Representations and Planners

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PAH (Planning and Games)

STRIPS
(STanford Research Institute Problem Solver)

- 1966-1972 – Shakey the Robot
- $\langle P, O, I, G \rangle$

  P finite set of propositional (true/false) variables

  O finite set of operators:

  pre: $\{p \in P | p = \text{true}\}$
  add: $\{p \in P | p \leftarrow \text{true}\}$
  del: $\{p \in P | p \leftarrow \text{false}\}$

  I initial state ($p \in P$ s.t. $p = \text{true}$, other false)

  G goal state ($p \in P$ s.t. $p = \text{true}$; $p' \in P$ s.t. $p = \text{false}$)

- Set representation
  - true/false determined by the set membership
- Plan existence PSPACE-Complete

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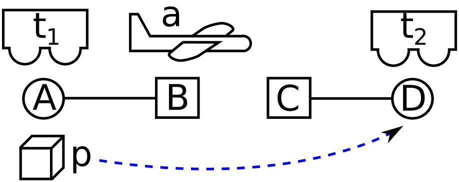
STRIPS
Example



STRIPS
Example

- *P* propositions:
  - truck-at-A, truck-at-B,
  - plane-at-B, plane-at-C,
  - package-at-A, package-at-B, package-at-C,
  - package-in-t, package-in-a
- $2^9 = 512$ states

STRIPS
Example

- O operators:
  - load-p-a-B

    pre: {plane-at-B, package-at-B}
    add: {package-in-a}
    del: {package-at-B}

  - move-t-A-B

    pre: {truck-at-A}
    add: {truck-at-B}
    del: {truck-at-A}

MPT/FDR

Multi-valued Planning Task / Finite Domain Representation (or SAS+)

- $\langle V, O, i, g \rangle$

  V finite set of state variables v with associated finite domain D_v

  - If $D_v = \{\text{true}, \text{false}\}$ equivalent to STRIPS
  - Partial state s defined on $V' \subseteq V$ variables is a function $s : v_1 \times ... \times v_k \longmapsto D_{v_1} \times ... \times D_{v_k}$
  - State is a partial state defined on all variables in V

  i The initial state

  g Partial state defining the goal

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  O finite set of operators $o = \langle \text{pre}(o), \text{eff}(o) \rangle$ where

  pre: partial state

  eff: partial state

- Application of o in state s resulting in s'
  - Values of variables defined in $\text{pre}(o)$ must be equal to their values in s
  - Values in of variables in s' are
    set to values in $\text{eff}(o)$ if defined
    set to values in s else

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MPT/FDR

Example

V variables and their domains:

- truck-at $\in \{A, B\}$
- plane-at $\in \{B, C\}$
- package-at $\in \{A, B, C, t, a\}$
- $2 \times 2 \times 5 = 20$ states

O operators:

load-p-a-B: pre: plane-at=B, package-at=B
eff: package-at=a

move-t-A-B: pre: truck-at=A
eff: truck-at=B

MPT/FDR

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PDDL

Planning Domain Definition Language

- General language (predicate logic) to describe planning problems

  Domain file definition of types, predicates, operators
  Problem file definition of objects, initial state and goal

  - Lisp-like syntax
  - Prefix notation (+12)
  - A lot of brackets
  - Several versions (1.2, 2.1, 3.1)

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Grounding

- Predicate logic
  - $\rightarrow$ STRIPS (propositional logic)
    - All possible instantiations of predicates - propositions
    - All possible instantiations of actions
    - Is it all necessary?
    - No! Reachability analysis can help
  - $\rightarrow$ FDR (finite domain representation)
    - Grounding as in STRIPS
    - Invariant analysis - variables and domains

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PDDL

Resources

- Online editor:
  http://editor.planning.domains
- Resources:
  http://ipc.informatik.uni-freiburg.de/PddlResources
  http://users.cecs.anu.edu.au/~patrik/pddlman/writing.html
  http://www.cs.toronto.edu/~sheila/2542/f10/A1/introtopddl2.pdf
  http://en.wikipedia.org/wiki/Planning_Domain_Definition_Language

Planners

Sub-optimal / Satisficing

- FF (Fast Forward, 2001)
  - Forward-chaining heuristic state space search
  - Enforced hill-climbing / Breadth-first search
  - FF heuristic (relaxation)
- FD-fdss (Fast Downward stone soup, 2006)
  - MPT, several search strategies, several heuristics
  - Automatic configuration
- Lama (2009,2011)
  - Weighted A*
  - Multi-heuristic search (FF, Landmarks)
  - (inadmissible)

Planners (2)

Sub-optimal / Satisficing

- PROBE (2011)
  - GBFS + relaxation heuristic (h_{add})
  - From each state a greedy probes with highly informed heuristics
- Mercury (2014)
  - GBFS + Red-black relaxation heuristic
- yahsp3 (2014)
  - Heuristic search with lookahead using relaxed plans
  - Not on FD codebase

Planners (3)

Optimal

- FD-ms (2011)
  - A^*
  - Merge&Shrink abstraction heuristic
- FD-lmcut (2011)
  - A^*
  - LM-Cut landmark heuristic
- SymBA* (2014)
  - A^* in BDD (binary decision diagram) representation
  - Perimeter-based abstraction heuristic (built from goal)