule)

Lecture Overview

- Recap: Planning Representation and Forward algorithm
- Heuristics for forward planning
- **CSP Planning**

Planning as a CSP

- An alternative approach to planning is to set up a planning problem as a CSP!

- We simply reformulate a STRIPS model as a set of variables and constraints

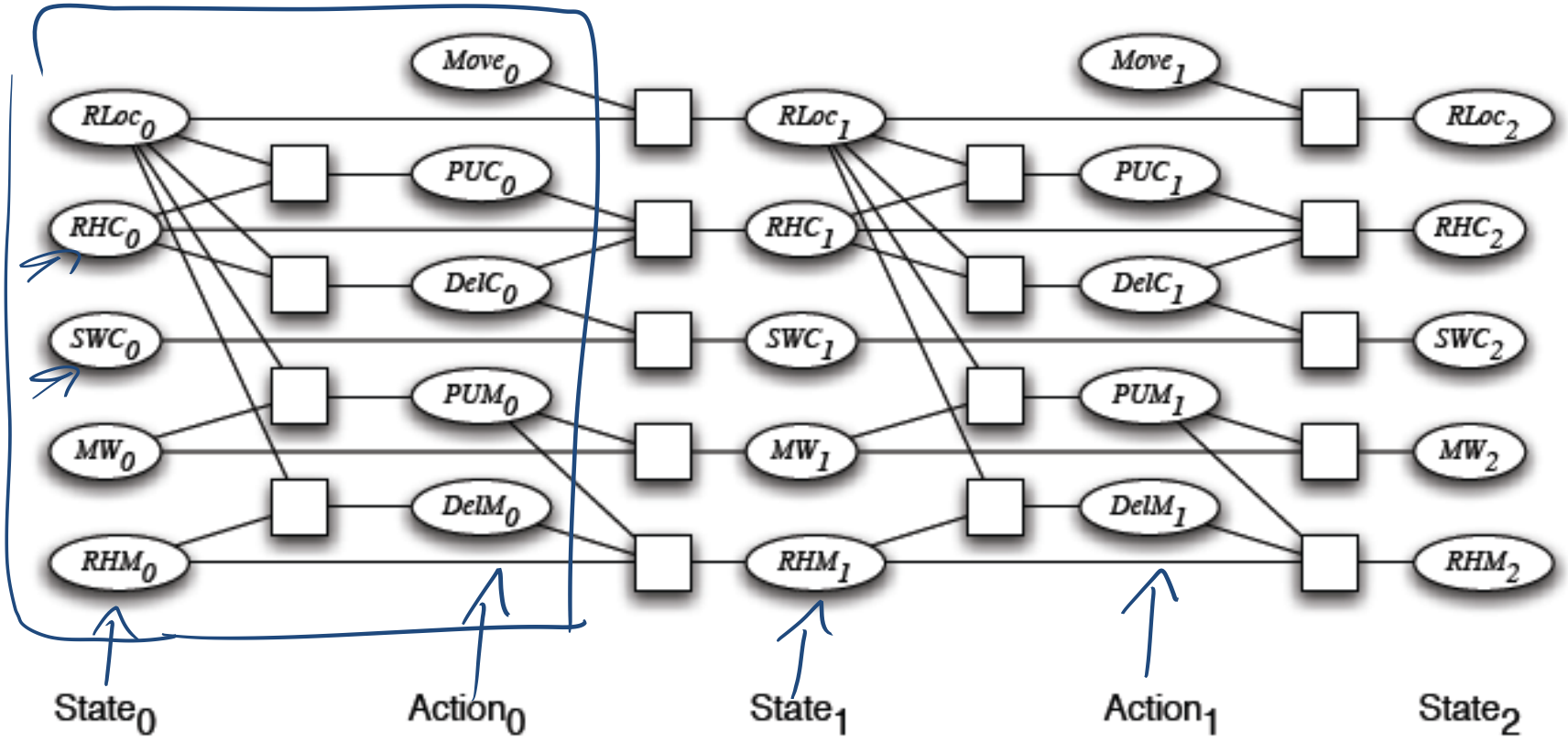
- Once this is done we can even express additional aspects of our problem (as additional constraints)

e.g., see Practice Exercise UBC commuting "*careAboutEnvironment*" constraint

Planning as a CSP: Variables

- We need to "unroll the plan" for a fixed number of steps: this is called the horizon
- To do this with a horizon of k:
  - construct a CSP variable for each STRIPS variable at each time step from 0 to k
  - construct a boolean CSP variable for each STRIPS action at each time step from 0 to k – 1.

