Planning: Representation and Forward Search

Computer Science cpsc322, Lecture 17

(Textbook Chpt 8.1 (Skip 8.1.1-2)- 8.2)

Oct, 15, 2012

Lecture Overview

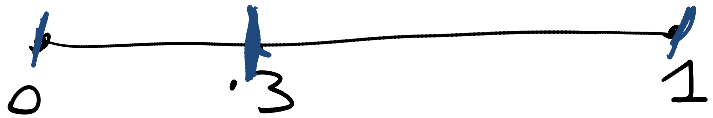
- Clarification
- Where are we?
- Planning
  - Example
  - STRIPS: a Feature-Based Representation
  - Forward Planning

Sampling a discrete probability distribution

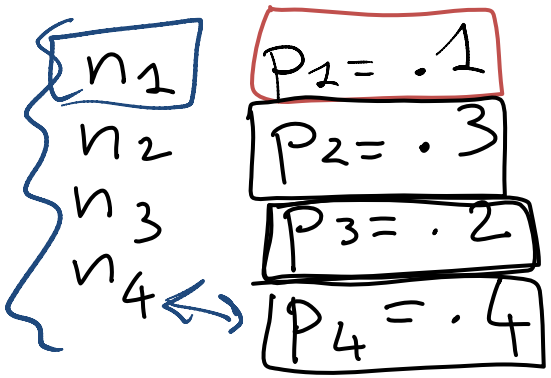
e.g. Sim. Annealing. Select n' with probability p

$p = .3$

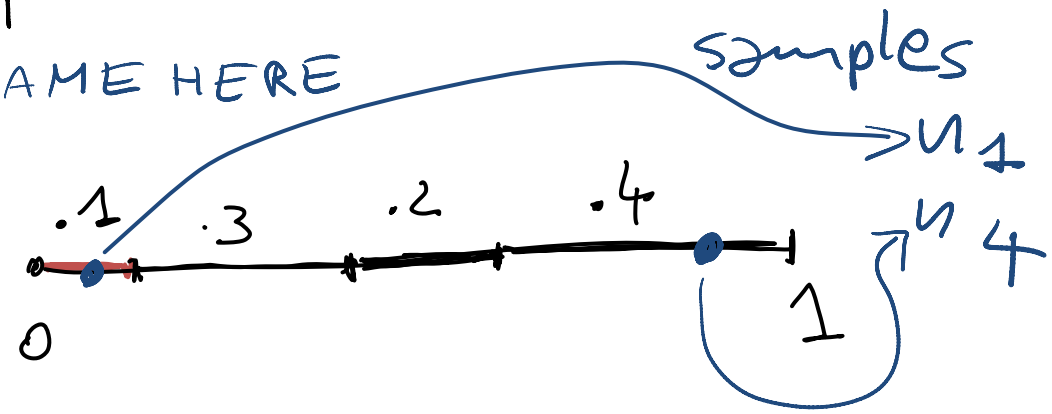
generate random number in $[0,1]$ if $< .3$ accept n'



e.g. Beam Search: Select K individuals. Probability of selection proportional to their value



