5th International Planning Competition: Results of the Deterministic Track

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IPC-5 Organizing Committee:

Y. Dimopoulos, A. Gerevini (chair), P. Haslum, A. Saetti

Talk Outline

- General Organization of IPC-5
- New Language for the Deterministic Part
- Benchmark Domains for the Deterministic Part
- Competing Planners and Evaluation Criteria
- Samples and Summary of the Results
- Awards and Best Performing Planners

General Organization (Deterministic Part)

- **Organizing Committee**:
  Y.Dimopoulos, A.Gerevini (chair), P.Haslum, A.Saetti

- **Consulting Committee**: S.Edelkamp, M.Fox, J.Hoffmann, D.Long, D.McDermott, L.Schubert, I.Serina, D.Smith, D.Weld

- **General Goals of IPC**:
  - analyzing and advancing the state-of-the-art
  - providing new benchmarks and data sets to the community
  - emphasizing new research issues in planning
  - promoting applicability of planning technology.

- **Focus of the 5th IPC**: **plan quality** ("traditional" quality measures + new measures related to the new planning language).

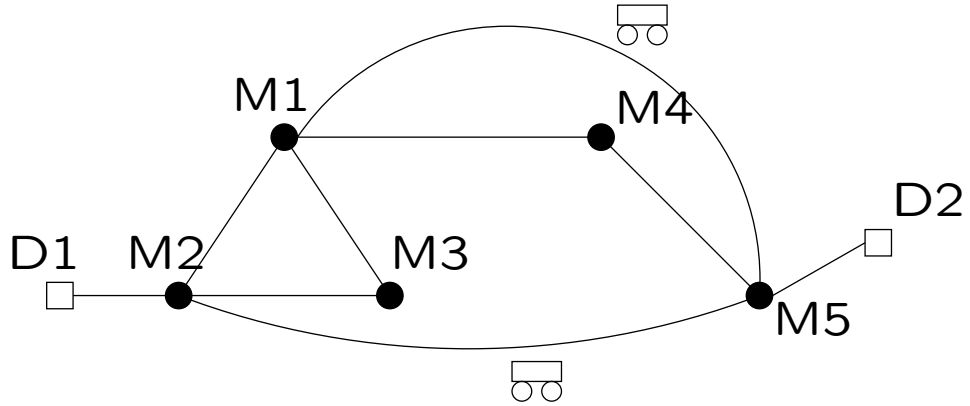
The Planning Language of IPC-5: PDDL3

Developed with D. Long. Extends previous versions of PDDL with

- **Soft Goals**: *desired* goals (don't have to be necessarily achieved)
- **State Trajectory Constraints**: constraints on the plan structure using a LTL-like language
  - *Strong*: must be satisfied in any valid plan
  - *Soft*: don't have to be necessarily satisfied
- **Preferences**: Soft goals and constraints with *penalty weights*
- **Plan Metric**: includes *preference penalties* to be minimized
  - satisfying all goals and constraints can be infeasible
  - tradeoff between computational cost and plan quality

Example of Benchmark Domain:

Travelling Purchaser Problem (TPP)



Given (1) a set of different types of goods (2) a set of markets (**M**) selling different types and amounts of goods at different prices, (3) a demand of each type of goods to be purchased and transported by trucks to some depot (**D**),

$\Longrightarrow$ *satisfy the demand minimizing the routing cost of the trucks and the purchasing cost*

6 different PDDL formulations with simplifications and extensions

Examples of trajectory constraints in TPP

Each market is visited at most once by a truck:

```
(forall (?m - market ?t - truck) (at-most-once (at ?t ?m)))
```

At most one truck at a market at the same time:

```
(forall (?m - market ?t1 ?t2 - truck)
   (always (imply (and (at ?t1 ?m) (at ?t2 ?m)) (= ?t1 ?t2))))
```

Each truck should be used (loaded with some goods):

```
(forall (?t - truck) (sometime (exists (?g - goods) (> (load ?g ?t) 0))))
```

Whenever goods3 are loaded, they should be in a depot within 100 units:

```
(forall (?t - truck)
   (always-within 100 (> (loaded goods3 ?t) 0) (= (loaded goods3 ?t) 0)))
```

We start storing goods2 in a depot only after we have stored the requested amount of goods1:

```
(sometime-before (> (stored goods2) 0) (>= (stored goods1) (request goods1)))
```

Benchmark Domains of IPC-5

5 new domains + 2 from IPC-3/4: **36 variants, 978 problems**

- **TPP**: traveling and buying goods at selected markets minimizing costs (from OR with variants, NP-hard)
- **Openstacks**: combinatorial optimization problem in production scheduling (from CSP benchmarks, NP-hard)
- **Storage**: moving and storing crates of goods by hoists from containers to depots with spatial maps
- **Pathways**: finding a sequence of biochemical (pathways) reactions in an organism producing certain substances
- **Trucks**: moving packages between locations by trucks under certain spatial constraints and delivering deadlines
- **Rovers** (IPC-3), **PipesWorld** (IPC-4).