CSP Planning: Robot Example



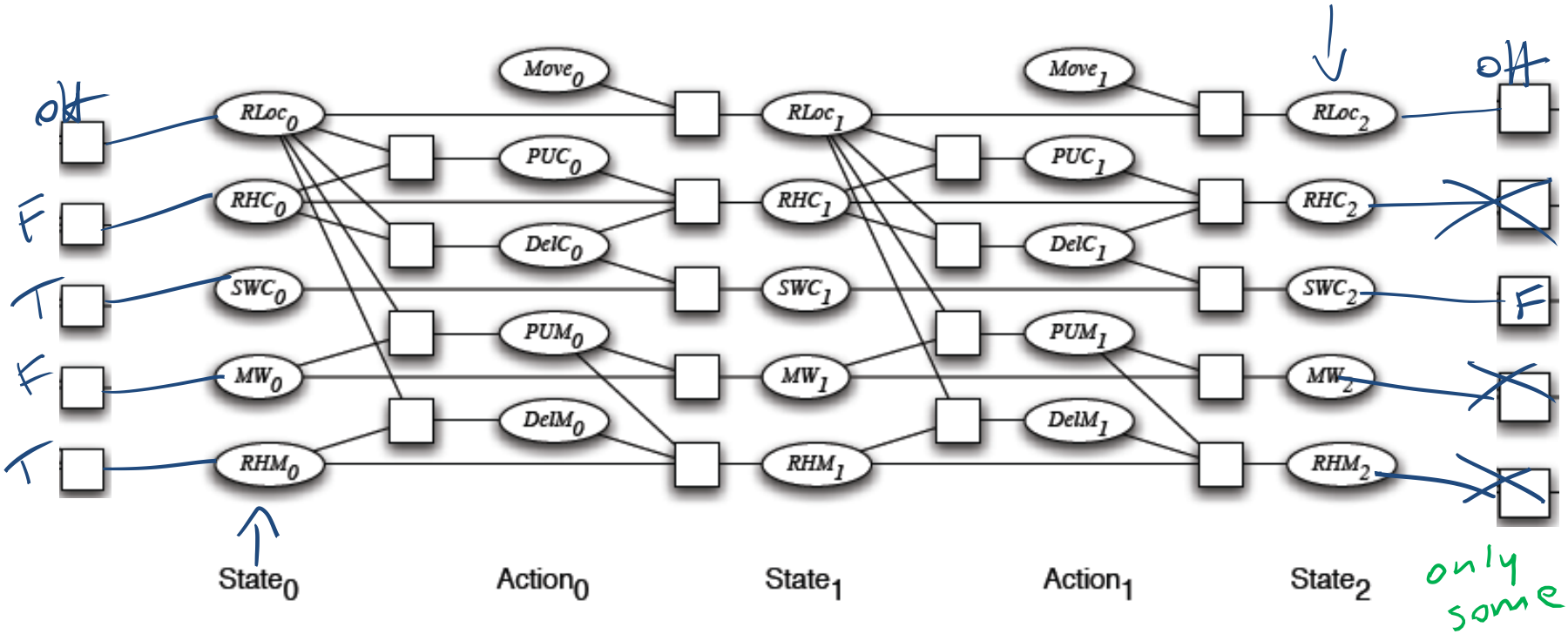
Variables for actions ..

binary

action (non) occurring at that step

CSP Planning: Initial and Goal Constraints

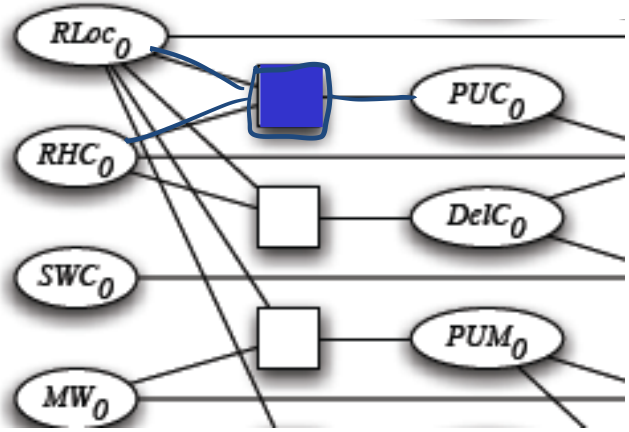
- initial state constraints constrain the state variables at time 0
- goal constraints constrain the state variables at time k



