Planning: Heuristics and CSP Planning

Computer Science cpsc322, Lecture 18

(Textbook Chpt 8)

February, 12, 2010

Lecture Overview

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

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)*

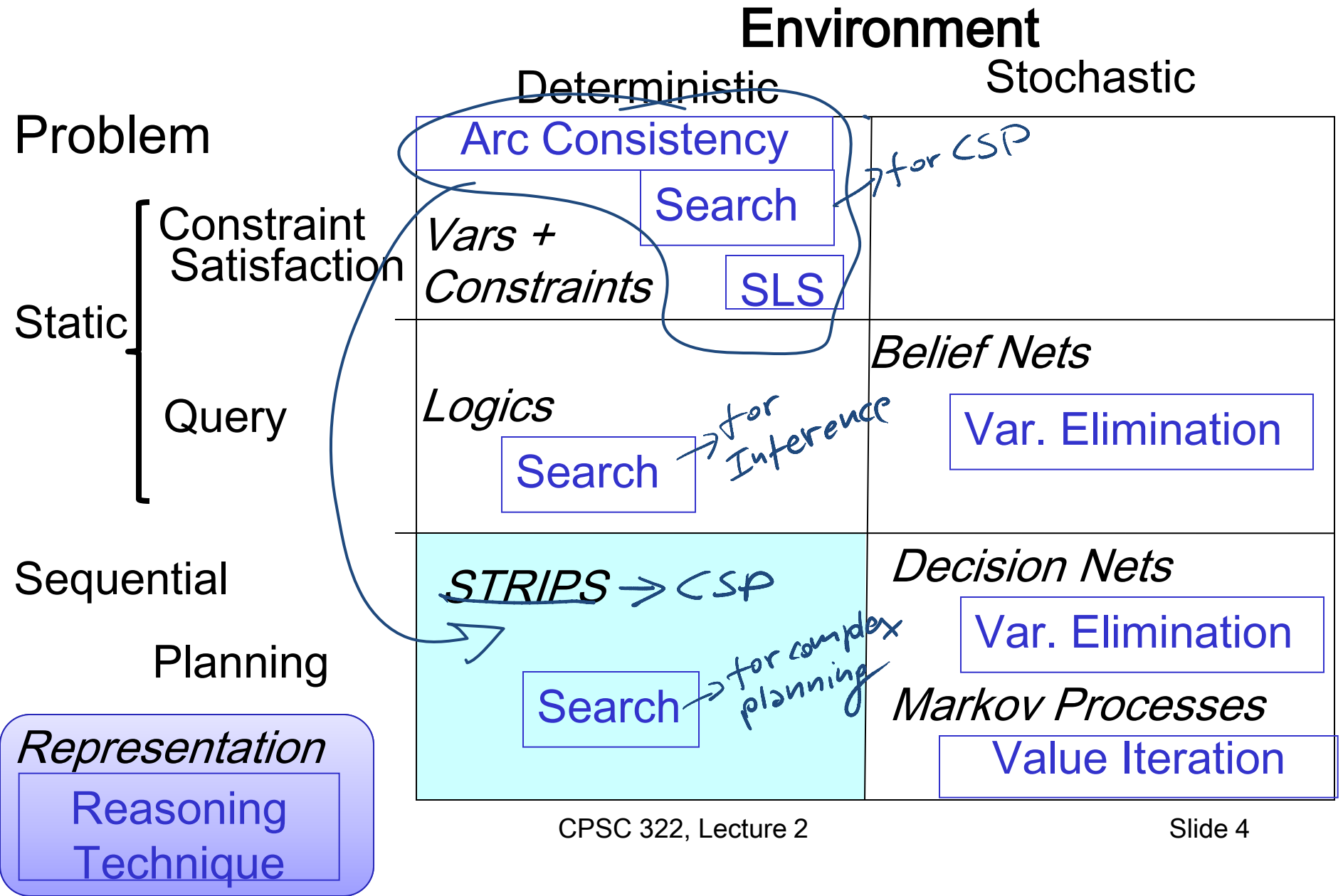
Planning :

- State p. world full assign.
- Successor function states reachable by applying valid actions
- Goal test partial assign.
- Solution sequence of actions
- Heuristic function TODAY

