Generalized Planning via Abstraction: Arbitrary Numbers of Objects

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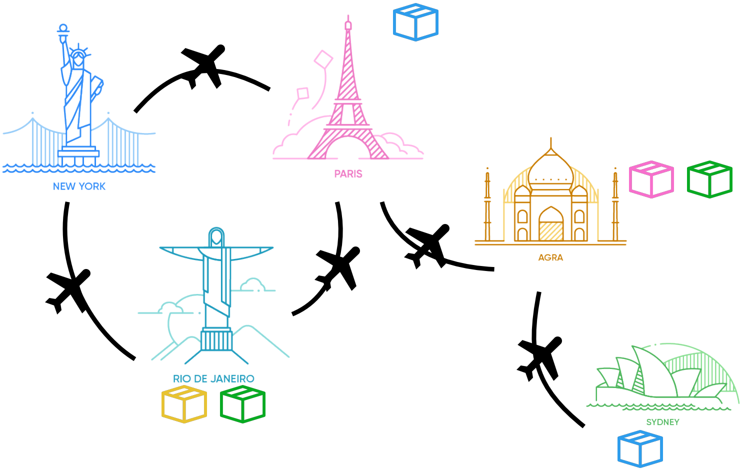
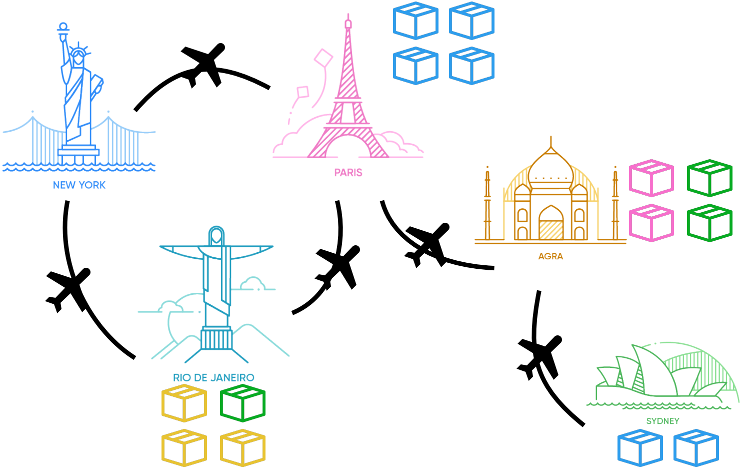
Motivating Example: Retail Delivery



Motivating Example: Retail Delivery



Retail Delivery Solution

Solution 1: A plan for a delivery problem instance

```
deliver package1
deliver package2
deliver package3
        ⋮
```

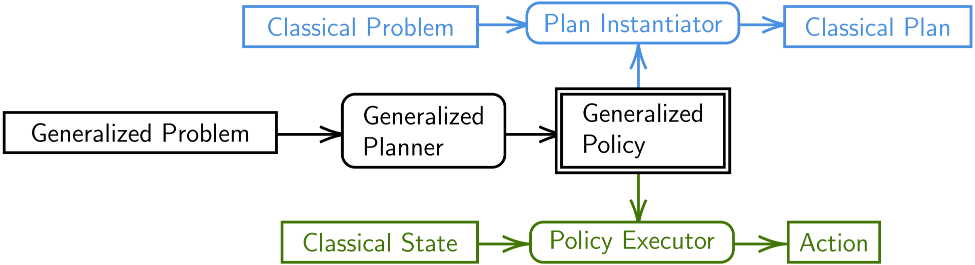
Retail Delivery Solution

Solution 2: A generalized solution for the problem

```
while there is some undelivered package do
    deliver it
```

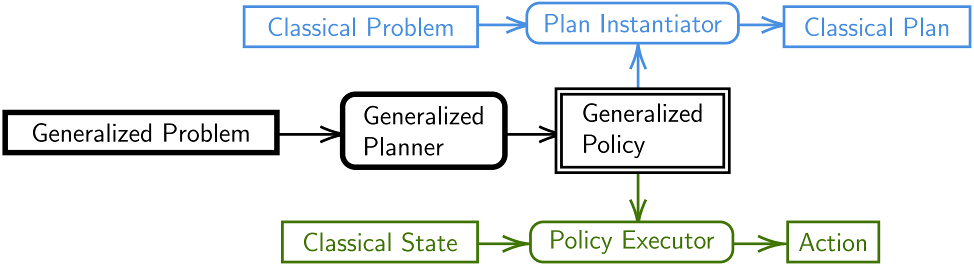
Generalized Planning

Workflow overview



Generalized Planning

Workflow overview



Classical Problem

Plan Instantiator

Classical Plan

Generalized Problem

Generalized Planner

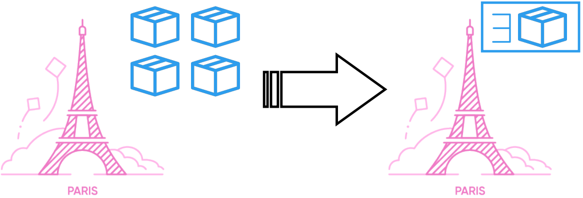
Generalized Policy

Classical State

Policy Executor

Action

Representation: Quantified Problems



"There is at least one package for NY in Paris"

