Planning Representation: Preferences in PDDL

Dra. Mª Dolores Rodríguez Moreno

Objectives

Specific Objectives

- Model in PDDL 3.0
- Comparison with NASA planning language

Source

- Gerevini & Long. Plan Constraints and Preferences in PDDL3. Technical Report, Department of Electronics for Automation, University of Brescia, Italy, August 2005

Outline

- **Introduction**
- Preferences in Planning
- PDDL 3 syntax
- PDDL3 examples
- XIDDL language
- XIDDL example
- Conclusions

Introduction

- PDDL2.X is still restrictive
  - Plan quality measured by plan size
  - Hard constraints on actions
  - Hard constraints on goals
- If not satisfied, NO plan!!
- Plan with soft constraints & goals
  - Best quality plan satisfy “as much as possible” the soft constraints & goals
- PDDL2.X is extended: PDDL3

Outline

- Introduction
- **Preferences in Planning**
- PDDL 3 syntax
- PDDL3 examples
- XIDDL language
- XIDDL example
- Conclusions

Preferences in planning (I)

- With soft constraints and goals, can be useful to give priorities
  - Numerical weight representing the cost of its violation in a plan (metric)
- Transportation example
  - We would like that every airplane is used (instead of using only a few airplanes, because it is better to distribute the workload among the available resources and limit heavy usage)
  - Whenever a ship is ready at a port to load the containers it has to transport, all such containers should be ready at that port
  - We would like that at the end of the plan all trucks are clean and at their source location
  - We would like no truck to visit any destination more than once

Preferences in planning (II)

- Can express that certain plans are more preferred than others
  - *I prefer a plan where every airplane is used, rather than a plan using 100 units of fuel less*, which could be expressed by weighting a failure to use all the planes by a number 100 times bigger than the weight associated with the fuel use in the plan metric
  - *I prefer a plan where each city is visited at most once, rather than a plan with a shorter makespan*, which could be expressed by using constraint violation costs penalising a failure to visit each city at most once very heavily
  - *I prefer a plan where at the end each truck is at its start location, rather than a plan where every city is visited by at most one truck*, which could be expressed by using goal costs penalising a goal failure of having every truck at its start location more heavily than a failure of having in the plan every city visited by at most one truck

Outline

- Introduction
- Preferences in Planning
- **PDDL 3 syntax**
- PDDL3 examples
- XIDDL language
- XIDDL example
- Conclusions

PDDL syntax: Domain

```
(define (domain name)
  (:requirements <require-key> :constraints :preferences)
  (:types <typed_list (name)>)
<PDDL list of predicates in the domain>
<PDDL list of functions in the domain>
<PDDL code for first action>
...
<PDDL code for last action>
)
```

PDDL syntax: Problem

```
(define (problem <problem name>)
…
(:goal (and …
[(preference [name] <GD>)]
(:constraints
  (at end <GD>) | (always <GD>) | (sometime <GD>) | (within <num> <GD>) | (at- most-
once <GD>) | (sometime-after <GD> <GD>) | (sometime-before <GD> <GD>) | (always-
within <num> <GD> <GD>) | (hold-during <num> <num> <GD> | (hold-after <num>
<GD> | ...
(:metric
 (is-violated <preference-name>)
))
```

Outline

- Introduction
- Preferences in Planning
- PDDL 3 syntax
- **PDDL3 examples**
- XIDDL language
- XIDDL example
- Conclusions

PDDL3 examples: Preferences

- (preference VisitParis (forall (?x - tourist) (sometime (at ?x Paris))))
  - yields a violation count of 1 for (is-violated VisitParis), if at least one tourist fails to visit Paris
- (forall (?x - tourist) (preference VisitParis (sometime (at ?x Paris))))
  - yields a violation count equal to the number of people who failed to visit Paris
- (:goal (and (at package1 London) (preference p1 (clean truck1))))

PDDL3 examples: Constraints

- Constraints can be used to weighted expressions in metrics

  (:metric minimize (+ (* 10 (fuel-used)) (is-violated VisitParis)))

  would weight fuel use as ten times more significant than violations of the VisitParis constraint

- Another example of multiple ones:

  (:constraints (and (preference p1 (always (clean truck1))) (preference p2 (and (at end (at package2 Paris)) (sometime (clean truck1)))) (preference p3 (...)) ...))