SAME HERE



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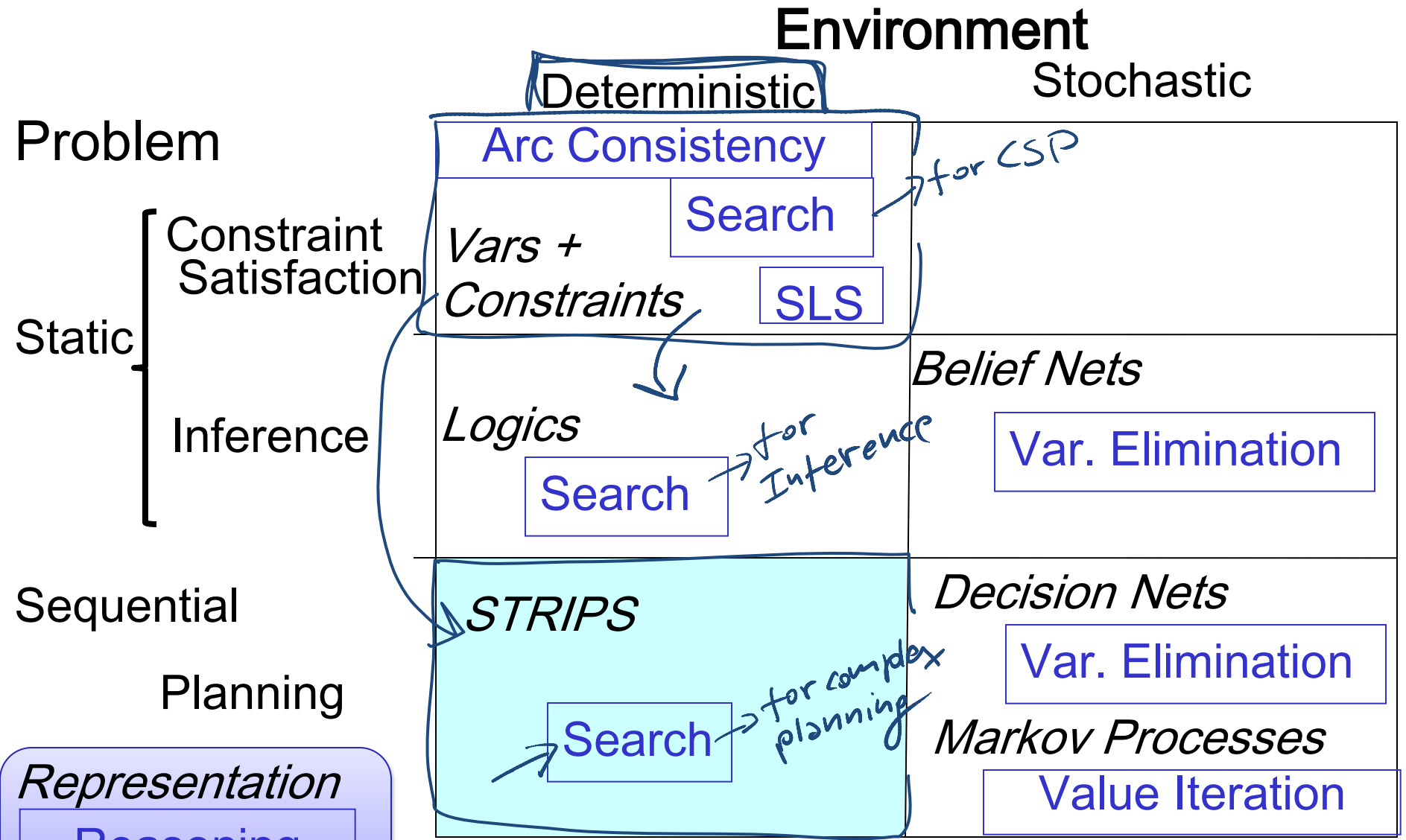
Modules we'll cover in this course: R&Rsys



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
- Successor function
- Goal test
- Solution
- Heuristic function (next class)

Inference

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

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Planning as Search: State and Goal

How to select and organize a sequence of actions to achieve a given goal…

State: Agent is in a possible world (**full assignments** to a set of variables/features)

A B C

domain(true, false) (T, F)
(1 0)

$$\begin{bmatrix} A=T \\ B=F \\ C=T \end{bmatrix}$$ sample state

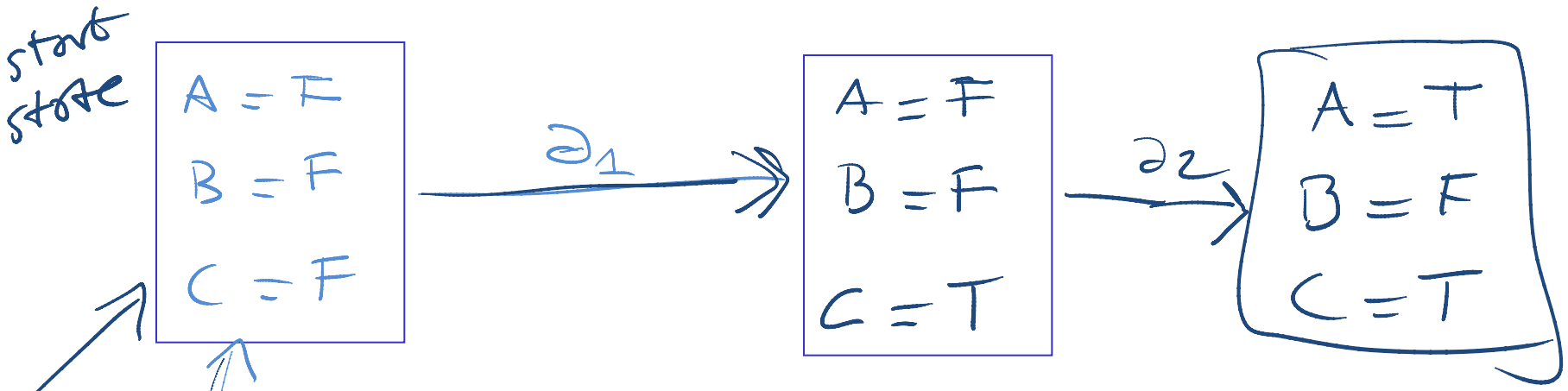
Goal: Agent wants to be in a possible world were **some** variables are given specific values

