Planning: Representation and Example

CPSC 322 Lecture 15

February 8, 2007
Textbook §11.1 - 11.2

Lecture Overview

Planning

Given:

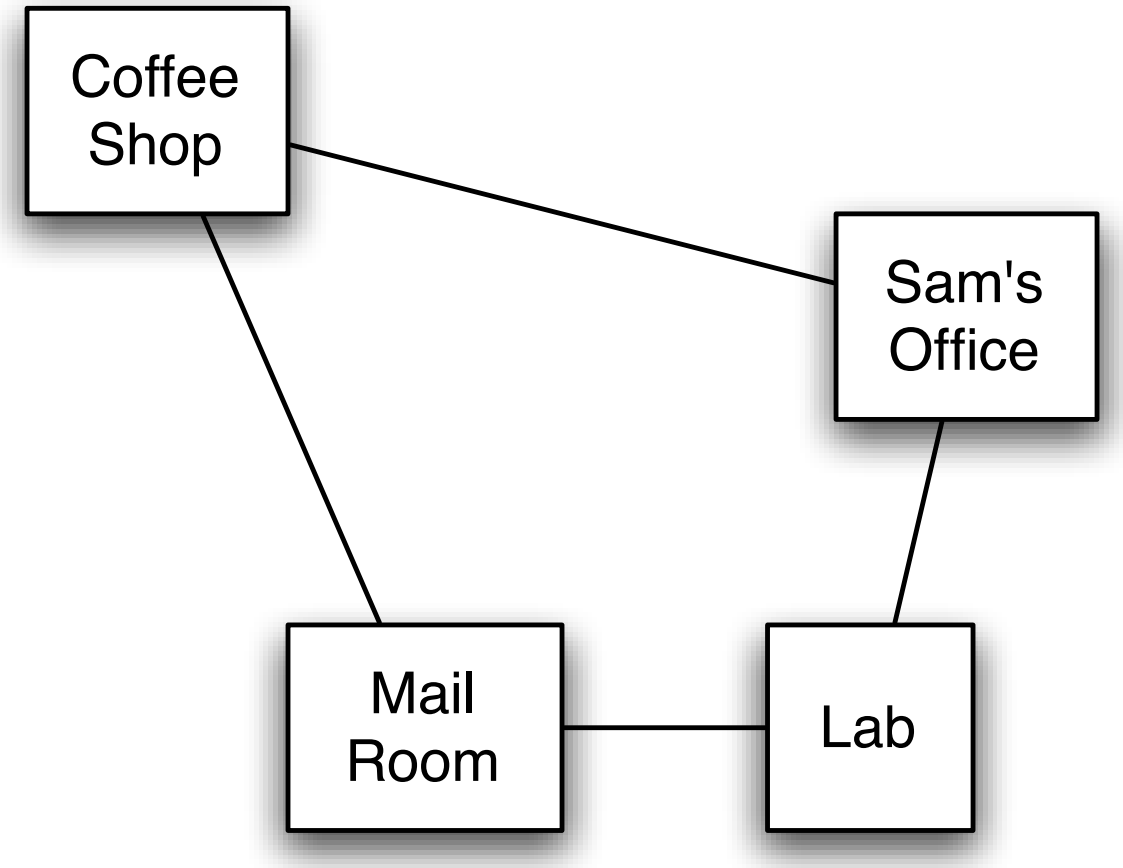
- A description of the effects and preconditions of the actions
- A description of the initial state
- A goal to achieve

find a sequence of actions that is possible and will result in a state satisfying the goal.

- recall: rather than looking for a single state that satisfies our constraints, look here for a sequence of states that gets us to a goal

Delivery Robot Example

Consider a delivery robot named Rob, who must navigate the following environment:



Delivery Robot Example

The state is defined by the following features:

$RLoc$ — Rob's location

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

RHC — Rob has coffee

- domain: true/false. By rhc indicate that Rob has coffee and by $\overline{rhc}$ that Rob doesn't have coffee.

SWC — Sam wants coffee (T/F)

MW — Mail is waiting (T/F)

RHM — Rob has mail (T/F)

An example state is $\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$. How many states are there:

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An example state is $\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$. How many states are there: $4 \times 2 \times 2 \times 2 \times 2 = 64$.

Delivery Robot Example

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

Assume that Rob can perform one action of each kind in a single step. Thus, an example action is $\langle mc, \overline{puc}, \overline{dc}, \overline{pum}, dm\rangle$; we can abbreviate it as $\langle mc, dm\rangle$.

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How many actions are there: $3 \times 2 \times 2 \times 2 \times 2 = 48$.