- Combine metrics and preferences

  (:metric (+ (* 10 (is-violated p1)) (* 5 (is-violated p2)) (is-violated p3)))

PDDL3 examples

- We want three jobs completed
- We would prefer to take a coffee-break and that we take it when everyone else takes it (at coffee-time) rather than at any time
- We would also like to finish reviewing a paper, but it is less important than taking a break
- Finally, we would like to be finished so that we can get home at a reasonable time, and this matters more than finishing the review or having a sociable coffee break

Outline

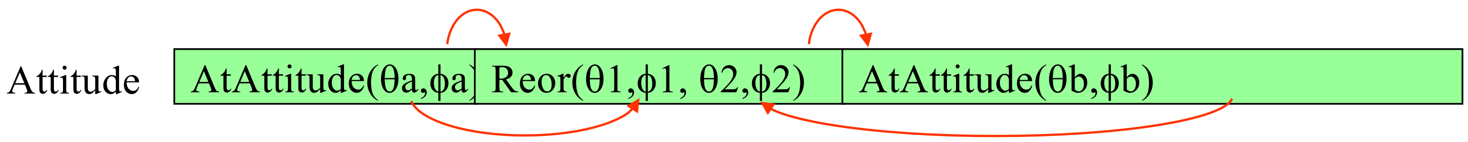
- Introduction
- Preferences in Planning
- PDDL 3 syntax
- PDDL3 examples
- **XIDDL language**
- XIDDL example
- Conclusions

XIDDL

- Declarative descriptions of legal operations of a system
- Models define:
  - Timelines: discrete state variables, populated over all time by predicates
  - Predicates/Tokens: parameterized state values that remain fixed over time intervals
  - Constraints: temporal and parameter restrictions between tokens/predicates

XIDDL

- What do we mean by a model?
  - For example, a spacecraft reorientation maneuver
    - MET_BY(Reor, AtAttitude) w/ $\theta_1 = \theta a$, $\phi_1 = \phi a$
    - MEETS(Reor, AtAttitude) w/ $\theta_2 = \theta b$, $\phi_2 = \phi b$



- Models written in XML-based language
- Enables automatic syntactic and semantic checking of the model

XIDDL: domain (I)

- Timeline (TL) is a logical structure used to represent states over time
- Class is a set of TLs
- Types:
  - ***Internal modes***: describes the internal state of the controlled subsystem. State transitions are not communicated outside
  - ***Goal***: represents a system which exerts control over the agent itself
  - ***Executable***: describes the state that will be communicated to the outside world when the state transition is at the current time

XIDDL: domain (II)

- Tokens/predicates: define the possible values that TLs can have:

$$P\ (i_1,\dots,\ i_n \rightarrow m_1,\dots,\ m_k \rightarrow o_1,\dots,\ o_m\ ;s)$$

  Each i_i, m_i y o_i represents: input arguments, mode and output argument

- Types:
  - *call_args*: are passed to the external system
  - *internal_modes*: set for internal reasoning and not to communicate out
  - *return_args*: returned by the external subsystem
  - *return_status*: returned by the external subsystem and used for close loop
- Constraints: temporal and parameter restrictions between tokens

XIDDL: problem

- Specify what token exists in the initial state in each TL
- Generally the goals are loaded in a different module

Outline

- Introduction
- Preferences in Planning
- PDDL 3 syntax
- PDDL3 examples
- XIDDL language
- **XIDDL example**
- Conclusions

Space Operator domain (PDDL)

```
(:action take_image
  :parameters (?s - satellite ?d - direction ?i - instrument ?m - mode)
  :precondition (and (calibrated ?i)
                     (on_board ?i ?s)
                     (supports ?i ?m)
                     (pointing ?s ?d)
                     (power_on ?i))
  :effect (have_image ?d ?m))
```