sample goal

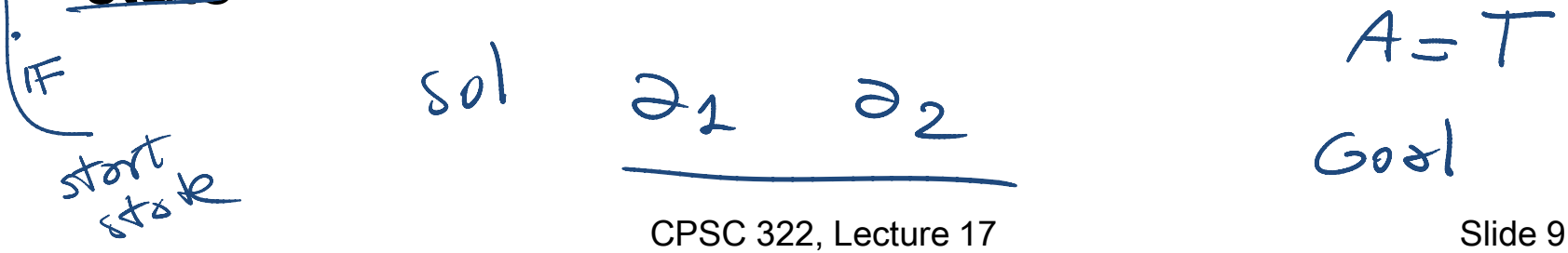
$$\begin{bmatrix} A=T & C=F \end{bmatrix}$$

Planning as Search: Successor function and Solution

Actions : take the agent from one state to another



Solution: sequence of actions that when performed will take the agent from the current state to a goal state



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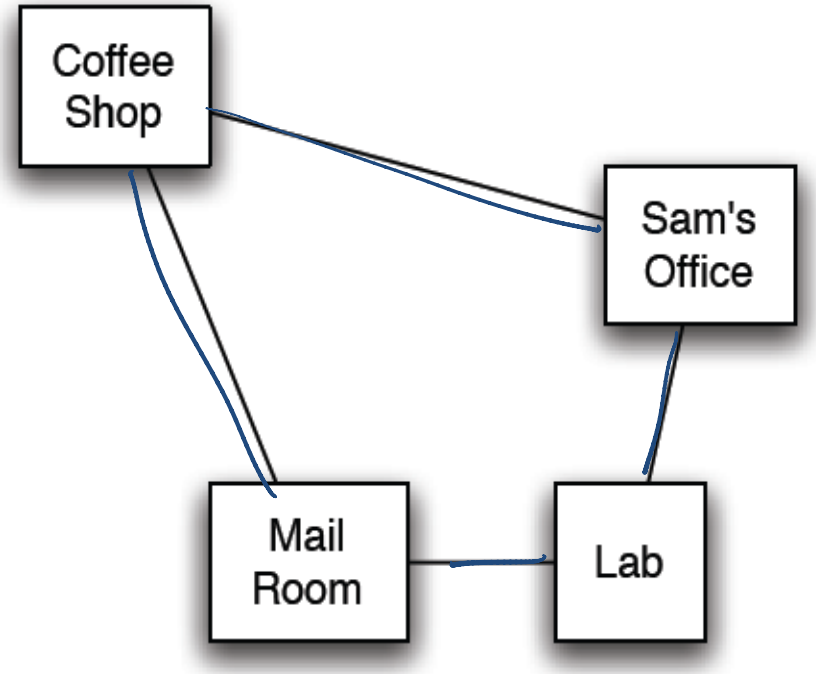
Delivery Robot Example (textbook)

