Planning

CSE 473
473 Topics

- Inference
- Supervised Learning
- Knowledge Representation
- Search
- Problem Spaces
- Reinforcement Learning
- Planning
- Probability
- Logic
- Reinforcement Learning
- Planning
- Probability

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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
Generative Planning

Input
Description of (initial state of) world \textit{(in some KR)}
Description of goal \textit{(in some KR)}
Description of available actions \textit{(in some KR)}

Output
Controller
\textit{E.g.} Sequence of actions
\textit{E.g.} Plan with loops and conditionals
\textit{E.g.} Policy = \( f: \text{states} \rightarrow \text{actions} \)
Input Representation

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

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

• **Description of available actions**
Simplifying Assumptions

- Environment
  - Static vs. Dynamic
  - Fully Observable vs. Partially Observable
  - Instantaneous vs. Durative
  - Deterministic vs. Stochastic

- Percepts
  - Perfect vs. Noisy
  - Fully Observable vs. Partially Observable

- Actions
  - What action next?

- Full vs. Partial satisfaction
Classical Planning

Environment

- Static
- Fully Observable
- Perfect
- Instantaneous
- Deterministic

\[ I = \text{initial state} \quad G = \text{goal state} \quad (\text{prec}) \quad O_i \quad (\text{effects}) \]

\[ \begin{bmatrix} I \\ O_i \\ O_j \\ O_k \\ O_m \end{bmatrix} \rightarrow \begin{bmatrix} G \end{bmatrix} \]
Static Deterministic Observable Instantaneous Propositional

"Classical Planning"

Dynamic

"Situated Plans"

Replanning/

Stochastic

Contingent/Conformant Plans, Interleaved execution MDP Policies

Partially Observable

Semi-MDP Policies

Durative

Temporal Reasoning

Continuous

Numeric Constraint reasoning (LP/ILP)

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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
  Actions:
    • 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
precond: (and (agent-at 1 1)
             (agent-facing north))

effect: (and (agent-at 1 2)
              (not (agent-at 1 1)))
```

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

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

\[
(:\text{operator} \ \text{pick-up} \\
\quad :\text{parameters} \ ((\text{block} \ ?\text{ob1})) \\
\quad :\text{precondition} \ (\text{and} \ (\text{clear} \ ?\text{ob1}) \\
\quad \quad \quad \quad \quad \ (\text{on-table} \ ?\text{ob1}) \\
\quad \quad \quad \quad \quad \ (\text{arm-empty})) \\
\quad :\text{effect} \ (\text{and} \ (\text{not} \ (\text{clear} \ ?\text{ob1})) \\
\quad \quad \quad \quad \quad \ (\text{not} \ (\text{on-table} \ ?\text{ob1})) \\
\quad \quad \quad \quad \quad \ (\text{not} \ (\text{arm-empty})) \\
\quad \quad \quad \quad \quad \ (\text{holding} \ ?\text{ob1})))
\]

Note: strips doesn’t allow derived effects; you must be complete!
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 conds

- **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