Quality of Solutions to IPC5 Problems – Preliminary Results and Observations

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NICTA & ANU

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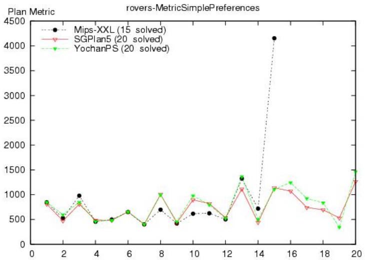
Motivation



Plan Quality, Rovers MSP:
All planners are roughly equal – but are they equally *good* or equally *bad*?

- 5th IPC: emphasis on plan quality in evaluation.
- But: optimal solutions (or good bounds) not known, so only relative quality compared.
- Find optimal solutions and/or good quality bounds, using domain-specific methods, for some IPC-5 domains.

Domains Considered

IPC5 Classification

- Propositional:
  - Openstacks
- Metric/Temporal:
  - Openstacks Time
  - Openstacks MetricTime
- Simple Preferences:
  - Openstacks SP
  - Rovers MSP
- Qualitative Preferences:
  - Openstacks QP
  - Rovers QP

Classification by Objective Fn.

- Plan cost (1-objective):
  - Openstacks (# actions)
  - Openstacks Time (makespan)
- Plan cost (2-objective trade-off):
  - Openstacks MetricTime
- End-state value ("soft goals"):
  - Openstacks SP
- Plan cost/goal-value trade-off:
  - Openstacks QP
  - Rovers MSP
- Trajectory preferences:
  - Rovers QP

Conclusions

1. There isn't enough data to support that many conclusions.
2. The quality of plans produced by (some) competitors appears somewhat "accidental".
3. Domain and problem hardness:
    1. 2-objective trade-off functions appear more difficult to optimise.
    2. Relative plan quality does not appear to correlate with planner run-time.

Competing Planners by Domain

	Openstacks					Rovers	
	P	SP	QP	T	MT	MSP	QP
Downward'04-SA	$\surd$						
FDP	$\surd$						
HPlan-P			$\surd$				$\surd$
IPPLAN-G1SC	$\surd$						
MaxPlan	$\surd$						
MIPS-BDD	$\surd$						
MIPS-XXL	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
SGPlan_5	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
$\text{Yochan}^{\mathcal{PS}}$		$(\surd)$		$\surd$		$\surd$	

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The "Min Max Open Stacks" Problem

- Set of products to be made in sequence.
- Set of orders, each requesting a subset of products.
- An order is open from when the first requested product is made to when the last requested product is made: during this time, it uses a stack.
- Objective: sequence making of products to minimise the maximum number of stacks in use at any point.
- Trivial upper bound: # orders (one stack per order).
- Problem is NP-hard, and equivalent to several graph theory problems (*e.g.*, pathwidth).
- Constraint Modelling Challenge 2005 problem:
  - Large library of problem instances.
  - Several solvers, and data on their performance.

Openstacks: Example

sequence:	2	3	4	5	1	|	1	2	3	5	4
order 1 ($\{1,2\}$):	X	–	–	–	X	|	X	X			
order 2 ($\{1,3\}$):		X	–	–	X	|	X	–	X		
order 3 ($\{2,4\}$):	X	–	X			|		X	–	–	X
order 4 ($\{3,5\}$):		X	–	X		|			X	X	
order 5 ($\{4,5\}$):			X	X		|				X	X
# open stacks:	2	4	5	4	2	|	2	3	3	3	2

The Openstacks Domain

- PDDL encoding of the open stacks problem.
- Actions `(make-product` *p*`)`, `(start-order` *o*`)` and `(ship-order` *o*`)` must each be done exactly once:
  - `(start-order` *o*`)` before `(make-product` *p*`)` when *o* includes *p*,
  - `(make-product` *p*`)` before `(ship-order` *o*`)` when *o* includes *p*.
- How to count current/max number of stacks in use?
  - Stacks are a resource: `start-order` takes 1, `ship-order` returns 1...
  - 4 different formulations (only 1 used in IPC5).
- Problem set: 25 selected – for variety – from CMC library, plus 5 trivially small instances.

The Openstacks Domain

- "Plain" Formulation:
  - Propositional counter for # free stacks.
    ((stacks-avail n0), (stacks-avail n1), ...)
  - Action `open-new-stack` creates one (free) stack.
  - max # stacks in use
    = # `open-new-stack` actions in plan
    = plan length − (problem-dependent) constant.
- "Sequenced" Formulation (IPC5 Propositional):
  - However, min # actions objective can't be specified in "propositional PDDL"; default is "(total-time)".
  - Forced sequentiality: # actions equals # "time steps".
  - Larger plan length constant.

The Openstacks Domain

- "Numeric" Formulation:
  - Fluents track current and max # stacks in use:

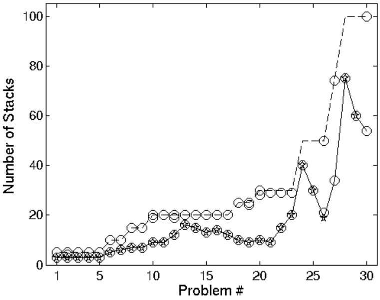
```
(and (increase (stacks-in-use) 1)
     (when (>= (stacks-in-use) (max-in-use))
           (increase (max-in-use) 1)))
```

  - `(:metric minimize (max-in-use))`
- "Preferences" Formulation:
  - Propositional counter for current # stacks in use.
  - PDDL3 trajectory preferences:

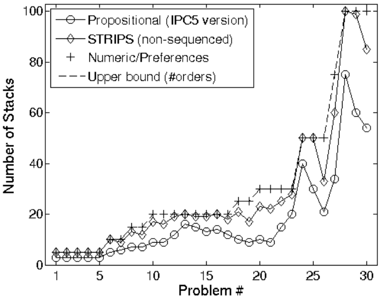
```
(and (preference p1
      (always (not (stacks-in-use n1))))
     (preference p2
      (always (not (stacks-in-use n2)))) ...)
```

  - `(:metric minimize (+ (is-violated p1) ...))`

Openstacks: Plan Quality



Competitor plans (○), best known (—) and upper bounds (- -). A star indicates solution is optimal.

