

Impact of Modeling Languages on the Theory and Practice in Planning Research

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Goal

Modeling languages that

- are suitable for modeling realistic large-scale planning problems, and
- support efficient implementations

Current issues

- Languages lacking features necessary for effective modeling
- Low-level modeling which limits efficient implementation possibilities

Modeling Languages Used by the Planning Community (IPC&ICAPS)

- Most visible language is PDDL (1.0, 2.1). Other languages exist, but their use is limited.
- Many types of works on classical and temporal planning exclusively use the Planning Competition (IPC) benchmark sets \sim PDDL
 - mostly toy problems (mix cocktails, park cars, naive logistics, ...)
 - small number of action schemas (often 3 to 6)
 - large instances obtained by increasing number of objects
- Most aspects of PDDL 2.1 were heavily criticized upon its introduction (Bacchus 2003; Boddy 2003; Geffner 2003; Smith 2003) and its limitations are widely recognized, but in last years have got little attention. (Many people seem perfectly happy with PDDL!)

PDDL unnecessarily low level, misses important concepts

- PDDL 1.0 (classical planning)
 - no **enumerated types**
 - no (bounded) **integers**
 - standard benchmark formulations ignore existing features
- PDDL 2.1 (temporal planning)
 - resources \subseteq state variables, no separate concept of resources
 - handling of action dependencies (implicit resources) incompatible with effective formulation with constraints (MILP, SAT, SMT, ...)
- No formal (= precise) semantics exists for either, which especially for PDDL 2.1 has been problematic. Correctness of implementations?

Why does it matter?

- ① Low-level of models have negative implications w.r.t. performance
 - PDDL models force poor implementation details
 - Cleverly recovering the underlying high-level models tricky, uninteresting
- ② Developing complex models tedious

Lack of Many-valued (Enum) State Variables

- Standard benchmark sets dominated by (implicit) many-valued variables, which have to be represented as Booleans
- Variable x with values v_1, \dots, v_n represented as Booleans x_1, \dots, x_n
- Many heuristics defined in terms of **many-valued** variables:
 - Domain-Transition Graphs a standard starting point (Helmert 2004)
 - DTGs probably main reason 50 per cent of IPC 2014 planners using FD
- All constraint-based PDDL planners extract **invariants** to be able to recognize dependencies between x_1, \dots, x_n .

Extraction of many-valued variables expensive: FD can spend **several minutes** doing it even in simple cases.

Extraction of invariants (mostly induced by many-valued variables) can similarly be expensive.

Lack of Bounded Integers

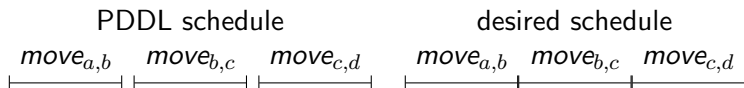
- integer variable n with range $0..N$ represented as Booleans n_1, \dots, n_N (in several standard benchmarks)
- Could use PDDL reals, but many/most planners do not support them.
- **increment** of $0..N$ modeled as N actions each turning some i to $i + 1$
- Does not seem to be an issue for explicit state-space search.
- Rintanen (AIJ 2012) observed correlation between poor performance with SAT-based planners and presence of implicit integers for standard benchmarks
- (*Could*, in principle, automatically “recognize” implicit integers, and derive sensible and efficient representations. (Uninteresting, makes little sense as scientific research))

Lack of Explicit Resources

- In PDDL 2.1 (implicit) **resources** are allocated by a two-step process:
 - ① Confirm that given resource is available (precondition $x = 0$)
 - ② Allocate the resource (assign $x := 1$ at start)

This takes place inside a 0-duration **critical section**.

- Bad for constraint-based frameworks SMT, MILP, CP: conceptually two **separate time points**, one with $x = 0$ and another with $x = 1$, leading to ϵ **gaps** in plans, with an **exponential performance penalty**.



- Explicit resources with allocations and deallocation preferable

What Should Be Done: A Proposal

Adopt a more **modern modeling language to replace PDDL**.

- Clean modern syntax, targeting human use (can also define XML/Lisp syntax if needed)
- Richer datatypes: enums, Booleans, (bounded) integers, rationals
- For temporal planning: explicit resources
- Support for modular construction of large-scale models
- Formal semantics

Role of classical planning needs to be re-assessed: most of “classical” planning actually temporal planning with time stripped off: standard benchmarks mostly multi-vehicle, multi-machine, multi-agent problems

What Should Be Done: A Proposal

Inspiration:

- **automata-based formalisms** (as used by Verification, Diagnosis communities), with synchronization of automata as a modular mechanism for building large models
- **Functional STRIPS** (Hector Geffner, 2000)

Requirements:

- **Compatibility** with leading search methods
 - constraint-programming
 - SAT, SMT
 - MILP

Benefits from A New Planning Modeling Language

- Easier to formulate more realistic and complex planning problems
- Bring Planning+Scheduling back to the agenda
- New research will emerge from more challenging and differently structured benchmark problems.

How to Transition to a New Language?

- Many planners already using higher-level models e.g. with many-valued variables, internally
Half of classical planners in IPC-2014 used FD front-end: modify FD
⇒ problem half solved for existing classical planners
- Temporal planning not very active area: only 6 planners in IPC-2014
- Opposition from inside IPC/ICAPS? Expected.
- Open question: Who will be modeling more complex planning & scheduling problems?

- Real-world applications have varying modeling requirements
 - Every language has something essential missing
 - Futile and fruitless to try to include everything in one language
- Domain-independent planning may be doomed anyway
 - domain-independent \nrightarrow less modeling work
 - domain-specific constraints, representations, heuristics too often vital
 - relevance to both theory and practice questionable
 - Constraint Programming, MILP, SAT, SMT etc often better as “domain-independent” languages than any *planning* language

- PDDL abstraction level too low → issues with modeling and implementation
- Connection between Planning and Scheduling forgotten
- Both issues could be fixed with more modern modeling languages
- Potential for similar fast progress in research as right after PDDL's initial adoption in 1998