Planning
CSE 473

Ways to make “plans”

Generative Planning
Reason from first principles (knowledge of actions)
Requires formal model of actions

Case-Based Planning
Retrieve old plan which worked on similar problem
Revise retrieved plan for this problem

Reinforcement Learning
Act “randomly” - noticing effects
Learn reward, action models, policy

Input Representation

• Description of initial state of world
  E.g., Set of propositions:
  ((block a) (block b) (block c) (on-table a) (on-table b) (clear a) (clear b) (clear c) (arm-empty))

• Description of goal: i.e. set of worlds or ??
  E.g., Logical conjunction
  Any world satisfying conjunction is a goal
  (and (on a b) (on b c)))

• Description of available actions

Simplifying Assumptions

Environment

Static vs. Dynamic

Perfect vs. Noisy

Fully Observable vs. Partially Observable

Percepts

Actions

Instantaneous vs. Durative

Deterministic vs. Stochastic

What action next?

Fully Observable

Partially Observable

Percepts

Actions

Inference

Supervised Learning

Reinforcement Learning

Plan

Logi

Knowledge Representation

Probability

Problem Spaces

Agency

Input

Description of (initial state of) world (in some KR)
Description of goal (in some KR)
Description of available actions (in some KR)

Output

Controller
E.g. Sequence of actions
E.g. Plan with loops and conditionals
E.g. Policy = f: states -> actions
Today's Hot Research Areas

- **Durative Actions**
  - Simultaneous actions, events, deadline goals

- **Planning Under Uncertainty**
  - Modeling sensors; searching belief states

Representing Actions

- **Situation Calculus**
- **STRIPS**
- **PDDL**
- **UWL**
- **Dynamic Bayesian Networks**

How Represent Actions?

- **Simplifying assumptions**
  - Atomic time
  - Agent is omniscient (no sensing necessary)
  - Agent is sole cause of change
  - Actions have deterministic effects

- **STRIPS representation**
  - World = set of true propositions
  - Precondition: (conjunction of literals)
  - Effects: (conjunction of literals)

STRIPS Actions

- **Action** = function: worldState $\rightarrow$ worldState
- **Precondition**
  - says where function defined
- **Effects**
  - say how to change set of propositions

```
north11

north12
```

Note: strips doesn't allow derived effects; you must be complete!
**Action Schemata**

- Instead of defining: pickup-A and pickup-B and ...
- Define a scheme:

  
  (:operator pickup

  \[\text{parameters} (\text{block} \ ?ob1))\]

  \[\text{precondition} (\text{and} (\text{clear} \ ?ob1))\]

  \[\text{(on-table} \ ?ob1)\]

  \[\text{(arm-empty))}\]

  \[\text{:effect} (\text{and} (\text{not} (\text{clear} \ ?ob1)))\]

  \[\text{(not} (\text{on-table} \ ?ob1))\]

  \[\text{(not} (\text{arm-empty}))\]

  \[\text{(holding} \ ?ob1)))\)

**Immediate Outline**

- Constraint satisfaction
- The planning problem
- Searching world states
  - Regression
  - Heuristics
- Graphplan
- SATplan
- Reachability analysis & heuristics
- Planning under uncertainty

**Planning as Search**

- **Nodes**
  - World states
- **Arcs**
  - Actions
- **Initial State**
  - The state satisfying the complete description of the initial conditions
- **Goal State**
  - Any state satisfying the goal propositions

**Forward-Chaining World-Space Search**

**Backward-Chaining Search**

**Thru Space of Partial World-States**

- Problem: Many possible goal states are equally acceptable.
- From which one does one search?

Initial State is completely defined