Consider a **delivery robot named Rob**, who must navigate the following environment, can deliver coffee and mail to Sam



Another example will be available as a Practice Exercise: "Commuting to UBC"

Delivery Robot Example: States

The state is defined by the following variables/features:

RLoc - Rob's location

- domain: coffee shop (*cs*), Sam's office (*off*), mail room (*mr*), or laboratory (*lab*)

RHC - Rob has coffee True/False.

SWC - Sam wants coffee T/F

MW - Mail is waiting T/F

RHM - Rob has mail T/F

two different notations

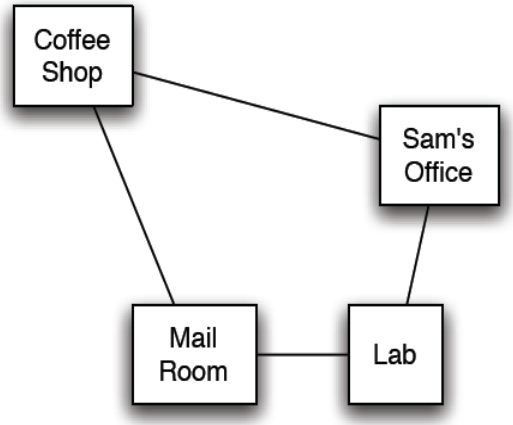
4 2 2 2 2

Example state: {cs, rhc, $\overline{swc}$, $\overline{mw}$, rhm}

Number of states: 64

32 64 48 16

Delivery Robot Example: Actions



The robot's actions are:

Move - Rob's move action

- move clockwise (*mc*), move anti-clockwise (*mac*)
  ~~not move (nm)~~

PUC - Rob picks up coffee

- must be at the coffee shop

DelC - Rob delivers coffee

- must be at the office, and must have coffee

PUM - Rob picks up mail

- must be in the mail room, and mail must be waiting

DelM - Rob delivers mail

- must be at the office and have mail

preconditions

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STRIPS action representation

The key to sophisticated planning is modeling actions

In STRIPS, an action has two parts:

1. Preconditions: a set of assignments to features that **must be satisfied** in order for the action to be legal
2. Effects: a set of assignments to features that are **caused** by the action

STRIPS actions: Example

STRIPS representation of the action pick up coffee, *PUC* :

- **preconditions** *Loc* = *cs* and *RHC* = F
- **effects** *RHC* = T

STRIPS representation of the action deliver coffee, *DelC* :

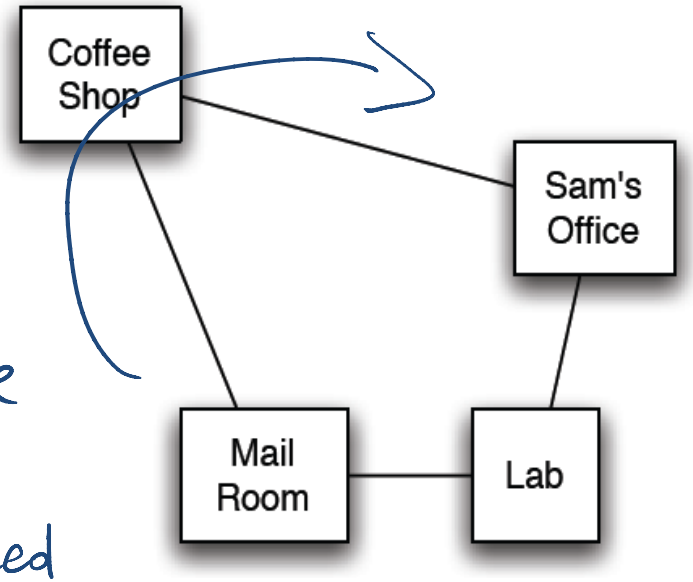
- **preconditions** *Loc* = *off* and *RHC* = T (SWC = T)
- **effects** RHC = F and SWC = F

Note in this domain Sam doesn't have to want coffee for Rob to deliver it; one way or another, Sam doesn't want coffee after delivery.