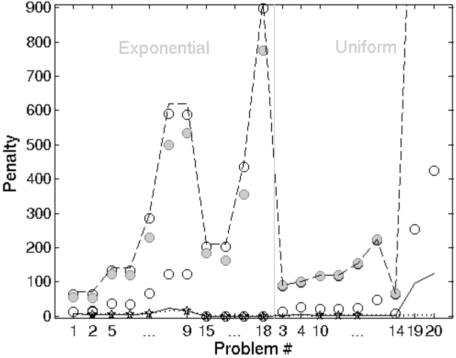


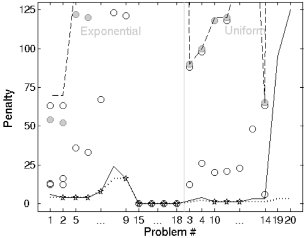
Plans found by SGPlan$_5$ on different domain formulations.

The Openstacks SP Domain

- Like Openstacks, but max # stacks in use is fixed and goals are soft: orders may be shipped without all requested products, but incur a penalty for missing products.
- Objective: minimise total penalty.
- Two formulations:
  - With conditional effects (used in IPC5):
    If *p* made while *o* is open, then *p* is "delivered" to *o*.
  - Without conditional effects:
    Explicit action `(deliver` *p* *o*`)` must take place while *o* is open and *p* is made (split `make-product` action).
- Problem instances:
  - Based on 20 selected CMC problems.
  - Max # stacks fixed slightly below the (believed-to-be) minimum, to force selection of requests to satisfy.

Openstacks SP: Plan Quality





Closeup of "lower" region of the graph.

- In IPC5 formulation (with c.e.), SGPlan_5 consistently best.
- In non-c.e. formulation, SGPlan_5 consistently finds plans of worst possible quality!

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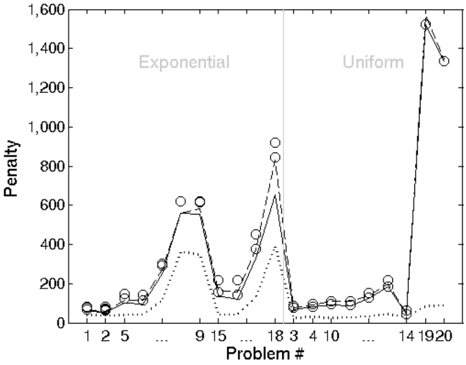
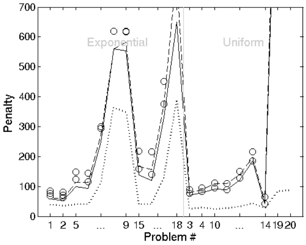
The Openstacks QP Domain

- Combines the objectives of the Openstacks and Openstacks SP domains: minimise sum of
  - penalty for unsatisfied product requests, plus
  - max # stacks used times (problem-specific) price / stack.
- IPC5 formulation uses:
  - conditional effects (as in Openstacks SP),
  - trajectory preferences to track max # stacks used.
- Aimed to set price / stack so "extreme" plans have equal value...
  - however, turned out stacks are somewhat "overpriced";
  - a simple, greedy single-stack construction finds plans of quality close to best known – and often better than competitors' – plans.

Openstacks QP: Plan Quality





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Rovers MSP: CPU Time *vs.* Plan Quality

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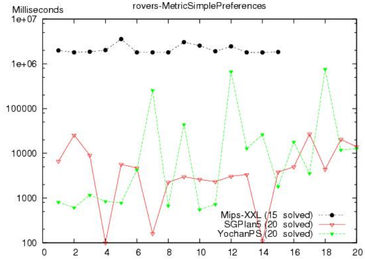
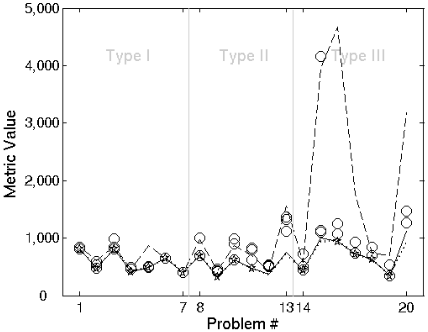


CPU time taken by planners in the competition.



Competitor plans (○), best known (—), upper (- -) and lower (· · ·) bounds. A star indicates solution is optimal.

Lessons Learned

- A lot of work (and CPU time!) invested, for questionable "science return"...
- Specifics of problem instances matter!
  - Properties / "biases" of optimal solutions (*e.g.*, "overpriced" stacks in Openstacks QP).
  - Instances with unintended "flaws" (*e.g.*, Openstacks SP `p15`–`p18`).
- Encourage coverage!
  - Offer domains in different formulations.
  - Make coverage part of competition evaluation criteria.

All Results & Additional Resources

http://users.rsise.anu.edu.au/~patrik/ipc5.html