CSP Planning: Prec. Constraints

As usual, we have to express the **preconditions** and **effects** of actions:

- precondition constraints
  - hold between state variables at time t and action variables at time t
  - specify when actions may be taken



PUC_0 (pick up coffee)

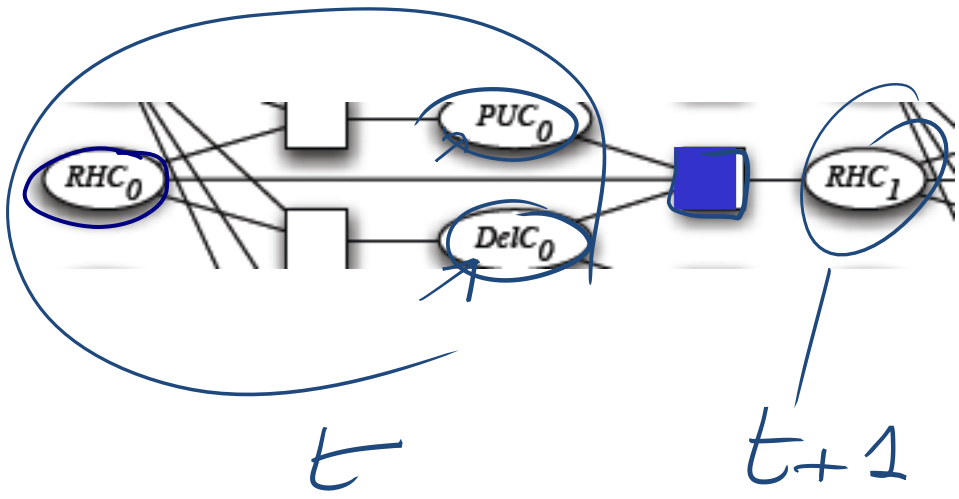
Rob Location

Rob has coffee

$RLoc_0$	RHC_0	PUC_0
cs	T	F
cs	F	T
cs	F	F
mr	*	F
lab	*	F
off	*	F

CSP Planning: Effect Constraints

- effect constraints
  - between state variables at time t, action variables at time t and state variables at time $t + 1$
  - explain how a state variable at time $t + 1$ is affected by the action(s) taken at time t and by its own value at time t



RHC_i	$DelC_i$	PUC_i	RHC_{i+1}
T	T	T	T
T	T	F	F
T	F	T	T
…	…	…	…
…	…	…	…

CSP Planning: Constraints Contd.

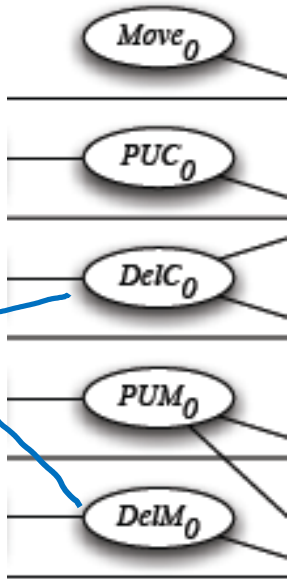
Other constraints we may want are action constraints:

- specify which actions cannot occur simultaneously
- these are sometimes called mutual exclusion (mutex) constraints

i-clicker

How can we specify that *DelM* and *DelC* **cannot** occur simultaneously ?

$DelM_i$	$DelC_i$
??	



A.

$DelM_i$	$DelC_i$
T	T
T	F
F	T

B.

$DelM_i$	$DelC_i$
T	T
F	F

C.

$DelM_i$	$DelC_i$
T	F
F	T
F	F

CSP Planning: Constraints Contd.

Other constraints we may want are action constraints:

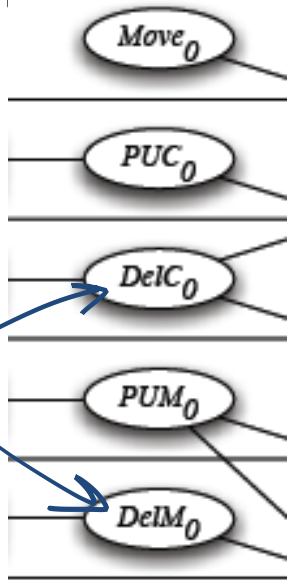
- specify which actions cannot occur simultaneously
- these are sometimes called mutual exclusion (mut constraints