Subtracks & Domain Categories

Subtracks: *Optimal Planning* and *Satisficing (sub-optimal) Planning*

Domain Categories:

- **Propositional**: ADL or (compiled) STRIPS domains
- **Metric-Time**: PDDL2.2 features (IPC-3/4), no derived effects
- **Simple Preferences**: propositional domains with soft goals
- **Qualitative Preferences**: propositional domains with soft trajectory constraints
- **Constraints**: Metric-Time domains with strong trajectory constraints
- **Complex Preferences**: Metric-Time domains with soft trajectory constraint and/or soft goals.

Competing Planners (optimal track)

- **CPT2** (V. Vidal and S. Tabary)
  Partial-order causal-link planning and constraint satisfaction

- **FDP** (S. Grandcolas and C. Pain-Barre)
  CSP techniques and planning graphs

- **IPPLAN-1SC** (M. van den Briel, S. Kambhampati and T. Vossen)
  Planning as integer programming

- **Maxplan** (Z. Xing, Y. Chen and W. Zhang)
  Planning as propositional satisfiability with problem decomposition

- **MIPS-BDD** (S. Edelkamp)
  Symbolic planning based on BDDs

- **SATPLAN** (H. Kautz, B. Selman, and S. Neph)
  Planning as propositional satisfiability (new encoding)

- SATPLAN.IPC4 and CPT.IPC4 (reference planners – IPC-4 winners)

Competing Planners (suboptimal track)

- **Downward-sa** (M. Helmert)
  Planning based on heuristic search

- **IPPLAN-G1SC** (M. van den Briel, S. Kambhampati and T. Vossen)
  Planning as integer programming

- **MIPS-XXL** (S. Edelkamp, S. Jabbar and M. Nazih)
  Planning based on heuristic search and domain compilation techniques

- **SGPlan5** (C. Hsu, B. W. Wah, R. Huang and Y. Chen)
  Planning based on problem partitioning and heuristic search

- **HPlan-P** (J. Baier, F. Bacchus and S. McIlraith)
  Planning based on heuristic search and domain compilation techniques

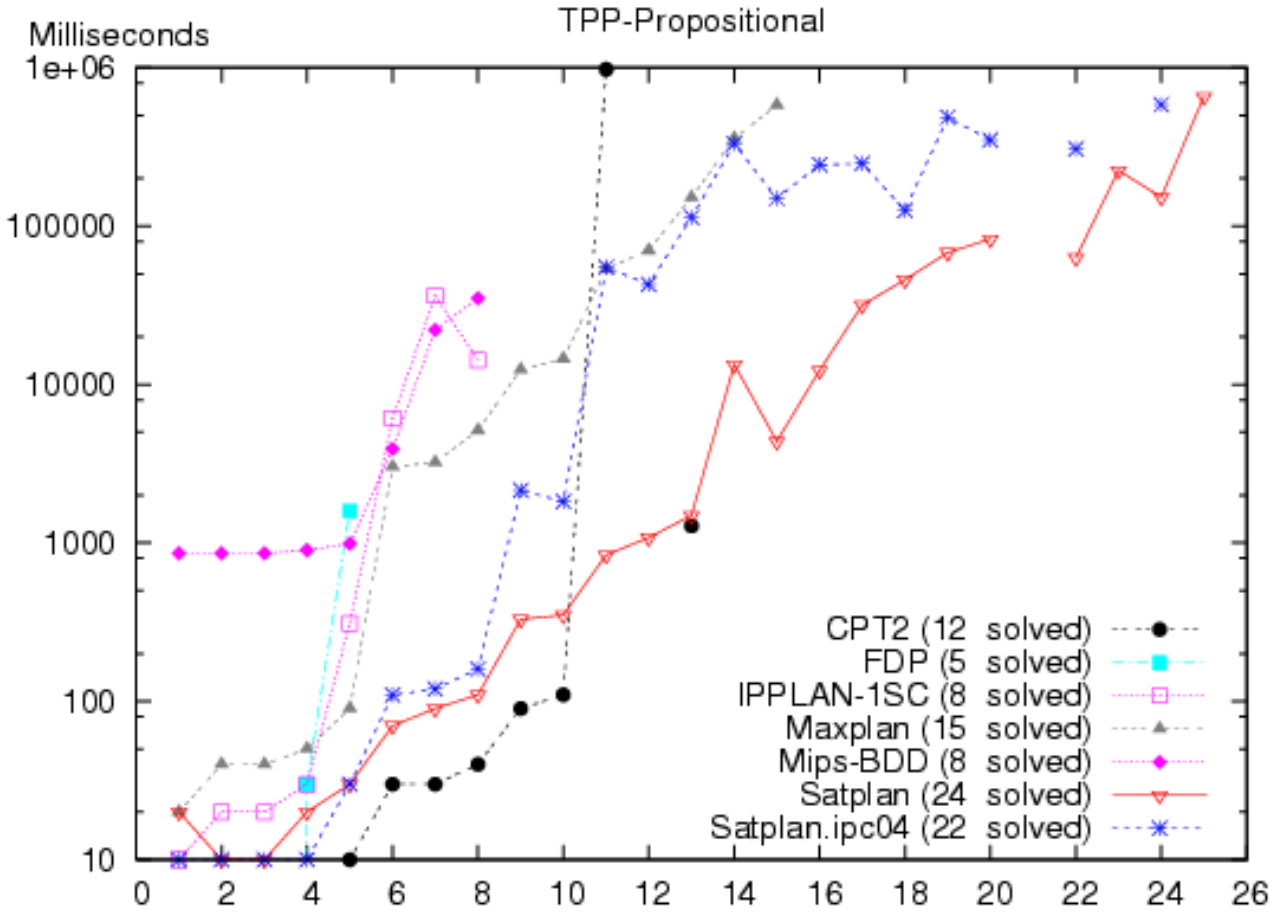
- **YochanPS** (J. Benton, S. Kambhampati and M. Do)
  Techniques for Partial satisfaction planning and heuristic search