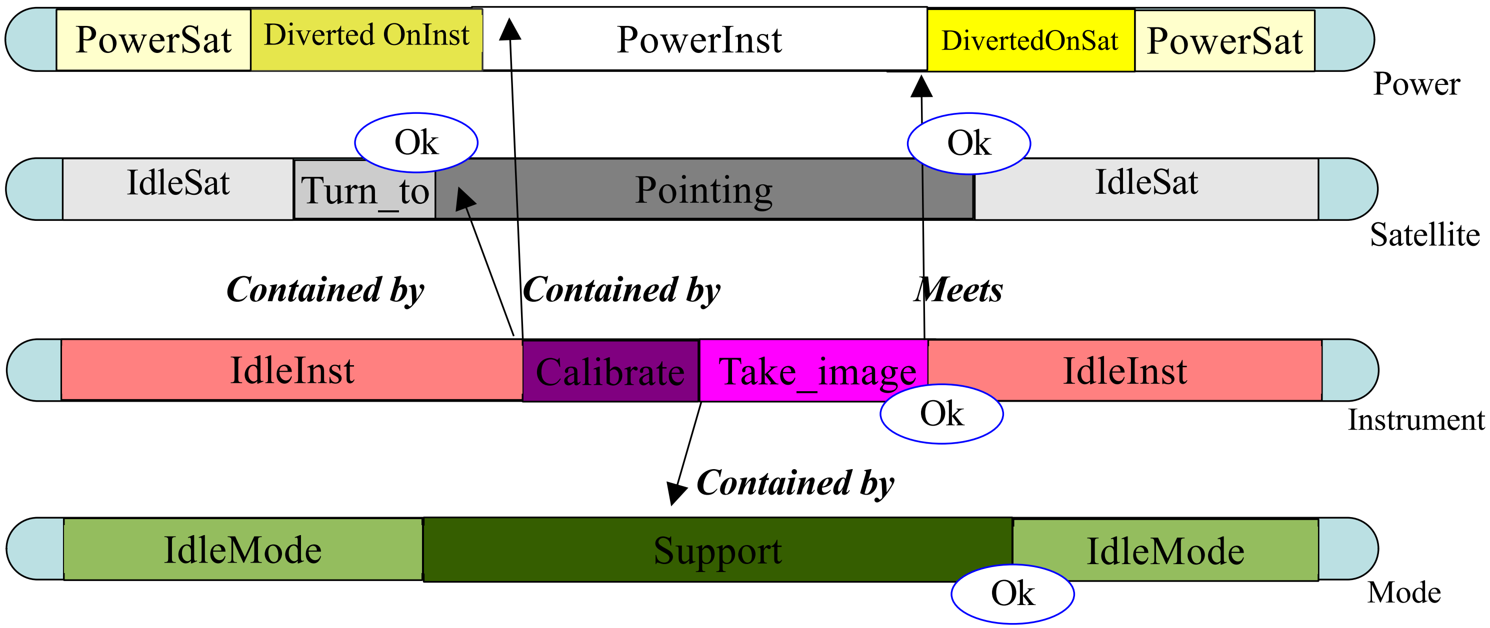
Space Operator problem (PDDL)

```
(:objects
        satellite0 satellite1 satellite2- satellite
        instrument0 instrument1 instrument2 - instrument
        ...
        Phenomenon4 Star5 Phenomenon6 – direction)
(:init
        (supports instrument0 thermograph0)
        (calibration_target instrument0 GroundStation2)
        ...
        (pointing satellite0 Phenomenon6))
(:goal    (have_image Phenomenon4 thermograph0)
          (have_image Star5 thermograph0)
          (have_image Phenomenon6 thermograph0))
```