E.g., in the Robot domain

DelM and *DelC* can occur in any sequence (or simultaneously)

But we could change that…

$DelM_i$	$DelC_i$
T	F
F	T
F	F

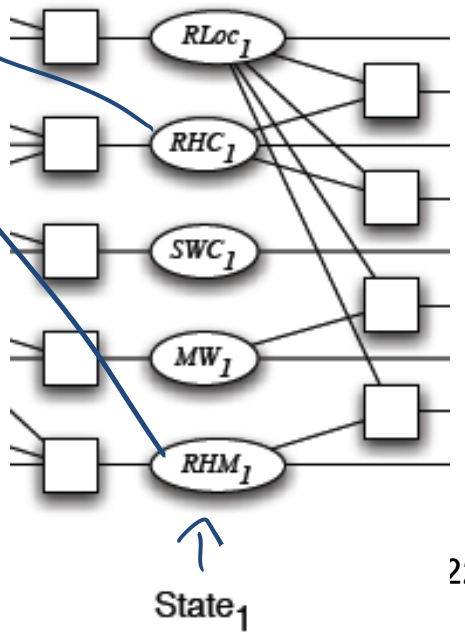


CSP Planning: Constraints Contd.

Other constraints we may want are state constraints

- hold between variables at the same time step
- they can capture physical constraints of the system (robot cannot hold coffee and mail)
- they can encode maintenance goals

RHC_i	RHM_i
T	F
F	T
F	F

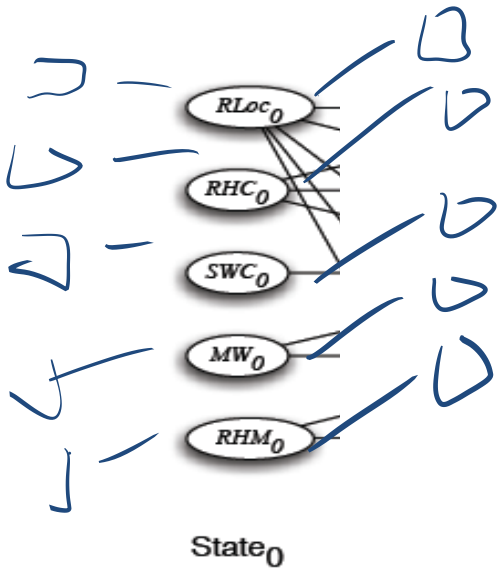


Charge 100% 80% ….
Distance recharger 1 2 3 4 5
Charge – 20% distance >= 0

CSP Planning: Solving the problem

Map STRIPS Representation for horizon 1, 2, 3, …, until solution found

Run arc consistency and search!



k = 0

Is $State_0$ a goal?

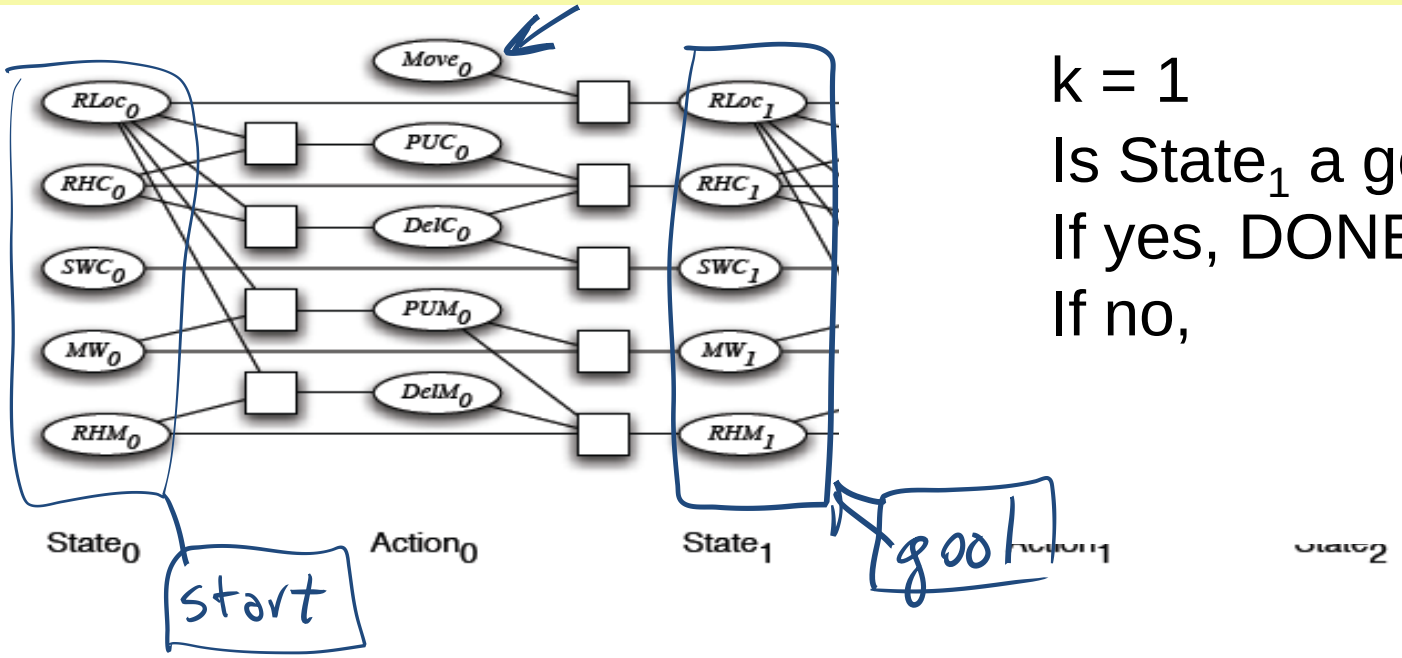
If yes, DONE!