- Downward.IPC4 and SGPlan.IPC4 (reference planners – IPC-4 winners)

General Evaluation Criteria

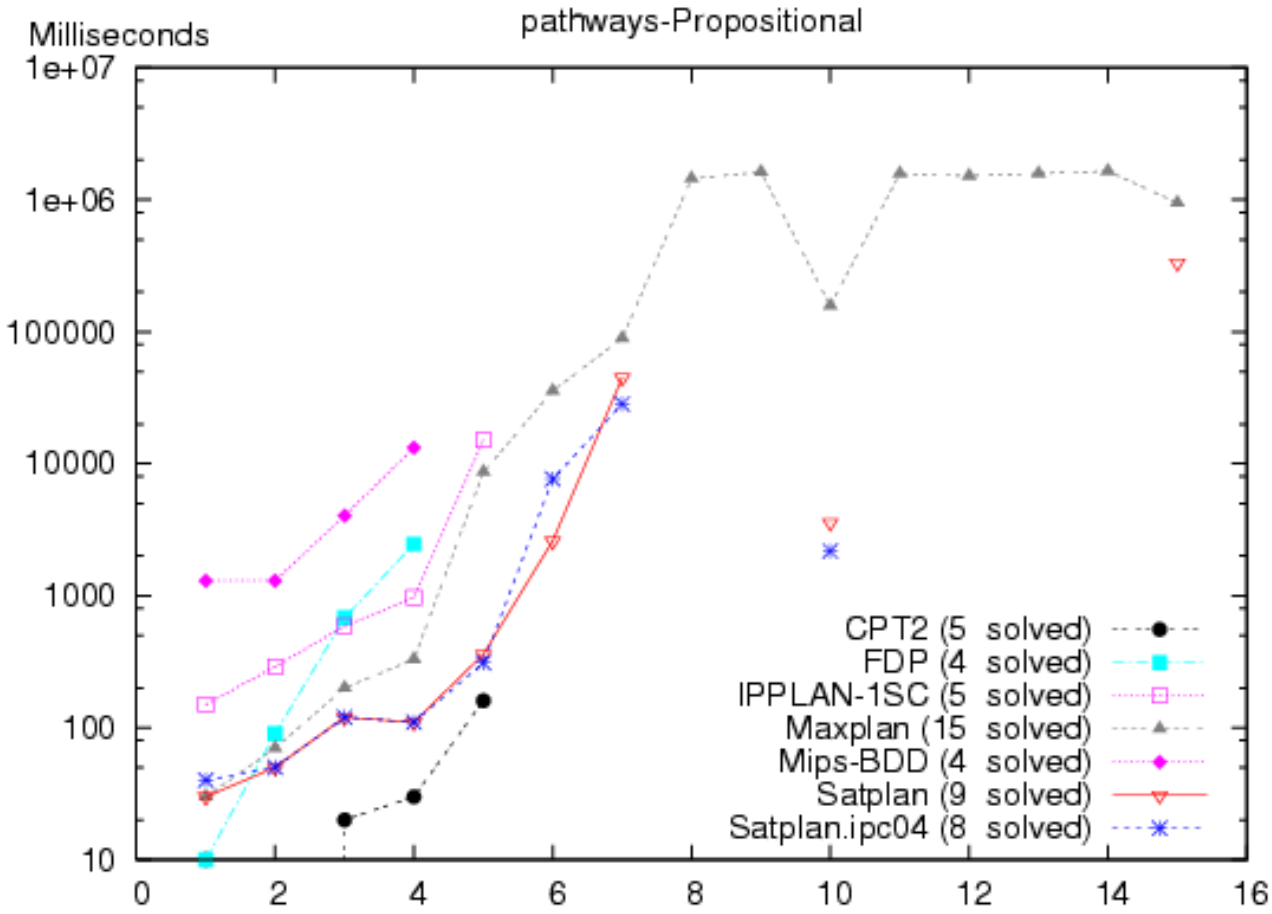
- Different evaluation/prizes for optimal and suboptimal planners
- **For optimal planners**: number of solved problems and CPU-time (CPU-time limit: 30 minutes)
- **For satisficing planners**:
  1. Number of solved problems and plan quality
  2. CPU-time (secondary measure)
- Planner ranking by domain category (as in IPC-4):
  - for each domain in a category we assign 1st/2nd places;
  - in each category, all 1st/2nd places are then summed
- IPC-4 best planners as reference for performance improvements.

