Principles of AI Planning

4. PDDL

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Schematic operators

Schematic operators

- Description of state variables and operators in terms of a given finite set of objects.
- Analogy: propositional logic vs. predicate logic
- Planners take input as schematic operators and translate them into (ground) operators. This is called grounding.

Schematic operators: example

Schematic operator `drive_car_from_to`(x, y_1, y_2):

$$x \in \{\text{car1}, \text{car2}\},$$
$$y_1 \in \{\text{Freiburg}, \text{Strasbourg}\},$$
$$y_2 \in \{\text{Freiburg}, \text{Strasbourg}\}$$

$$\langle in(x, y_1), in(x, y_2) \land \neg in(x, y_1) \rangle$$

corresponds to the operators

$$\langle in(\text{car1}, \text{Freiburg}), in(\text{car1}, \text{Strasbourg}) \land \neg in(\text{car1}, \text{Freiburg}) \rangle,$$
$$\langle in(\text{car1}, \text{Strasbourg}), in(\text{car1}, \text{Freiburg}) \land \neg in(\text{car1}, \text{Strasbourg}) \rangle,$$
$$\langle in(\text{car2}, \text{Freiburg}), in(\text{car2}, \text{Strasbourg}) \land \neg in(\text{car2}, \text{Freiburg}) \rangle,$$
$$\langle in(\text{car2}, \text{Strasbourg}), in(\text{car2}, \text{Freiburg}) \land \neg in(\text{car2}, \text{Strasbourg}) \rangle,$$

plus four operators that are never applicable (inconsistent change set!) and can be ignored, like

$$\langle in(\text{car1}, \text{Freiburg}), in(\text{car1}, \text{Freiburg}) \land \neg in(\text{car1}, \text{Freiburg}) \rangle.$$

Schematic operators: quantification

Existential quantification (for formulae only)

Finite disjunctions $\varphi(a_1) \vee \cdots \vee \varphi(a_n)$ represented as $\exists x \in \{a_1, \ldots, a_n\} : \varphi(x)$.

Universal quantification (for formulae and effects)

Finite conjunctions $\varphi(a_1) \wedge \cdots \wedge \varphi(a_n)$ represented as $\forall x \in \{a_1, \ldots, a_n\} : \varphi(x)$.

Example

$\exists x \in \{\mathrm{A}, \mathrm{B}, \mathrm{C}\} : \mathit{in}(x, \mathrm{Freiburg})$ is a short-hand for $\mathit{in}(\mathrm{A}, \mathrm{Freiburg}) \vee \mathit{in}(\mathrm{B}, \mathrm{Freiburg}) \vee \mathit{in}(\mathrm{C}, \mathrm{Freiburg})$.

PDDL

PDDL: the Planning Domain Definition Language

- used by almost all implemented systems for deterministic planning
- supports a language comparable to what we have defined above (including schematic operators and quantification)
- syntax inspired by the Lisp programming language: e.g. prefix notation for formulae

```
(and (or (on A B) (on A C))
     (or (on B A) (on B C))
     (or (on C A) (on A B)))
```

PDDL: domain files

A domain file consists of

- (define (domain DOMAINNAME)
- a :requirements definition (use :strips :typing by default)
- definitions of types (each parameter has a type)
- definitions of predicates
- definitions of operators

Example: blocks world (with hand) in PDDL

- Note: Unlike in the previous chapter, here we use a variant of the blocks world domain with an explicitly modeled gripper/hand.

```
(define (domain BLOCKS)
  (:requirements :strips :typing)
  (:types block)
  (:predicates (on ?x - block ?y - block)
               (ontable ?x - block)
               (clear ?x - block)
               (handempty)
               (holding ?x - block)
               )
```

PDDL: operator definition

- (:action OPERATORNAME
- list of parameters: (?x - type1 ?y - type2 ?z - type3)
- precondition: a formula

```
<schematic-state-var>
(and <formula> ... <formula>)
(or <formula> ... <formula>)
(not <formula>)
(forall (?x1 - type1 ... ?xn - typen) <formula>)
(exists (?x1 - type1 ... ?xn - typen) <formula>)
```