If no,

CSP Planning: Solving the problem

Map STRIPS Representation for horizon k =1

Run arc consistency and search!



k = 1

Is $State_1$ a goal

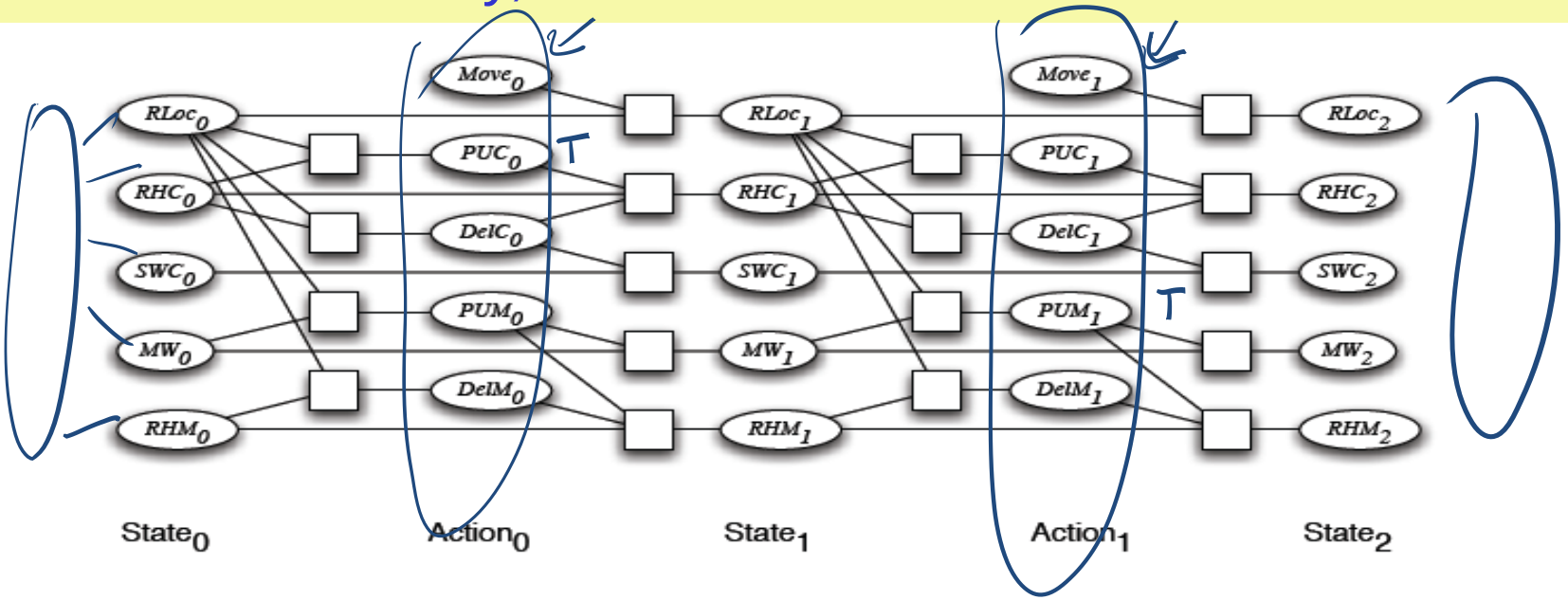
If yes, DONE!