Sample of Results: TPP-prop.
(speed optimal planners)



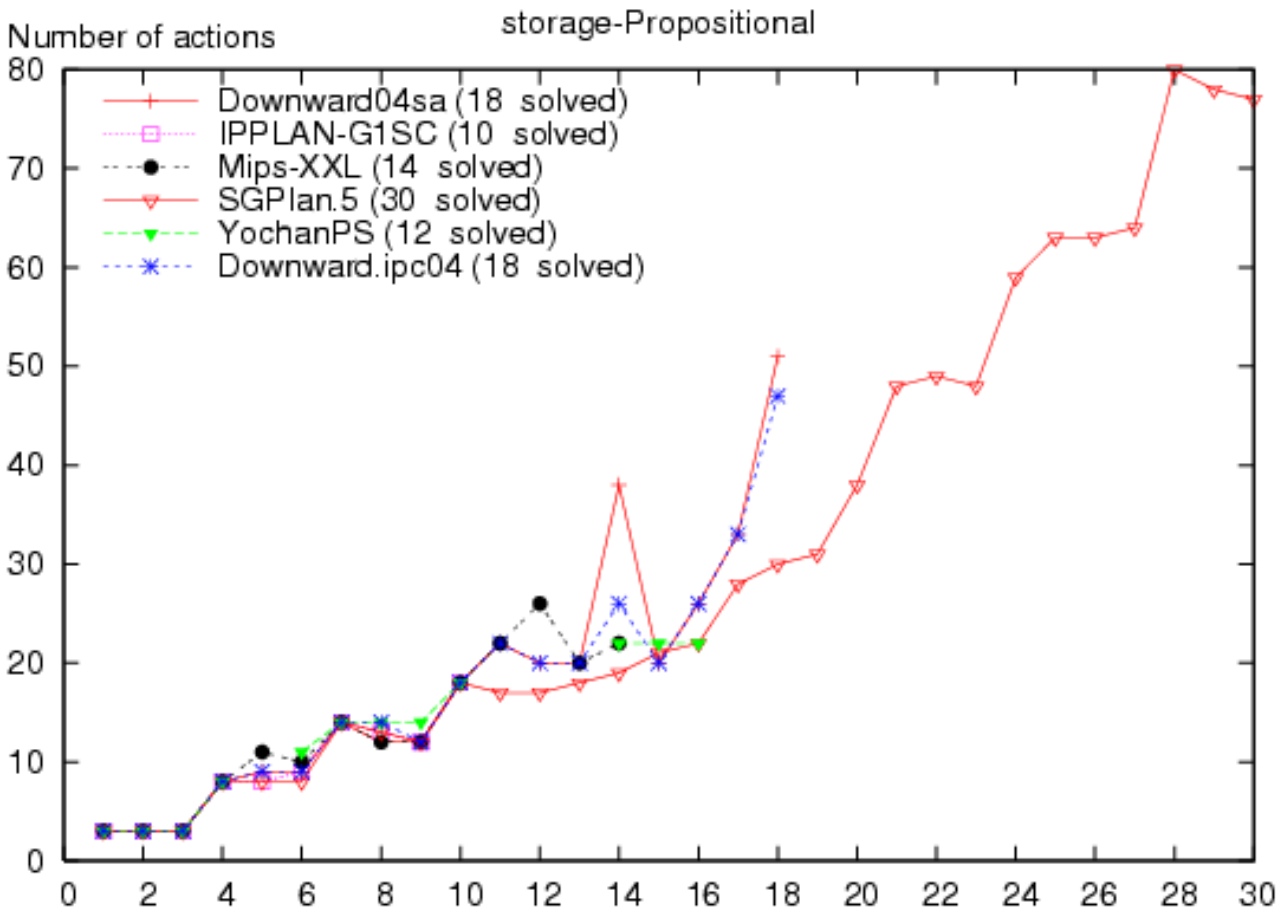
30 problems. Largest problem solved by SATPLAN: 163 actions, 11 levels

Sample of Results: Pathways-prop.
(speed optimal planners)

