Motivating Example: Retail Delivery
Motivating Example: Retail Delivery
Retail Delivery Solution

Solution 1: A plan for a delivery problem instance

1. deliver package1
2. deliver package2
3. deliver package3

...
Retail Delivery Solution

Solution 2: A generalized solution for the problem

1 while there is some undelivered package do
2 deliver it
Generalized Planning

Workflow overview

Generalized Problem → Generalized Planner → Generalized Policy

Plan Instantiator → Classical Plan

Classical Problem

Classical State → Policy Executor → Action

León Illanes, Sheila A. McIlraith: Generalized Planning: Arbitrary Numbers of Objects
Generalized Planning
Workflow overview

Generalized Problem

Generalized Planner

Generalized Policy

Plan Instantiator

Classical Problem

Classical Plan

Classical State

Policy Executor

Action
There is at least one package for NY in Paris

\[ \exists x: \text{NY-pkg}(x) \text{ in-Paris}(x) \]
Automated Generalization

- From classical problem to quantified problem
- Use recent reformulation techniques:\(^1\)\(^2\)
  - Model indistinguishable objects with counting
- Abstract away the counters

\(^1\)Riddle et al. 2015.
\(^2\)Fuentetaja and de la Rosa 2016.
Nondeterministic Actions
Nondeterministic Actions
Nondeterministic Actions

- Problem dynamics are actually deterministic
- Results in \textit{unfair} nondeterminism
  - Some of the outcomes are actually impossible
- Strong cyclic solvers typically assume fairness
- We need to deal with the unfairness\textsuperscript{345}

\textsuperscript{3}Bonet et al. 2017.
\textsuperscript{4}Illanes and McIlraith 2017.
\textsuperscript{5}Bonet and Geffner 2018.
Generalized Planning
Workflow overview

Classical Problem → Plan Instantiator → Classical Plan

Generalized Problem → Generalized Planner → Generalized Policy

Classical State → Policy Executor → Action
The **LOOM** Algorithm

- Based on PRP\(^6\)
  - state-of-the-art planner for *fair* fully-observable nondeterministic (FOND) problems
- Incorporates verification step for termination\(^7\)

---

\(^6\)Muise, McIlraith, and Beck 2012.

\(^7\)Srivastava et al. 2011.
Background: Idealized Version of PRP

Start with empty policy

Goal-closed?

Yes

Incorporate it into the policy

Done

No

Find a new weak plan for some state not handled by the policy

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Idealized Version of LOOM

1. Start with empty policy
2. Goal-closed?
   - Yes: Done
   - No: Find a new weak plan for some state not handled by the policy
3. Terminating?
   - Yes: Done
   - No: Incorporate it into the policy
Evaluation

- Given a generalized problem, produce a generalized solution
- Execute it over a many problem instances
- Compare to a classical planning approach
  - Produce a plan for every instance
  - Using Lama-First
Generalized solutions with \textbf{LOOM}
Small overhead in most cases

<table>
<thead>
<tr>
<th>Domain</th>
<th>Time to generalized solution (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling</td>
<td>0.03</td>
</tr>
<tr>
<td>Logistics</td>
<td>0.53</td>
</tr>
<tr>
<td>Hamburger</td>
<td>0.03</td>
</tr>
<tr>
<td>Construction</td>
<td>0.17</td>
</tr>
<tr>
<td>Roundabout</td>
<td>297.89</td>
</tr>
</tbody>
</table>
## Executing generalized solutions

Significant improvements in most cases

<table>
<thead>
<tr>
<th>Domain</th>
<th><strong>LOOM</strong> Execution time (s) (normalized average)</th>
<th><strong>LAMA-FIRST</strong> Planning time (s) (normalized average)</th>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling</td>
<td>5.39</td>
<td>11.99</td>
<td>45%</td>
</tr>
<tr>
<td>Logistics</td>
<td>0.04</td>
<td>0.03</td>
<td>133%</td>
</tr>
<tr>
<td>Hamburger</td>
<td>0.05</td>
<td>0.26</td>
<td>19%</td>
</tr>
<tr>
<td>Construction</td>
<td>0.10</td>
<td>1.47</td>
<td>7%</td>
</tr>
<tr>
<td>Roundabout</td>
<td>0.004</td>
<td>0.006</td>
<td>67%</td>
</tr>
</tbody>
</table>
Problems solved over time
Construction domain

![Graph showing problems solved over cumulative time]

- Loom
- Lama
Summary

- GP is synthesis of domain-specific planners
- Arbitrary numbers of objects can be abstracted into unfair nondeterminism
  - This can be done automatically
- Solve with modified FOND planning
  - In turn leveraging classical planning techniques
Related Work


Fuentetaja, Raquel and Tomás de la Rosa (2016). “Compiling irrelevant objects to counters. Special case of creation planning”. *Al Comm. 29.3*.


Generalized Planning via Abstraction: Arbitrary Numbers of Objects

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