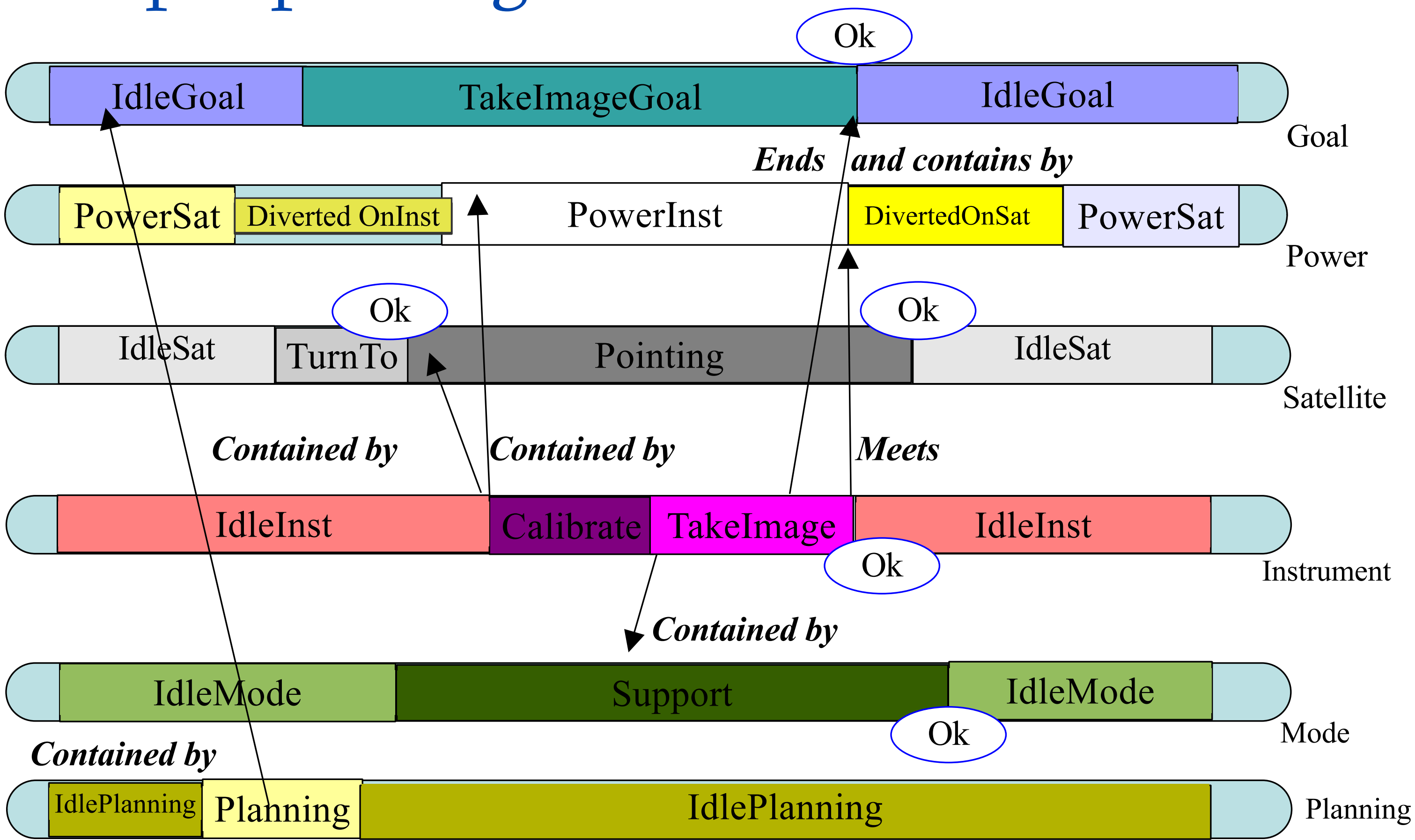
XIDDL example

- How to represent this information?
- What system do I want to know its evolution?
- How many TLs do I need?