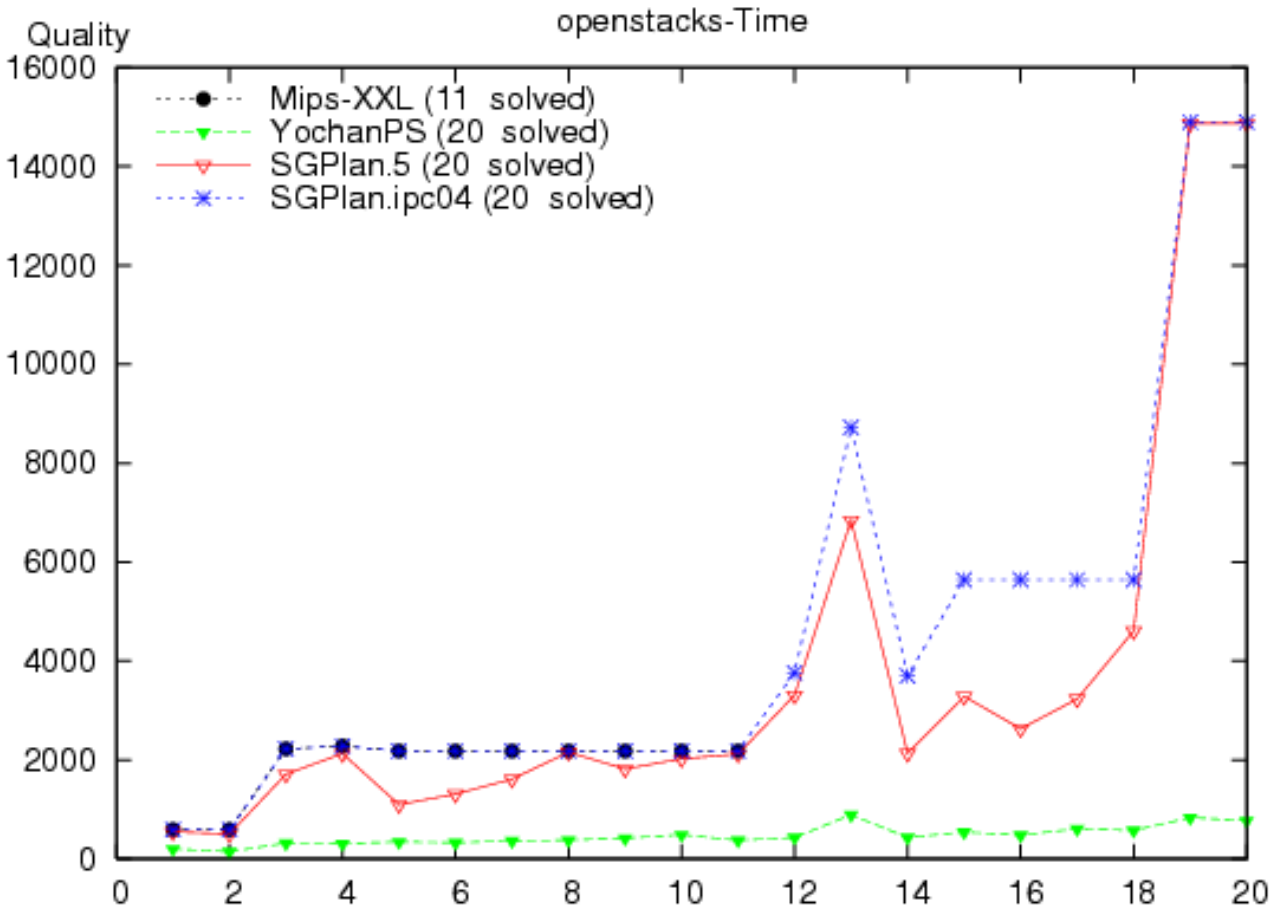


30 problems. Largest problem solved by Maxplan: 135 actions, 20 levels

Sample of Results: Storage-prop.
(quality suboptimal planners)

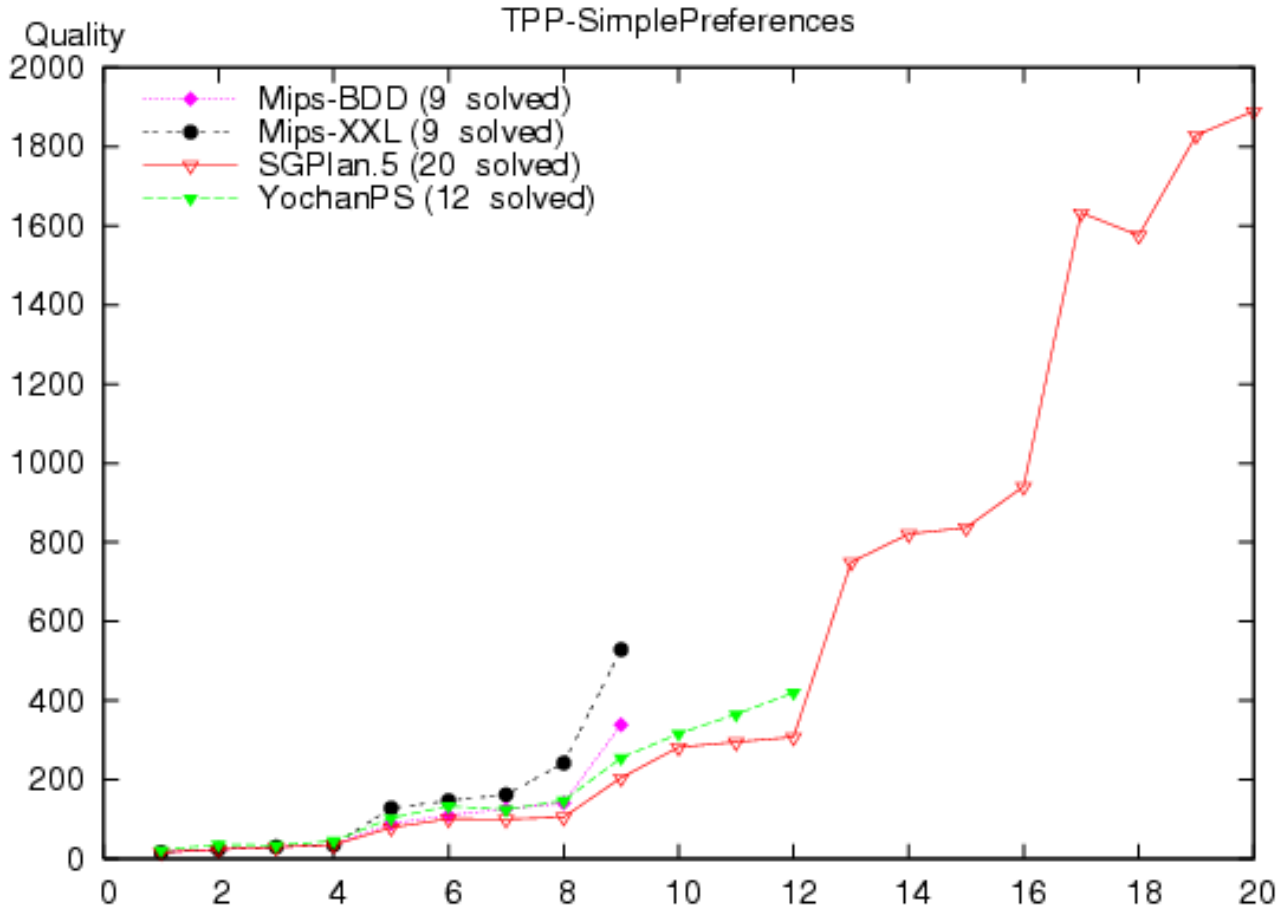


Sample of Results: Openstacks-time
(quality suboptimal planners)