Inference

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

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



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……

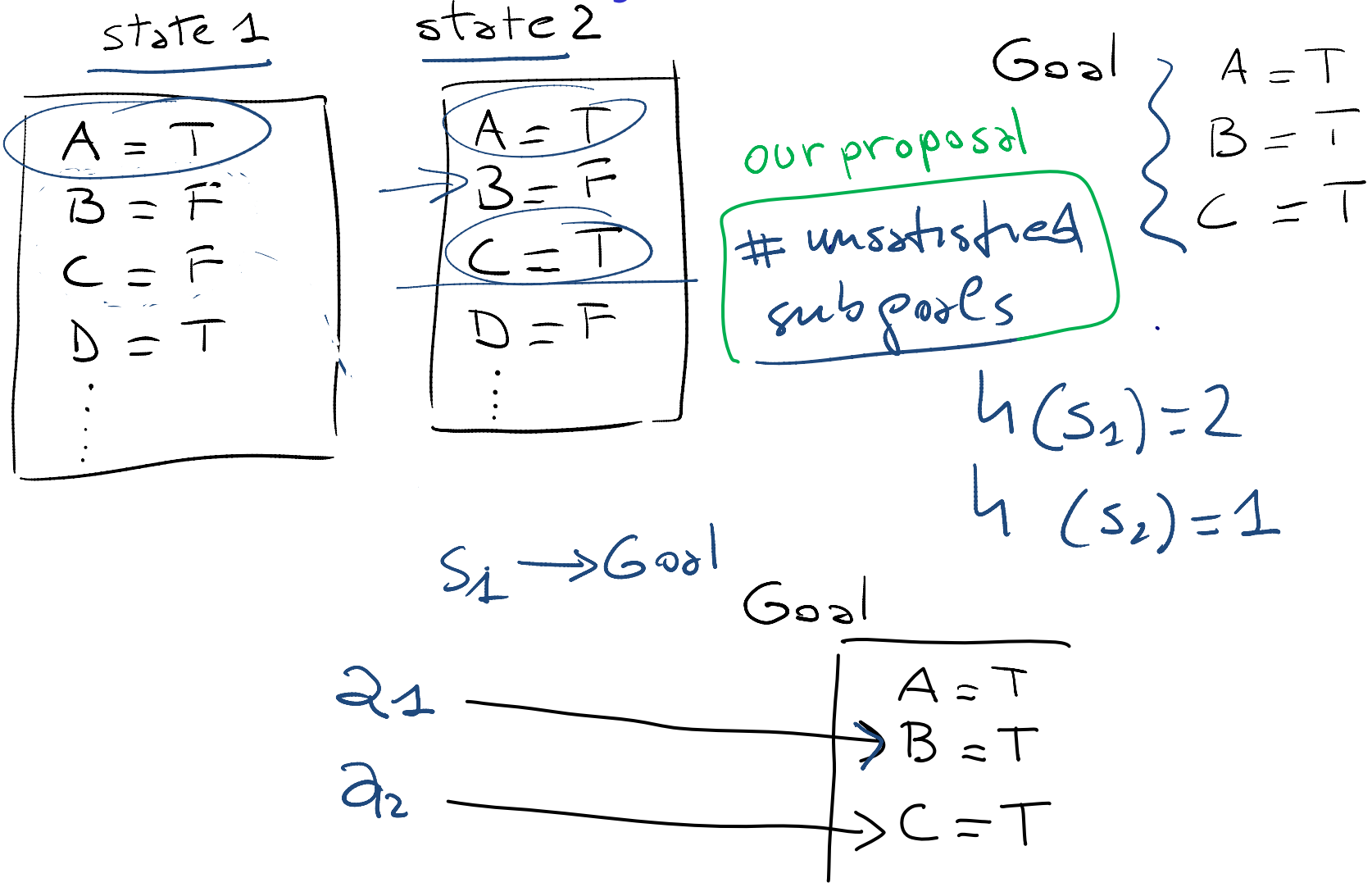
Two simplifications in the representation:

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

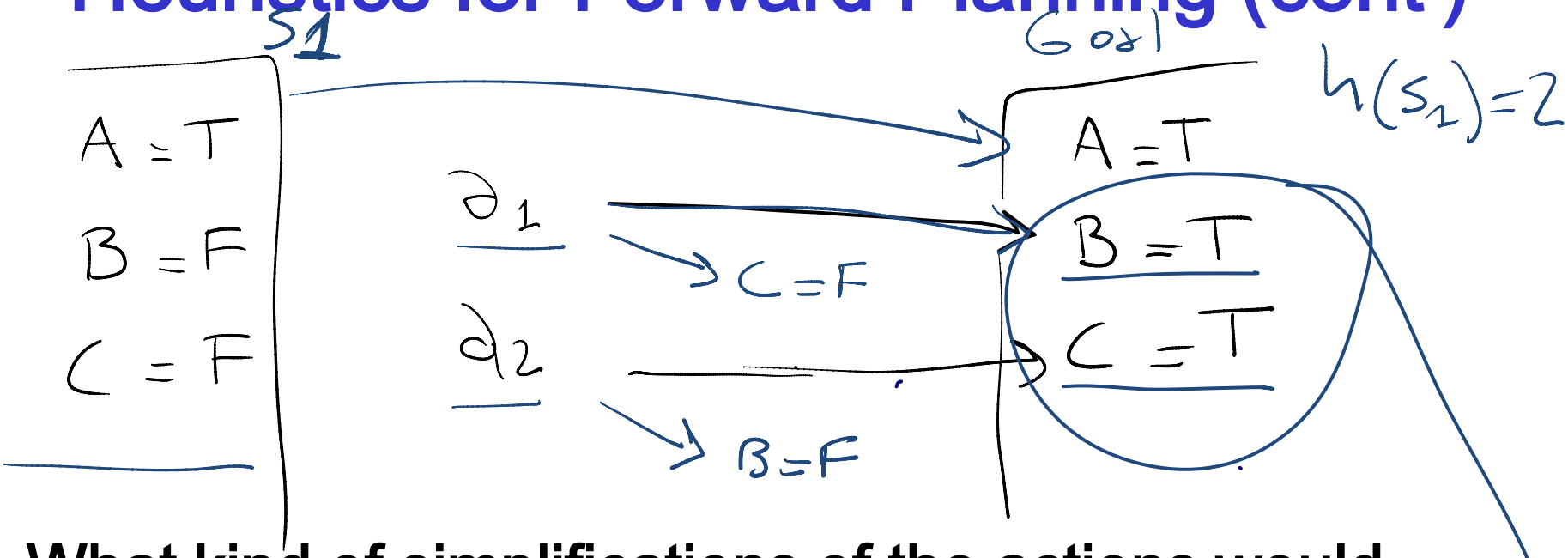
And a Def. a subgoal is a particular assignment in the goal e.g., if the goal is <A=T, B=T, C=T> then….

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

Heuristics for Forward Planning: Any ideas?



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*)

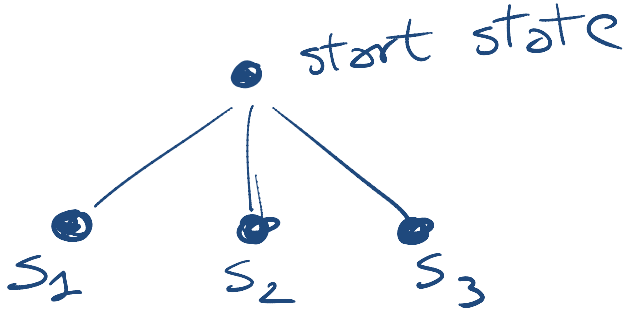
- **But then how do we compute the heuristic?**

……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

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!

