Quality of Solutions to IPC5 Problems – Preliminary Results and Observations

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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

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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.
“Plain” Formulation:
- Propositional counter for # free stacks.
  \((\text{stacks-avail n0}), (\text{stacks-avail n1}), \ldots)\)
- Action \text{open-new-stack} creates one (free) stack.
- max # stacks in use
  \(= \# \text{open-new-stack} \text{ actions in plan}\)
  \(= \text{plan length} - \) (problem-dependent) constant.

“Sequenced” Formulation (IPC5 Propositional):
- However, min # actions objective can’t be specified in
  “propositional PDDL”; default is “\((\text{total-time})\)”.
- Forced sequentiality: # actions equals # “time steps”.
- Larger plan length constant.
“Numeric” Formulation:
Fluents track current and max # stacks in use:
(\(\text{increase } (\text{stacks-in-use}) 1\))
\(\text{when } (\geq (\text{stacks-in-use}) (\text{max-in-use}))\)
(\(\text{increase } (\text{max-in-use}) 1\))
\(:\text{metric minimize } (\text{max-in-use})\)

“Preferences” Formulation:
Propositional counter for current # stacks in use.
PDDL3 trajectory preferences:
(\(\text{and } (\text{preference } p1\)
(\(\text{always } (\text{not } (\text{stacks-in-use } n1)))\))
(\(\text{preference } p2\)
(\(\text{always } (\text{not } (\text{stacks-in-use } n2)))\)) ...)
\(:\text{metric minimize } (+ (\text{is-violated } p1) ...))\)
Competitor plans (○), best known (—) and upper bounds (- -). A star indicates solution is optimal.

Plans found by SGPlan\textsubscript{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 \((\text{deliver } p \ o)\) must take place while \( o \) is open and \( p \) is made \((\text{split make-product action})\).

- 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.
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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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

Competitor plans (○), best known (—), upper ( - -) and lower (· · ·) bounds.

Closeup of “lower” region of the graph.
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Domain and problem hardness:

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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.