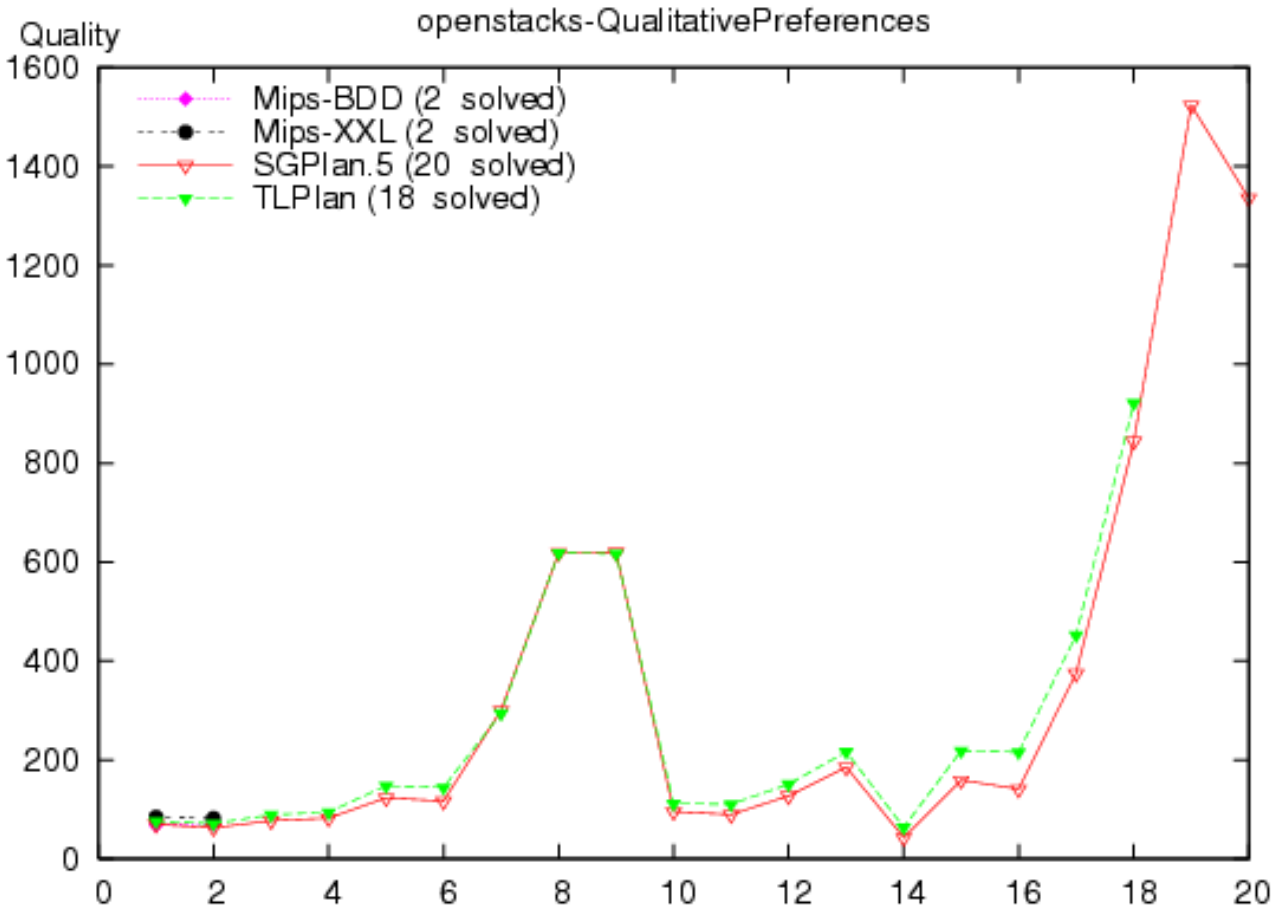
Plan quality: makespan

Sample of Results: TPP-SimplePref.
(quality suboptimal planners)