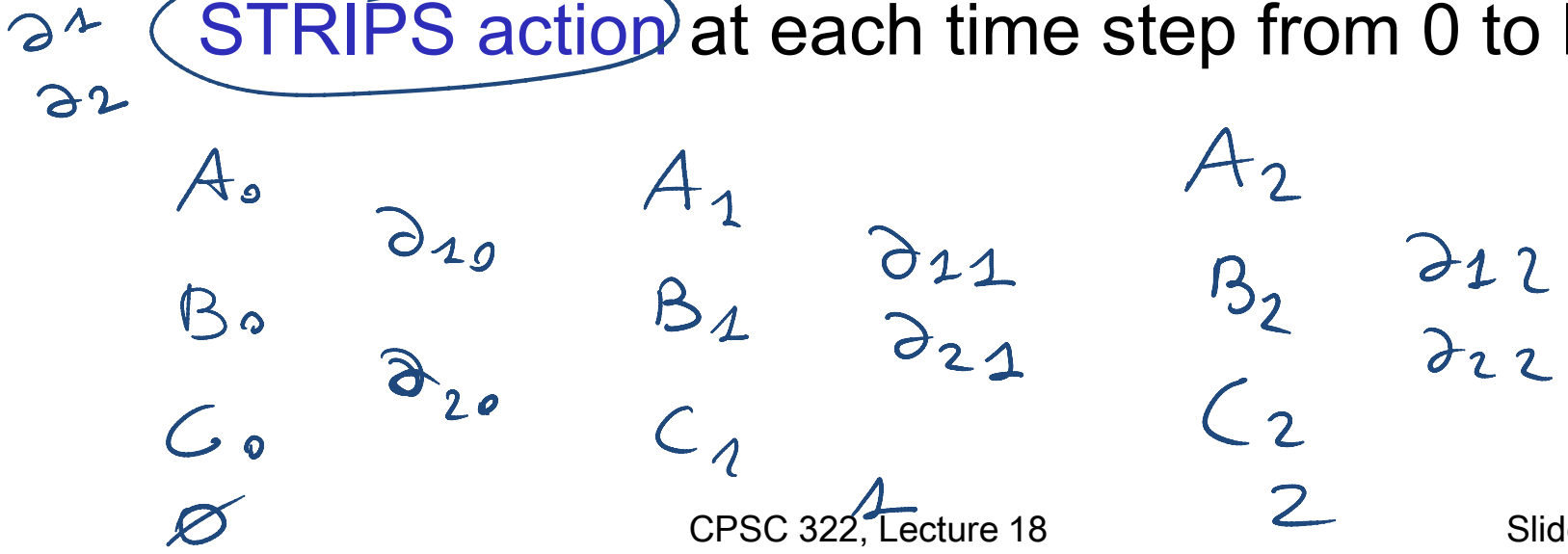
- We simply reformulate a STRIPS model as a set of variables and constraints

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

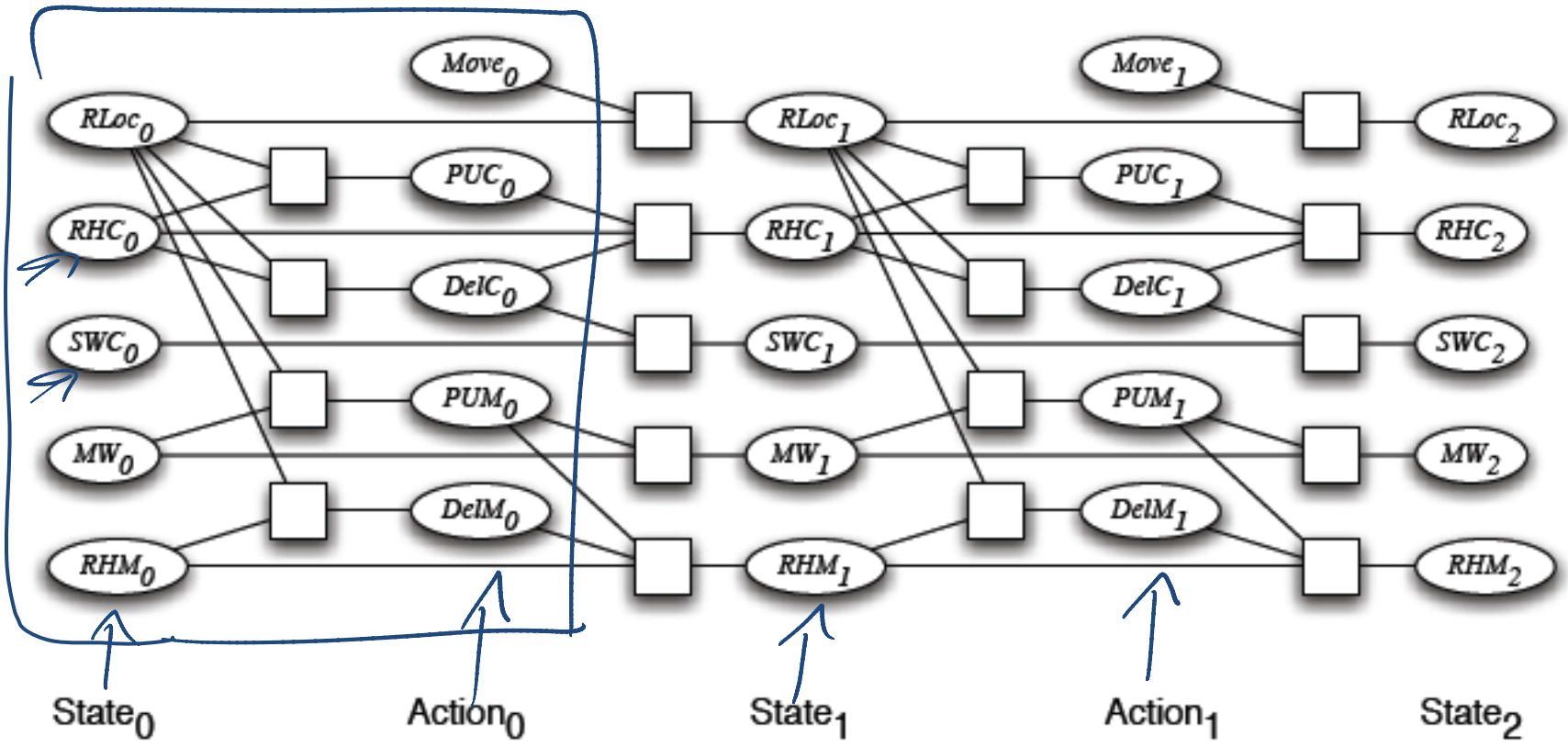
e.g., see Practice Exercise UBC commuting "*careAboutEnvironment*" constraint