- effect:

```
<schematic-state-var>
(not <schematic-state-var>)
(and <effect> ... <effect>)
(when <formula> <effect>)
(forall (?x1 - type1 ... ?xn - typen) <effect>)
```

```
(:action stack
    :parameters (?x - block ?y - block)
    :precondition (and (holding ?x) (clear ?y))
    :effect (and (not (holding ?x))
                 (not (clear ?y))
                 (clear ?x)
                 (handempty)
                 (on ?x ?y)))
```

PDDL: problem files

A problem file consists of

- (define (problem PROBLEMNAME)
- declaration of which domain is needed for this problem
- definitions of objects belonging to each type
- definition of the initial state (list of state variables initially true)
- definition of goal states (a formula like operator precondition)

```
(define (problem example)
  (:domain BLOCKS)
  (:objects a b c d - block)
  (:init (clear a) (clear b) (clear c) (clear d)
         (ontable a) (ontable b) (ontable c)
         (ontable d) (handempty))
  (:goal (and (on d c) (on c b) (on b a)))
)
```

Example

The Fast Downward Planner

Fast Downward is the state-of-the-art planner, usable both for research and applications.

Main developers:

- Malte Helmert
- Gabi Röger
- Erez Karpas
- Jendrik Seipp
- Silvan Sievers
- Florian Pommerening

Fast Downward is available at
`http://www.fast-downward.org/`

Installation:
Follow instructions at
`http://www.fast-downward.org/`
`ObtainingAndRunningFastDownward`

Running:
Follow instructions at
`http://www.fast-downward.org/PlannerUsage`

Example run of Fast Downward

```
# ./fast-downward.py --plan-file plan.txt \
domain.pddl problem.pddl  --search "astar(blind())"

[...]
INFO     Running search.
[...]
Solution found!
[...]
Plan length: 6 step(s).
[...]
Expanded 85 state(s).
[...]
Search time: 0s
[...]
```

Example plan found by Fast Downward


```
# cat plan.txt
(pick-up b)
(stack b a)
(pick-up c)
(stack c b)
(pick-up d)
(stack d c)
; cost = 6 (unit cost)
```

In case you are looking for a decent PDDL editor:

- Check out the PDDL editor in the cloud:
  `http://editor.planning.domains/`
- The website also includes a built-in solver:
  `http://solver.planning.domains/`
- …and an API + domain repository:
  `http://api.planning.domains/`

Example: blocks world in PDDL


```
(define (domain BLOCKS)
  (:requirements :strips :typing)
  (:types block)
  (:predicates (on ?x - block ?y - block)
       (ontable ?x - block)
       (clear ?x - block)
       (handempty)
       (holding ?x - block)
       )
```

```
(:action pick-up
  :parameters (?x - block)
  :precondition (and (clear ?x) (ontable ?x)
                     (handempty))
  :effect (and (not (ontable ?x))
               (not (clear ?x))
               (not (handempty))
               (holding ?x)))
```

```
(:action put-down
  :parameters (?x - block)
  :precondition (holding ?x)
  :effect (and (not (holding ?x))
               (clear ?x)
               (handempty)
               (ontable ?x)))
```

```
(:action stack
  :parameters (?x - block ?y - block)
  :precondition (and (holding ?x) (clear ?y))
  :effect (and (not (holding ?x))
               (not (clear ?y))
               (clear ?x)
               (handempty)
               (on ?x ?y)))
```

```
(:action unstack
  :parameters (?x - block ?y - block)
  :precondition (and (on ?x ?y) (clear ?x)
                     (handempty))
  :effect (and (holding ?x)
               (clear ?y)
               (not (clear ?x))
               (not (handempty))
               (not (on ?x ?y))))
)
```

```
(define (problem example)
  (:domain BLOCKS)
  (:objects a b c d - block)
  (:init (clear a) (clear b) (clear c) (clear d)
         (ontable a) (ontable b) (ontable c)
         (ontable d) (handempty))
  (:goal (and (on d c) (on c b) (on b a)))
)
```