If no,

CSP Planning: Solving the problem

Map STRIPS Representation for horizon k = 2

Run arc consistency, search!



k = 2: Is $State_2$ a goal

If yes, DONE!

If no….continue

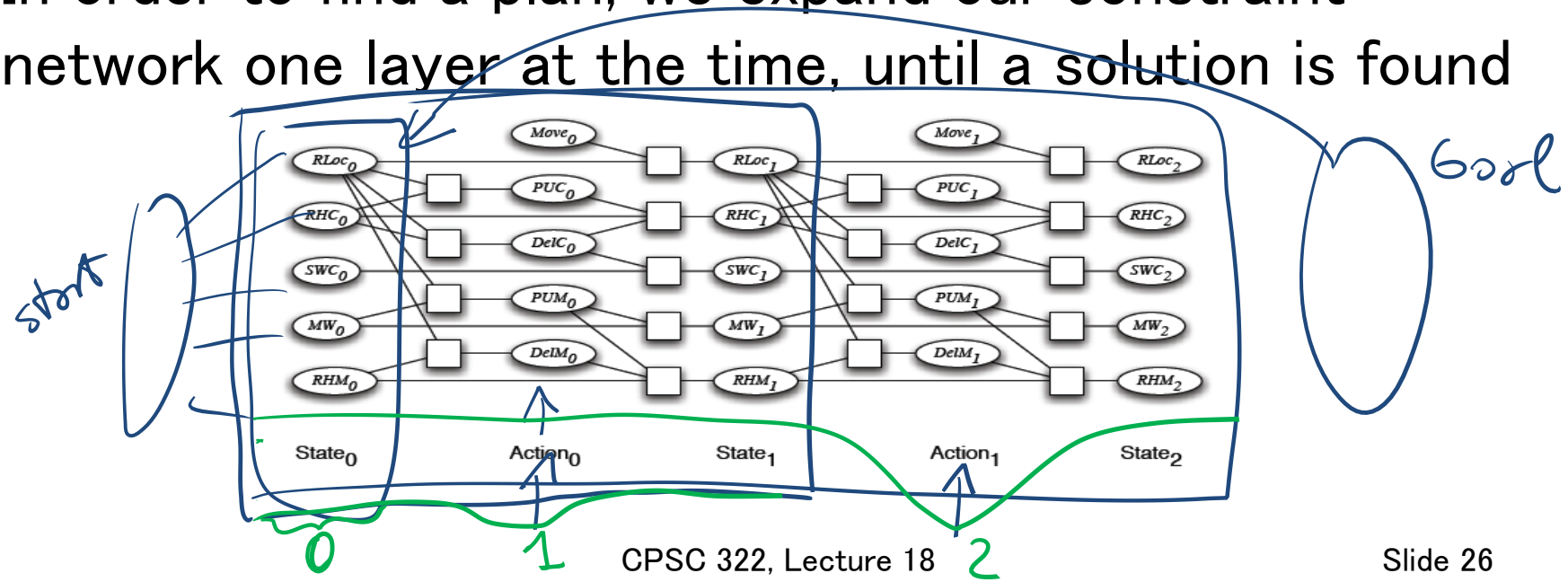
CSP Planning: Solving the problem

Map STRIPS Representation for horizon: 0 1 2 ....

Run **arc consistency** and **search**,

Plan: all actions with assignment T

In order to find a plan, we expand our constraint network one layer at the time, until a solution is found



Solve planning as CSP: pseudo code

```
solved = false
horizon = 0

while not solved
    map STRIPS to CSP with horizon
    solve CSP -> solution
    if solution found then
        solved = true
    else
        horizon = horizon + 1

return solution
```

State of the art planner

A similar process is implemented (more efficiently) in the **Graphplan** planner

STRIPS to CSP applet

Allows you:

- to specify a planning problem in STRIPS
- to map it into a CSP for a given horizon
- the CSP translation is automatically loaded into the CSP applet where it can be solved