STRIPS actions: MC and MAC

STRIPS representation of the action

MoveClockwise ?



mc-cs

Prec loc=cs

Eff loc=office

mc-off

:

:

mac-cs

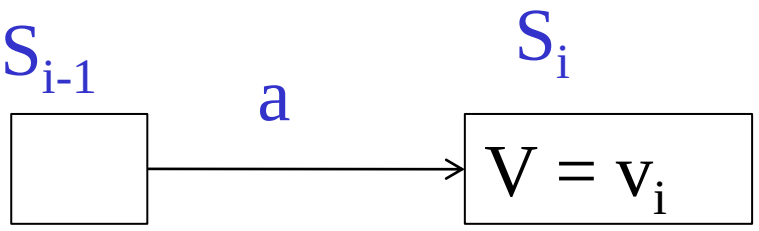
→ you need 4 specific actions

→ and 4 specific actions for move anticlockwise

STRIPS Actions (cont')

The STRIPS assumption: all features not explicitly changed by an action stay unchanged

- So if the feature V has value v_i in state S_i , after action **a** has been performed,
  - what can we conclude about **a** and/or the state of the world S_{i-1} ,immediately preceding the execution of **a**?



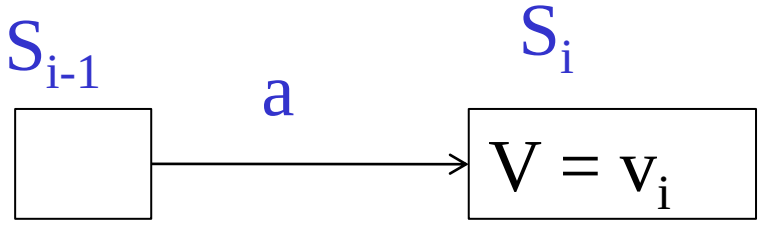
what can we conclude about *a* and/or the state of the world S_{i-1} ,immediately preceding the execution of *a*?

1 $V = v_i$ was TRUE in S_{i-1}

2 One of the effects of **a** is to set $V = v_i$

3 At least one of the above

4 None of the above



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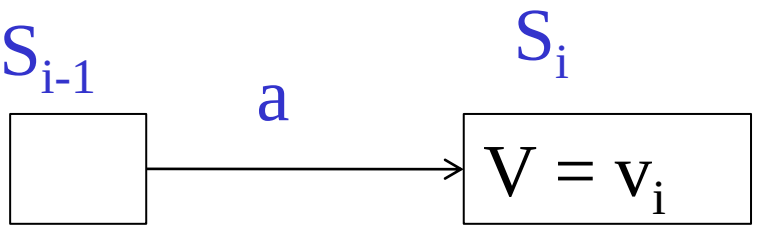

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Forward Planning

To find a plan, a solution: search in the state-space graph.

- The **states** are the **possible worlds**
- The **arcs** from a state ***s*** represent all of the **actions** that are legal in state ***s***.
- A **plan** is a path from the state representing the initial state to a state that satisfies the goal.

What actions *a* are legal/possible in a state s?

Those where **a**'s effects are satisfied in **s**

Those where the state **s'** reached via **a** is on the way to the goal

Those where **a**'s preconditions are satisfied in **s**

Forward Planning

To find a plan, a solution: search in the state-space graph.