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



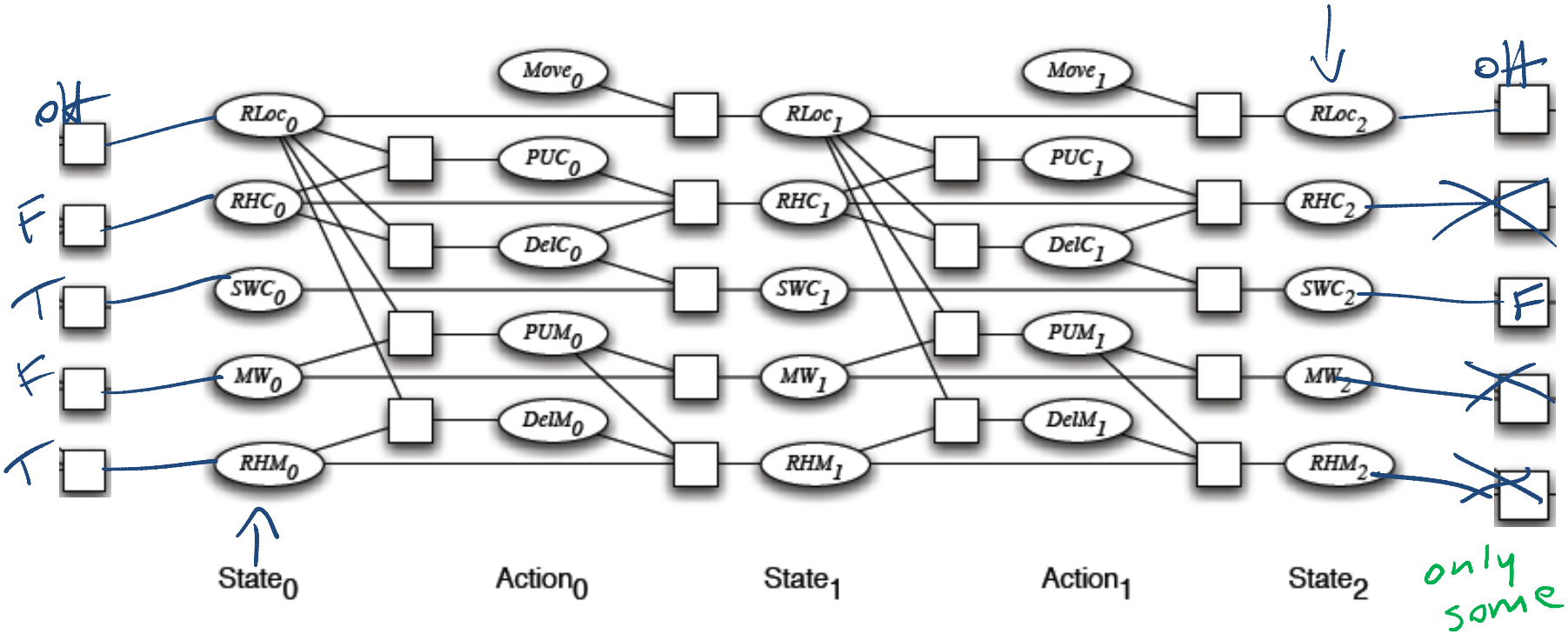
Variables for actions ….