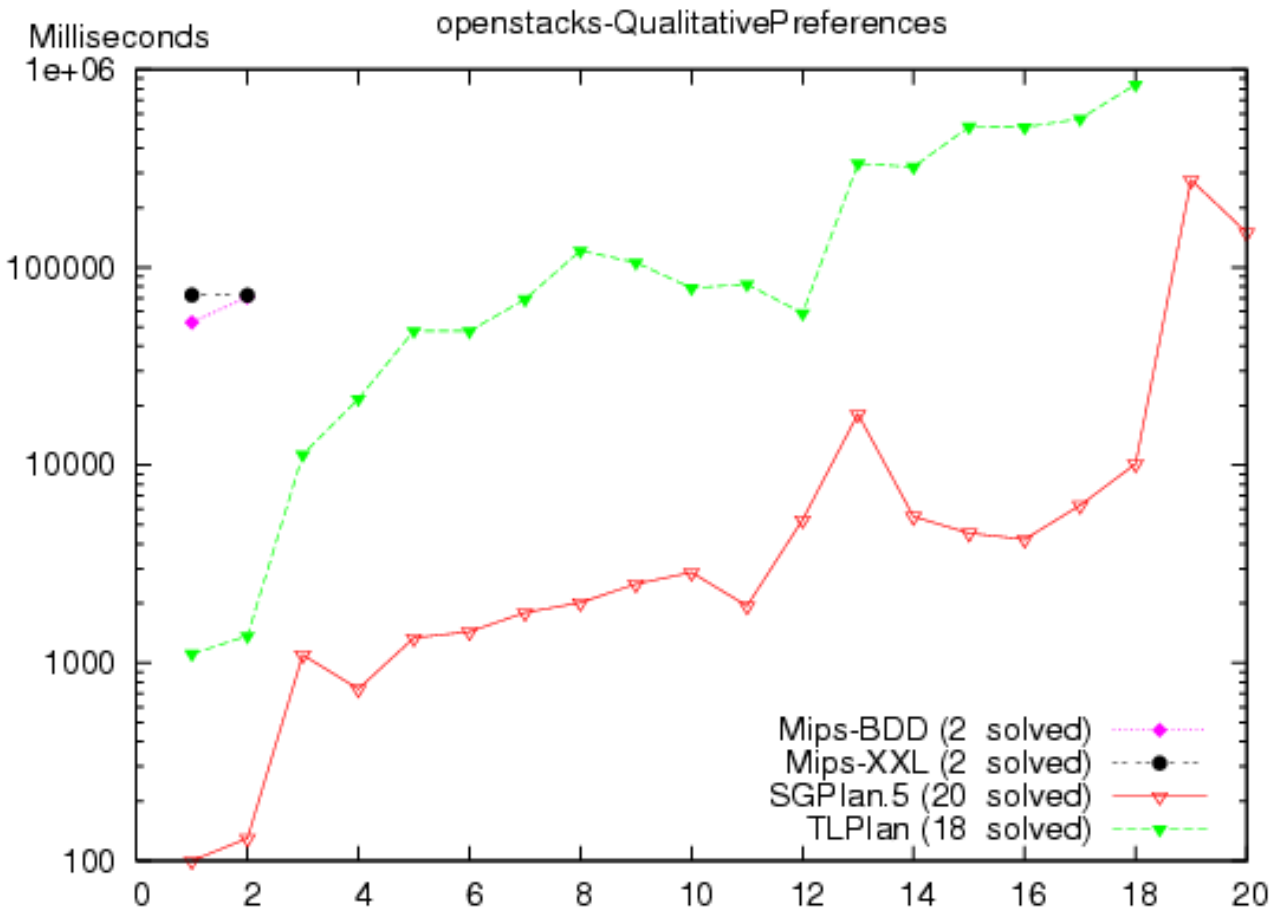
Plan quality: linear combination of preference violation penalties
Only soft goals. Not all preferences can be satisfied

Sample of Results: Openstacks-QP
(quality suboptimal planners)