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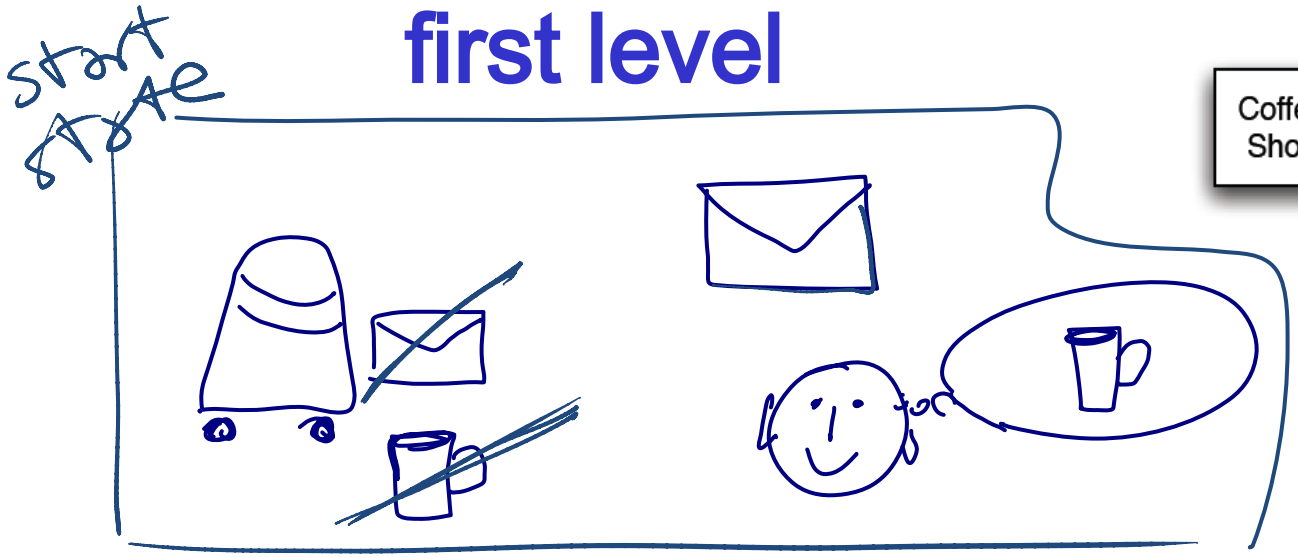
What actions *a* are legal/possible in a state s?