binary

action (non) occurring at that step

CSP Planning: Initial and Goal Constraints

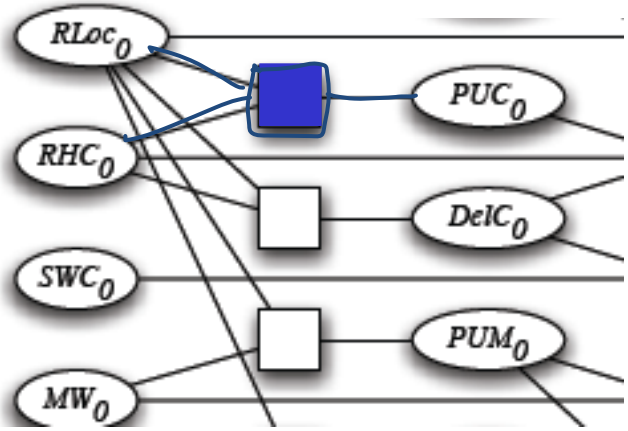
- initial state constraints constrain the state variables at time 0
- goal constraints constrain the state variables at time *k*



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



Rob Location

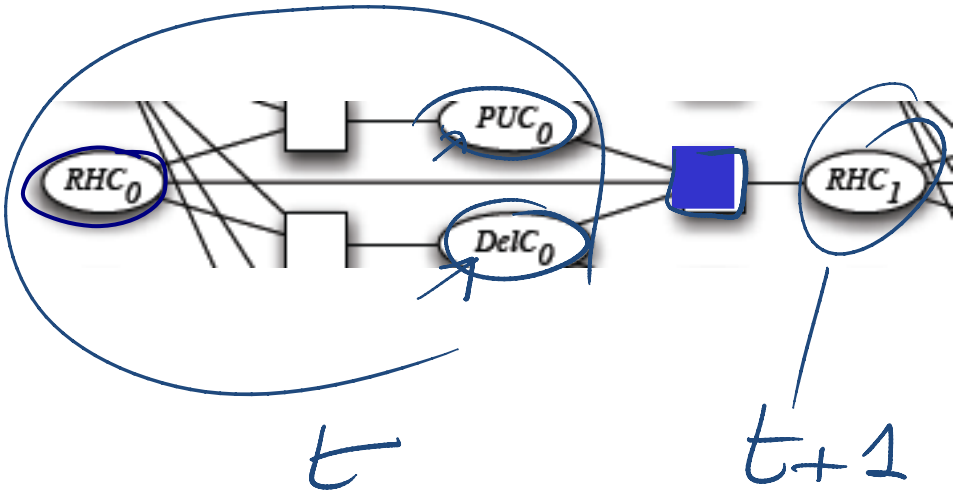
Rob has coffee

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

PUC_0 (pick up coffee)

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:

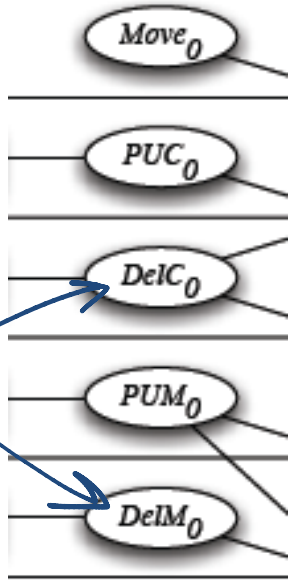
- specify which actions cannot occur simultaneously
- these are sometimes called mutual exclusion (mutex) constraints