Practice exercise using STRIPS to CSP is available on AIspace

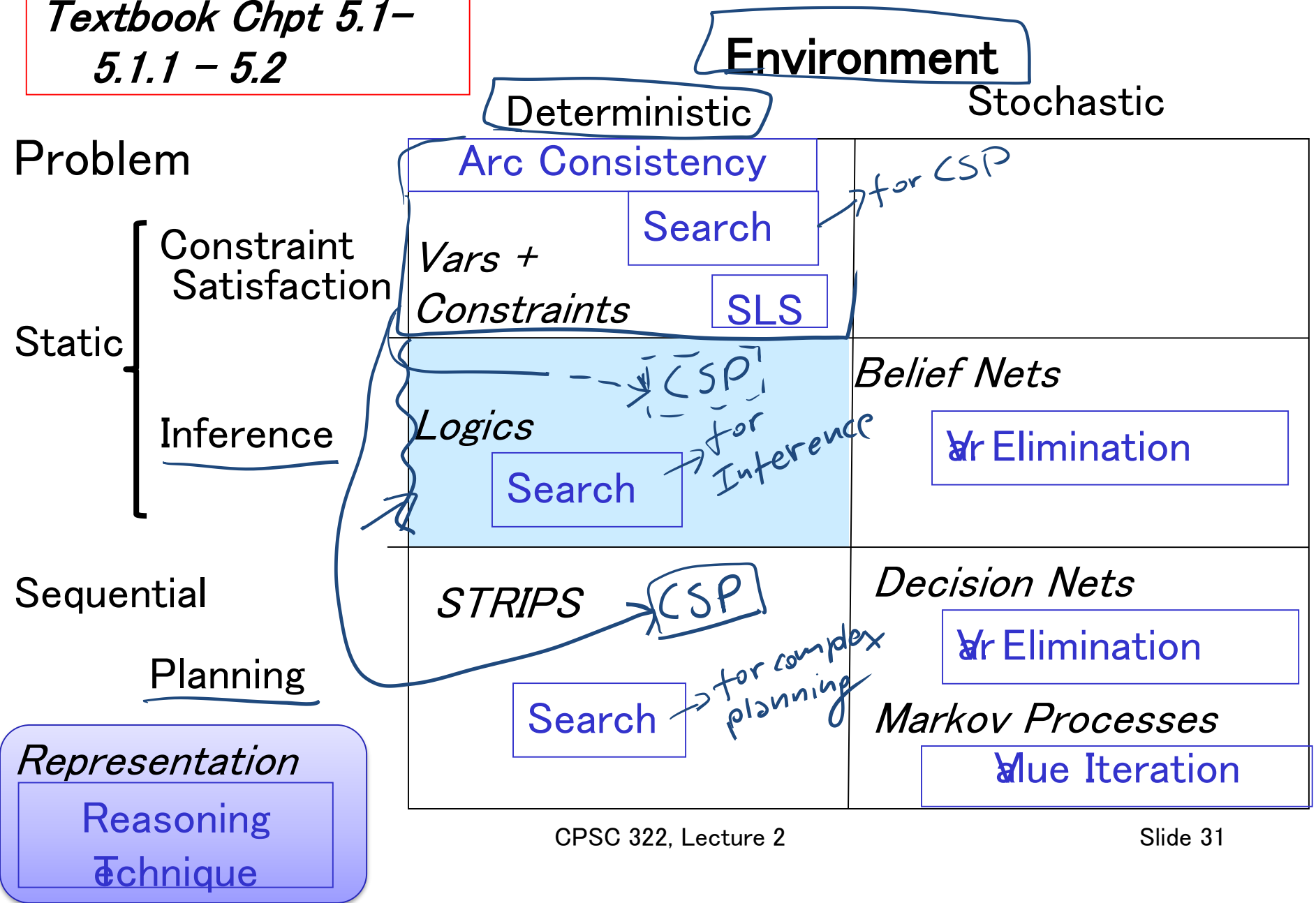
Learning Goals for today's class

You can:

- Construct and justify a **heuristic function** for forward planning.
- Translate a planning problem represented in STRIPS into a corresponding CSP problem (and vice versa)
- Solve a planning problem with CPS by expanding the horizon (new one)

What is coming next ?

Textbook Chpt 5.1–
5.1.1 – 5.2



Logics

- **Mostly only propositional**…. This is the starting point for more complex ones ….
- **Natural** to express **knowledge** about the world
  - What is true (boolean variables)
  - How it works (logical formulas)
- Well understood formal properties
- Boolean nature can be exploited for efficiency
- ……