Those where **a**'s preconditions are satisfied in **s**

Example state-space graph: first level



Actions

mc: move clockwise

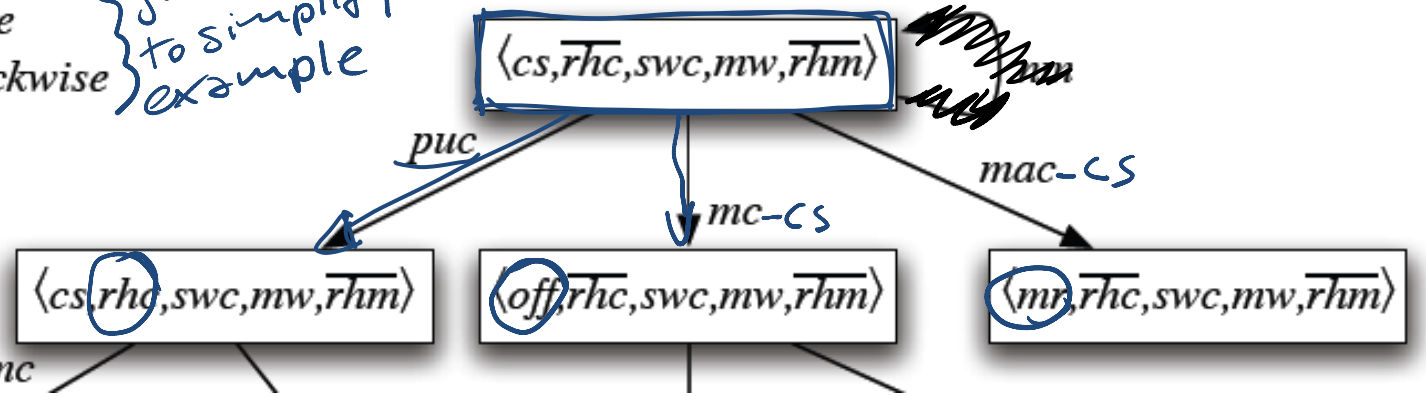
mac: move anticlockwise

puc: pick up coffee

dc: deliver coffee

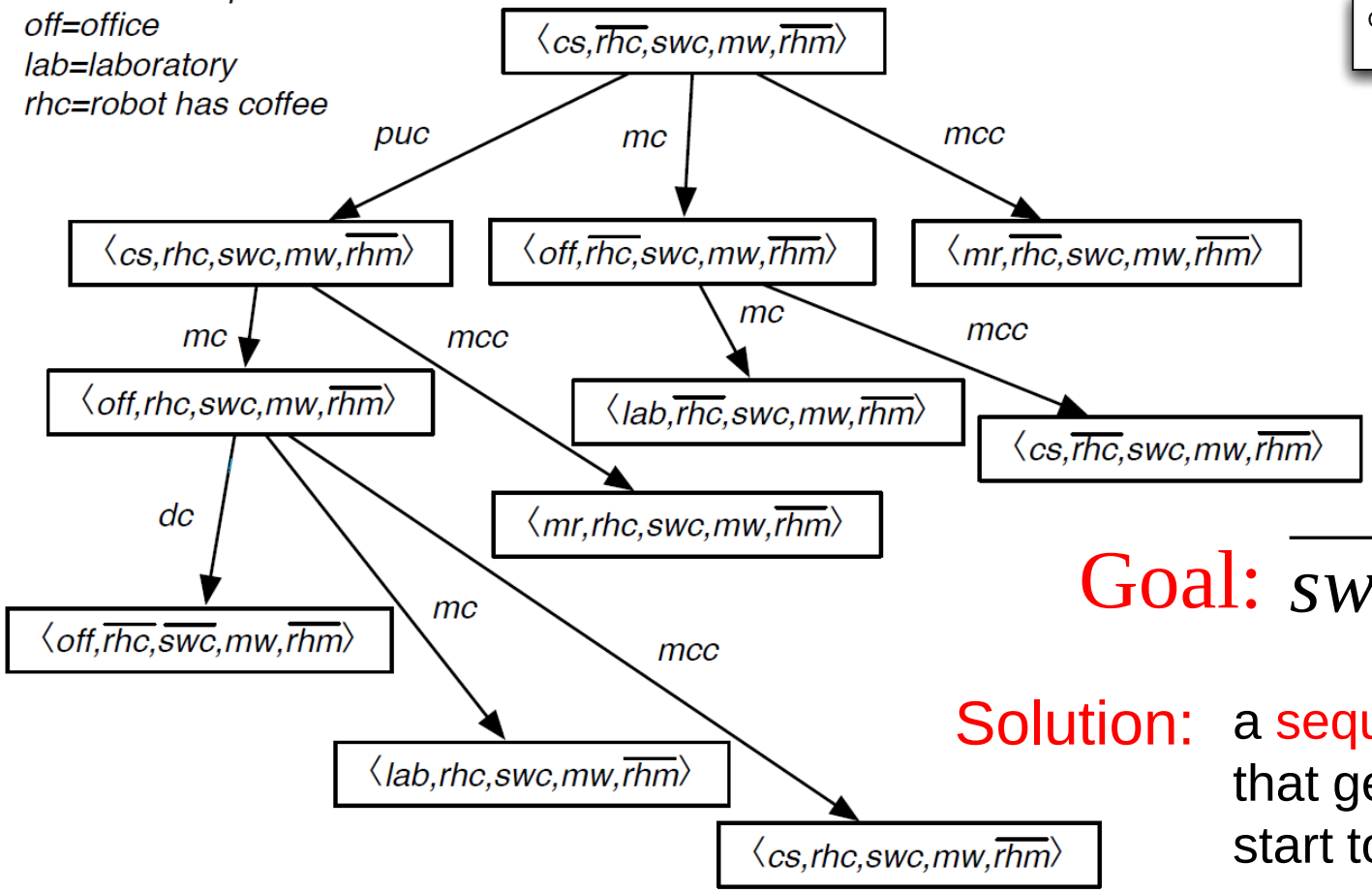
pum: pick up mail

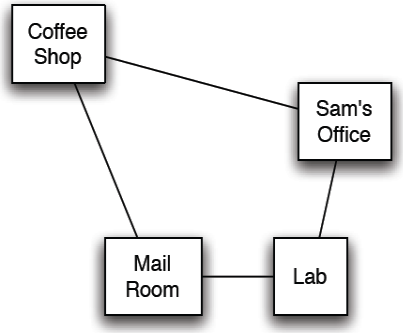
dm: deliver mail



Example for state space graph

cs=coffee shop
off=office
lab=laboratory
rhc=robot has coffee





Goal: $\overline{swc}$

Solution: a sequence of actions that gets us from the start to a goal

What is a solution to this planning problem?