E.g., in the Robot domain

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

But we could change that…

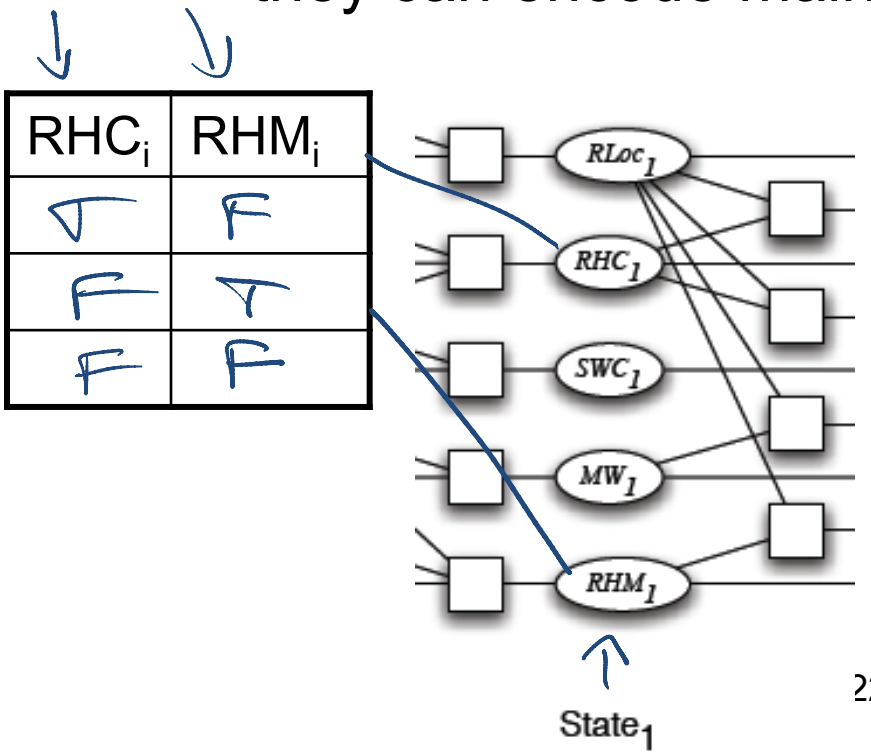
$DelM_i$	$DelC_i$
T	F
F	T
F	F



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



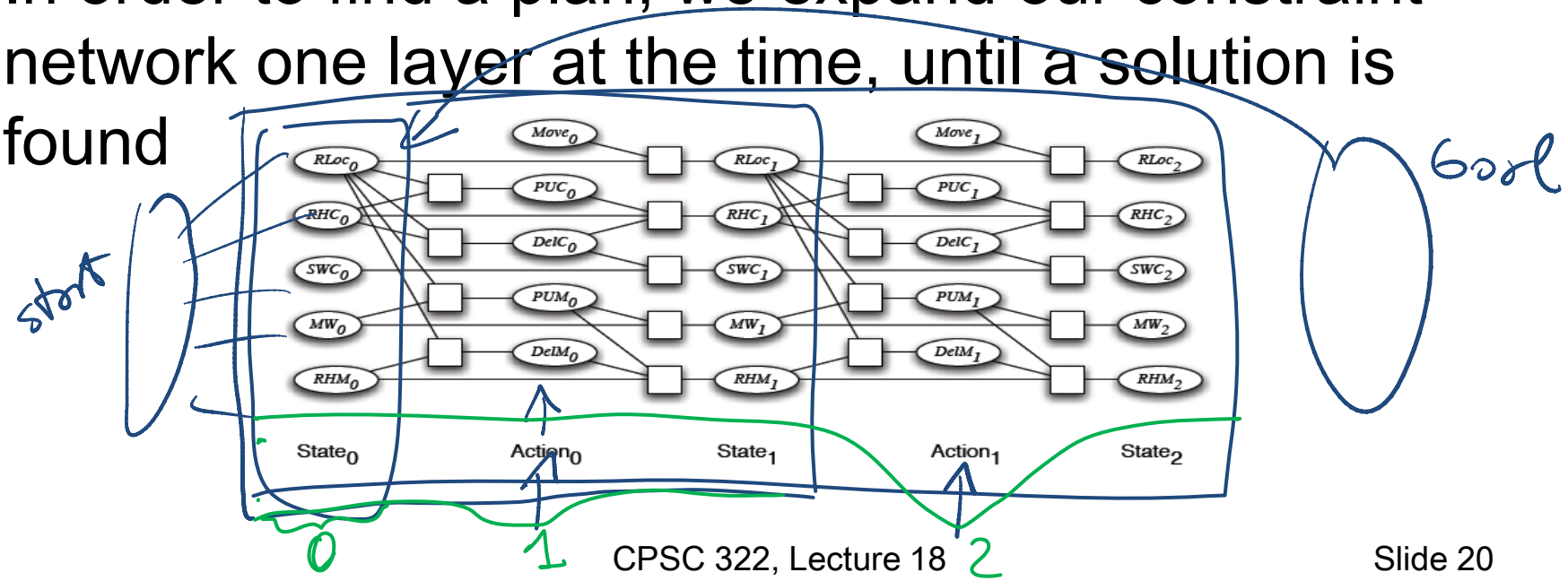
CSP Planning: Solving the problem

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

Run **arc consistency**, **search**, **stochastic local 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