XIDDL example: domain



XIDDL example: plan & goals



XIDDL: Domain

- TLs
  - satellite_TL
  - instrument_TL
  - power_TL
  - mode_TL

XIDDL: Domain

- Procedures
  - satellite_TL
    - Pointing(?s – satellite, ?d - direction)
    - TurnTo(?s – satellite, ?ds – direction, ?de - direction)
  - instrument_TL
    - Calibrate(?s – satellite, ? d – direction, ?i - instrument)
    - TakeImage(?s – satellite, ? d – direction, ?i -instrument, ?m – mode)
  - power_TL
    - DivertedOnSat(?s – satellite, ?i - instrument)
    - DivertedOnInst(?s – satellite, ?i - instrument)
    - PowerInst(?i – instrument)
    - PowerSat(?s – satellite)
  - mode_TL
    - Support(?i -instrument, ?m – mode)

```
<!--                                   -->
<!-- TURN TO (Sat, Dir, NewDir)        -->
<!--                                   -->

<define_procedure>
  <name>TurnTo</name>
  <call_args>
    <arg>
    <type>SatelliteValues</type>
    <name>satellite</name>
    </arg>
    <arg>
    <type>DirectionValues</type>
    <name>prevDir</name>
    </arg>
    <arg>
    <type>DirectionValues</type>
    <name>newDir</name>
    </arg>
  </call_args>
 <return_status>
    <type>ReturnResult</type>
    <name>resultTT</name>
    <flag>resultTTflag</flag>
 </return_status>
</define_procedure>
```

Universidad de Alcalá ISG

XIDDL: Domain

- Compatibilities

```
<!--                                          -->
<!-- IdleSat meets TurnTo(s,pd,nd)            -->
<!--                                          -->

<define_compatibility>
  <master type="single">
    <class>SatelliteDomain</class>
    <attr>SatelliteTL</attr>
    <pred>IdleSat</pred>
  </master>
  <duration_bounds>
    <range>
      <lb>*latency*</lb>
     <ub>_plus_infinity_</ub>
      <!-- <ub>*dur*</ub>  -->
    </range>
  </duration_bounds>
  <subgoals>
    <meets>
          <class>SatelliteDomain</class>
          <attr>SatelliteTL</attr>
          <pred>TurnTo</pred>
    </meets>
  </subgoals>
</define_compatibility>
```

Universidad de Alcalá ISG

XIDDL: Objects (I)

```
<define_label_set>
  <name>SatelliteValues</name>
  <value>satellite0</value>
  <value>satellite1</value>
</define_label_set>

<define_label_set>
  <name>InstrumentValues</name>
  <value>instrument0</value>
  <value>instrument1</value>
</define_label_set>
```

XIDDL: Objects (II)

```
<define_label_set>
    <name>DirectionValues</name>
    <value>GroundStation1</value>
     ...
    <value>Phenomenon6</value>
</define_label_set>
<define_label_set>
    <name>ModeValues</name>
    <value>image1</value>
    <value>spectrograph2</value>
    <value>thermographo</value>
</define_label_set>
```

Universidad de Alcalá ISG

XIDDL: Initial State

```
Object_Timelines SpaceOpDomain SpaceOpInstance
(
  SatelliteTL ([0] IdleSat() ...)
  InstrumentTL ([0] IdleInst()  ...)
  PowerTL ([0] PowerSat ( satellite0) ...)
  ModeTL ([0] IdleMode()  ...)
)
```

XIDDL: IS & Goal

Object_Timelines SatelliteDomain SatelliteInstance (

SatelliteTL ([0] IdleSat() ...) ...

ModeTL ([0] IdleMode() ...))

Object_Timelines GoalClass GoalInstance (

GoalTL([0] IdleGoal() [10] TakeImageGoal(satelliteo instrumento Phenomenon4 thermographo * *) [60] ...))

Object_Timelines PlanningClass PlanningInstance (

PlanningSV ([0] IdlePlanning() [10] Planning() ...))

Outline

- Introduction
- Preferences in Planning
- PDDL 3 syntax
- PDDL3 examples
- XIDDL language
- **Conclusions**

Conclusions

- Represent plan with soft constraints & goals
  - Best quality plan satisfy "as much as possible" the soft constraints & goals
- PDDL2.X is extended: PDDL3
- XIDDL based on NDDL (EUROPA planner)
  - Evolution of system along time
  - Basic structure TL