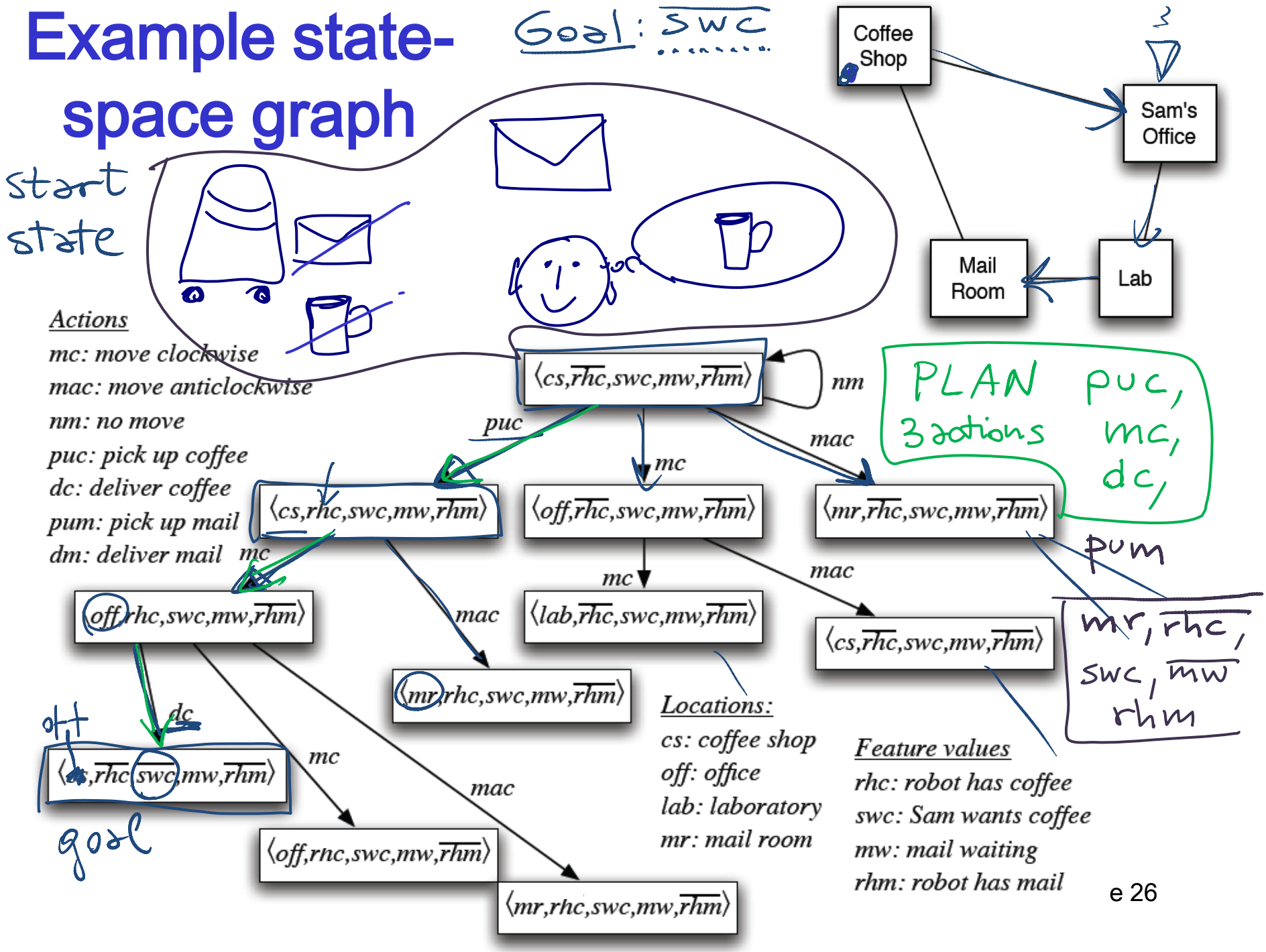
(puc, mc)

(puc, mc, mc)

(puc, dc)

(puc, mc, dc)

Example state-space graph



Learning Goals for today's class

You can:

- Represent a planning problem with the **STRIPS representation**
- Explain the **STRIPS assumption**
- Solve a planning problem by search (**forward planning**). Specify states, successor function, goal test and solution.

Next class

Finish Planning (Chp 8)

- Heuristics for planning (*not on textbook*)
- Mapping planning problem into a CSP (8.4)

Course Announcements

- Start working on Assignment2 (CSP) – due Oct 22
- Work on Practice Exercises (under Aispace)