Lecture Overview

State-Based Representation of a Planning Domain

- The domain is characterized by states, actions and goals
  - note: a given action may not be possible in all states
- Key issue: representing the way we transition from one state to another by taking actions
- We can't do better than a tabular representation:

Starting state	Action	Resulting state
⋮	⋮	⋮

- Problems with this representation:
  - too big
  - hard to modify
  - doesn't capture underlying structure

Example State-Based Representation

State	Action	Resulting State
$\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mc \rangle$	$\langle mr, \overline{rhc}, swc, \overline{mw}, rhm \rangle$
$\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mac \rangle$	$\langle off, \overline{rhc}, swc, \overline{mw}, rhm \rangle$
$\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle nm \rangle$	$\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$
$\langle off, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mac, dm \rangle$	$\langle cs, \overline{rhc}, \overline{swc}, \overline{mw}, \overline{rhm} \rangle$
$\langle off, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mac, \overline{dm} \rangle$	$\langle cs, \overline{rhc}, swc, \overline{mw}, rhm \rangle$
$\langle off, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mc, dm \rangle$	$\langle lab, \overline{rhc}, \overline{swc}, \overline{mw}, \overline{rhm} \rangle$
$\langle off, \overline{rhc}, swc, \overline{mw}, rhm \rangle$	$\langle mc, \overline{dm} \rangle$	$\langle lab, \overline{rhc}, swc, \overline{mw}, rhm \rangle$
...	...	...

Lecture Overview

Feature-Based Representation

- Features helped us to represent CSPs more compactly than states could. Can they help us here?
- Note that our problem is trickier than the original CSP problem:
  - we used to be looking for a single variable assignment, out of the space of all variable assignments, that satisfies our constraints
- Now we are looking for a sequence of variable assignments that
  - begins at the initial state
  - proceeds from one state to another by taking valid actions
  - ends up at a goal
- This means that instead of having one variable for every feature, we must instead have one variable for every feature at each time step, indicating the value taken by that feature at that time step!

Feature-Based Representation

1. Model when the actions are possible, in terms of the values of the features of the current state
2. Model the state transitions in a "factored" way:

Why might this be more tractable/managable than the tabular representation?

Feature-Based Representation

1. Model when the actions are possible, in terms of the values of the features of the current state
2. Model the state transitions in a "factored" way:

Why might this be more tractable/managable than the tabular representation?

- if some action doesn't depend on or modify some feature of the state, we can achieve some representational savings here
- The representation can be easier to modify/update.

Feature-Based Representation

We need two things to replace the tabular representation:

1. Modeling when actions are possible:
   - Provide a function that indicates when an action can be executed
   - Precondition of an action: a function (proposition) of the state variables that is true when the action can be carried out

Feature-Based Representation

We need two things to replace the tabular representation:

1. Modeling when actions are possible
2. Modeling state transitions in a "factored" way:
   - causal rules: explain how the value of a variable describing a feature at time step t depends on the action taken at time $t-1$
     - things that are changed in the world
     - example: act causes $V_1 = v_1$

Feature-Based Representation

We need two things to replace the tabular representation:

1. Modeling when actions are possible
2. Modeling state transitions in a "factored" way:
   - causal rules
   - frame rules: explain how the value of a variable describing a feature at time step t depends on the value of the variable that describes the same feature at time step $t-1$
     - things that are not changed in the world
     - example: $V_4 = v_7$ is maintained when condition c holds
     - the need for frame rules is counter-intuitive: but remember, a computer doesn't know that the variables describing the same feature at different time steps have anything to do with each other, unless they are related to each other using appropriate constraints.

Example

When is $RLoc_{t+1} = cs$?

- $RLoc_{t+1} = cs$ when $RLoc_t = cs$ and $Move_t = nm$
- $RLoc_{t+1} = cs$ when $RLoc_t = off$ and $Move_t = mac$
- $RLoc_{t+1} = cs$ when $RLoc_t = mr$ and $Move_t = mc$

When is rhc true?

- $RHC_{t+1} = rhc$ when $RHC_t = rhc$ and $DelC_t = \overline{dc}$
- $RHC_{t+1} = rhc$ when $PUC_t = puc$

Which of these rules are frame rules?

Lecture Overview

The STRIPS Representation

- The previous representation was feature-centric:
  - for every feature, where does its value come from?
- STRIPS is an action-centric representation:
  - for every action, what does it do?
- This leaves us with no way to state frame rules.
- The STRIPS assumption:
  - all variables not explicitly changed by an action stay unchanged

STRIPS Actions

- In STRIPS, an action has two parts:
  1. Precondition: a logical test about the features that must be true in order for the action to be legal
  2. Effects: a set of assignments to variables that are caused by the action
- If the feature V has value v after the action a has been performed, what can we conclude about a and/or the state of the world?

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- If the feature V has value v after the action a has been performed, what can we conclude about a and/or the state of the world?
  - either $V = v$ was true in the state of the world immediately preceding execution of action a, or a sets $V = v$, or both.

STRIPS vs. Feature Representation

- How can we write causal rules and frame rules for an action act with effects list $[V_1 = v_1, \ldots, V_k = v_k]$?

STRIPS vs. Feature Representation

- How can we write causal rules and frame rules for an action act with effects list $[V_1 = v_1, \ldots, V_k = v_k]$?
  - For each variable V_i in the effects list, write the causal rule "$V_i = v_i$ when act"
  - For each variable V_j not in the effects list, and every one of V_j's values v_k, write the frame axiom "$V_{j,t+1} = v_k$ when act_t and $V_{j,t} = v_k$"

Example

STRIPS representation of the action pick up coffee, PUC:

- **preconditions** $Loc = cs$ and $RHC = \overline{rhc}$
- **effects** $RHC = rhc$

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

- **preconditions** $Loc = off$ and $RHC = rhc$
- **effects** $RHC = \overline{rhc}$ and $SWC = \overline{swc}$

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