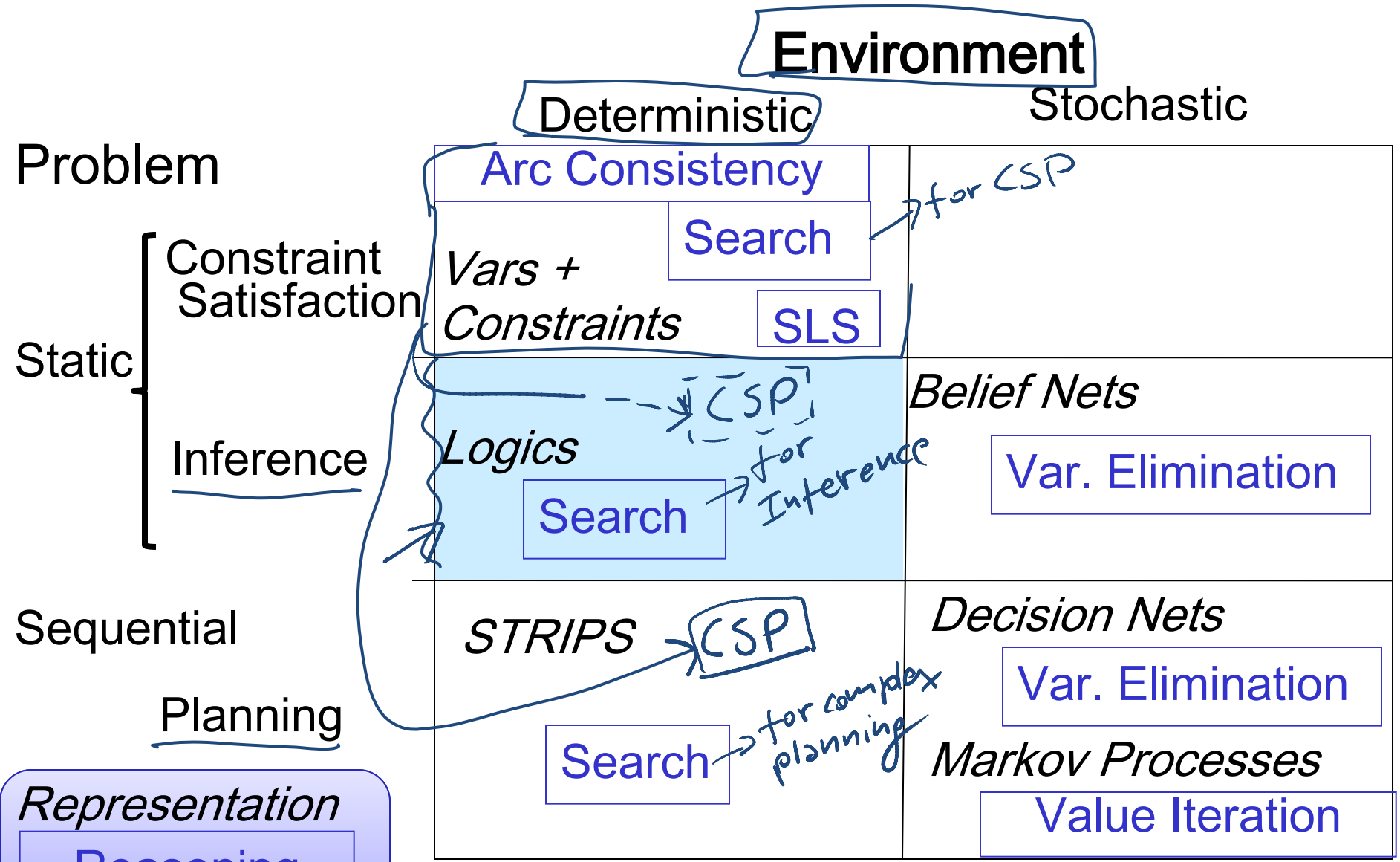
Practice exercise using STRIPS to CSP will be posted next week (maybe a couple ☺)

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 ?



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
- ……

Coming up course elements

Assign-1 returned……

Office hours during break: Giuseppe (Wed17 …..)

- **Sunjeet;** will be available on vista chat during his hours
- **Hammad:** not available, but will be monitoring b-board
- **Scott :** regular time
- **Ken:** next week regular hour, following week WedFeb. 24 3-4pm.

Please send email if you plan to attend a particular office hour

Wed, March 3: **Assign-2 due**

- **Two programming exercises. Start asap. Work in pairs. If stuck, …..**

Wed, March 10 **Midterm exam (1 hour, regular room)**