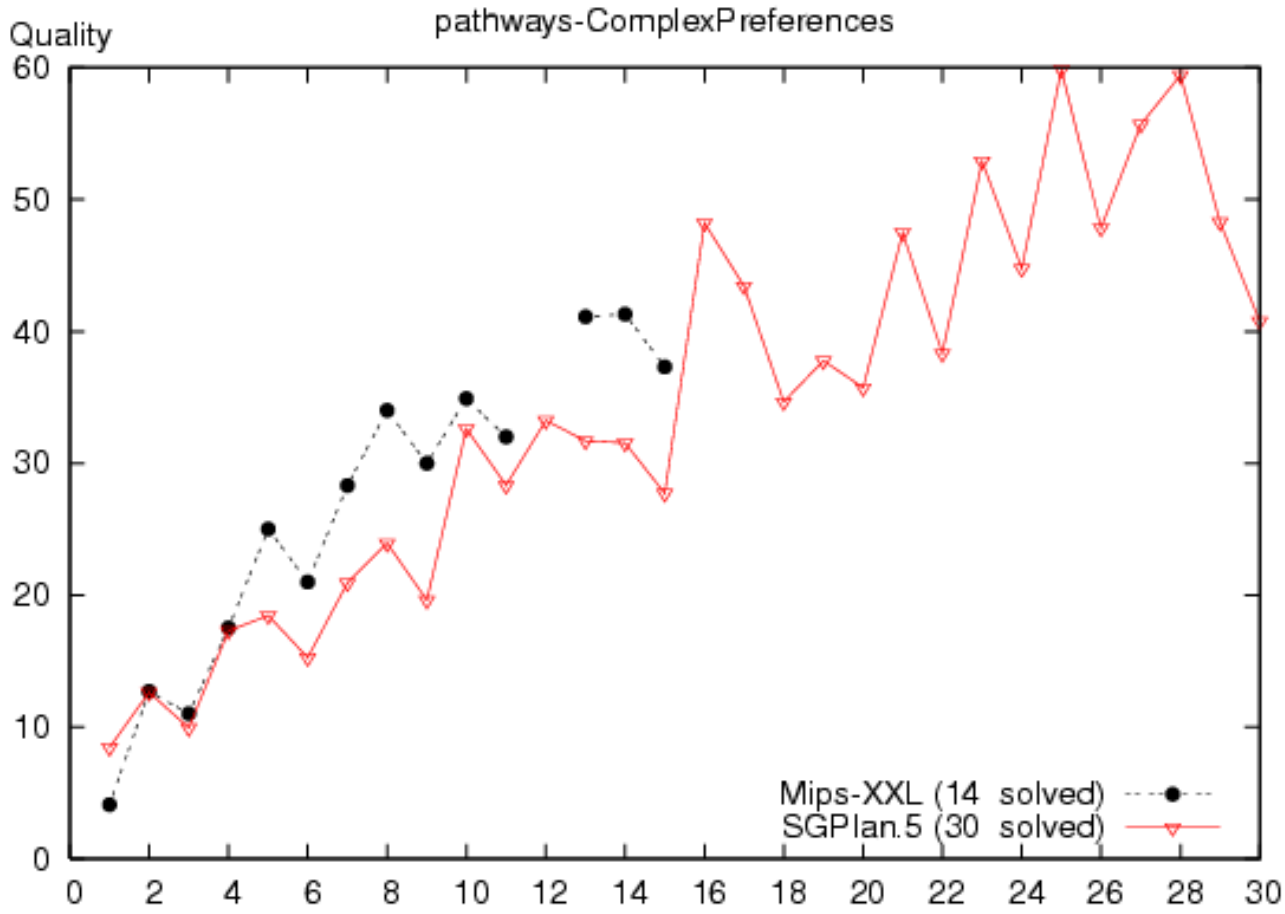


Plan quality: linear combination of preference violation penalties
Strong and soft goals. Not all preferences can be satisfied

Sample of Results: Openstacks-QP
(speed suboptimal planners)



Sample of Results: Pathways-ComplexP.
(quality suboptimal planners)



Plan quality: preference violation penalties, chemical substances, makespan
Only soft goals. Not all preferences can be satisfied

Summary of 1st/2nd Places

(optimal planners with at least one 1st or 2nd place)

IPC-5

Category	CPT2	MIPS-bdd	SATPLAN	Maxplan	FDP
Prop.	0/1	1/1	3/2	3/2	0/3
Time	2/0				

IPC-4

Category	SATPLAN.ipc04	CPT.ipc04
Prop.	0/2	
Time		0/2

Summary of 1st/2nd Places

(suboptimal planners with at least one 1st or 2nd place)

IPC-5

Category	Downward	Mips-bdd	Mips-xxl	SGPlan.5	HPlan-P	YochanPS
Propositional	1/4		0/1	5/2		0/1
MetricTime			0/3	8/1		1/3
SimplePref.		0/1	0/4	6/0		0/4
QualPref.				5/0	0/5	
Constraints			0/3	3/0		
ComplexPref.			0/3	5/0		

IPC-4

Category	Downward.ipc04	SGPlan.ipc04
Propositional	3/4	
MetricTime		0/5

IPC-5 Prizes (deterministic part)

- Optimal planning:

  - **1st Prize: best propositional planner of IPC-5**

  - Distinguished performance in temporal domains

- Suboptimal (satisficing) planning:

  - **1st Prize: best satisficing planner of IPC-5**

  - Some 2nd prizes for distinguished performance in the new domain categories (soft goals, qualitative preferences, strong/soft constraints)

And the Winner is....

- Optimal planning:

- Suboptimal (satisficing) planning:

And the Winner is....

- Optimal planning:

  Distinguished performance in temporal domaions: **CPT2**

- Suboptimal (satisficing) planning:

And the Winner is....

- Optimal planning:

  1st Prize: SATPLAN and Maxplan (propositional domains)

  Distinguished performance in temporal domains: **CPT2**

- Suboptimal (satisficing) planning:

And the Winner is....

- Optimal planning:

  1st Prize: SATPLAN and Maxplan (propositional domains)

  Distinguished performance in temporal domains: **CPT2**

- Suboptimal (satisficing) planning:

  Distinguished performance:

  - **Mips-xxl** (Simple/Complex Preferences, Constraints)
  - **HPlan-P** (Qualitative Preferences)
  - **YochanPS** (Simple Preferences)

And the Winner is....

- Optimal planning:

  1st Prize: SATPLAN and Maxplan (propositional domains)

  Distinguished performance in temporal domains: **CPT2**

- Suboptimal (satisficing) planning:

  1st Prize: SGPLAN5 (best overall performance)

  Distinguished performance:

  - **Mips-xxl** (Simple/Complex Preferences, Constraints)
  - **HPlan-P** (Qualitative Preferences)
  - **YochanPS** (Simple Preferences)

Conclusions: Overall Results

- New language for modeling preferences and soft constraints/goals
- A large set of new benchmarks
- 12 competing planners (5 of them handle PDDL3 features). Significant advances in both the optimal and suboptimal tracks!
- Suboptimal planners evaluated by plan quality (*other criteria may reveal other improvements and different evaluation results*).
- An archive of all data (soon available on the IPC-5 website) to be used as reference for the community.