$$\exists[x\colon \texttt{NY-pkg}(x)]\ \texttt{in-Paris}(x)$$

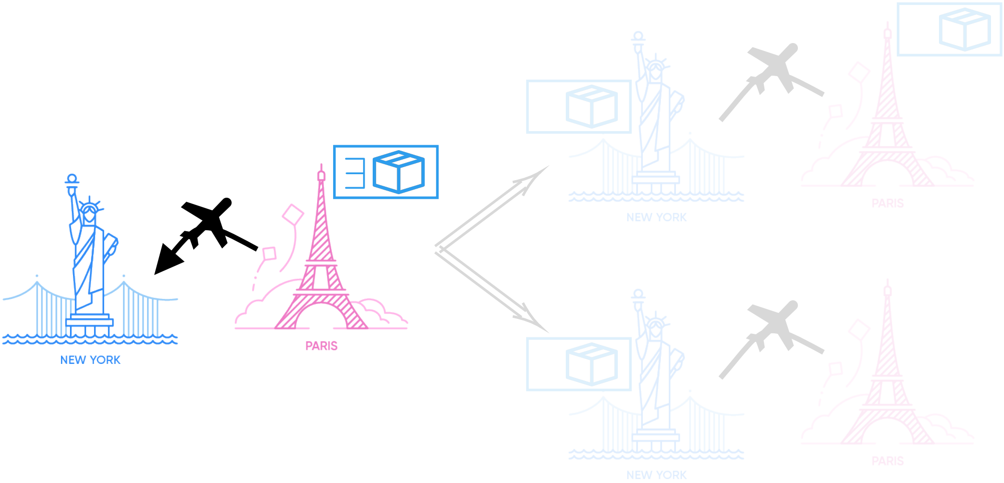
Automated Generalization

- From classical problem to quantified problem
- Use recent reformulation techniques:[1][2]
  - Model indistinguishable objects with counting
- Abstract away the counters

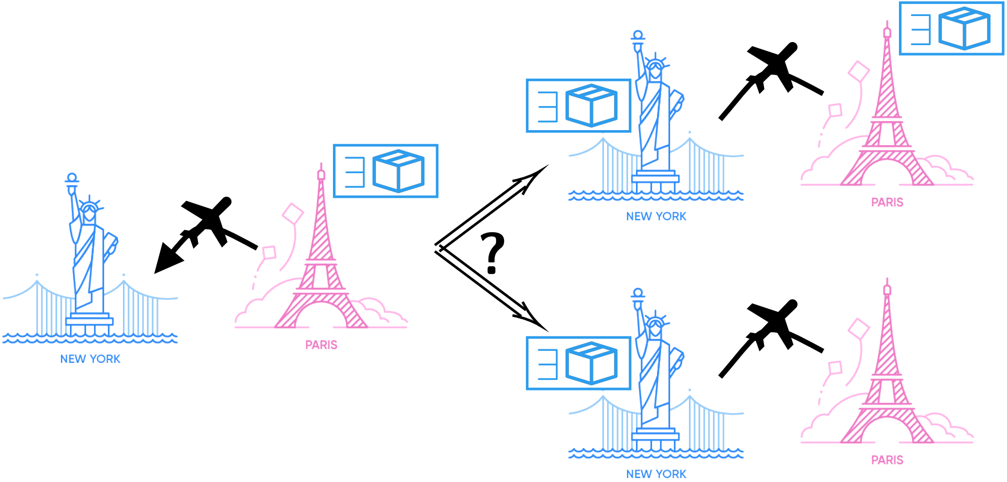
[1] Riddle et al. 2015.

[2] Fuentetaja and de la Rosa 2016.

Nondeterministic Actions



Nondeterministic Actions



Nondeterministic Actions

- Problem dynamics are actually deterministic
- Results in **unfair** nondeterminism
  - Some of the outcomes are actually impossible
- Strong cyclic solvers typically assume fairness
- We need to deal with the unfairness[3][4][5]

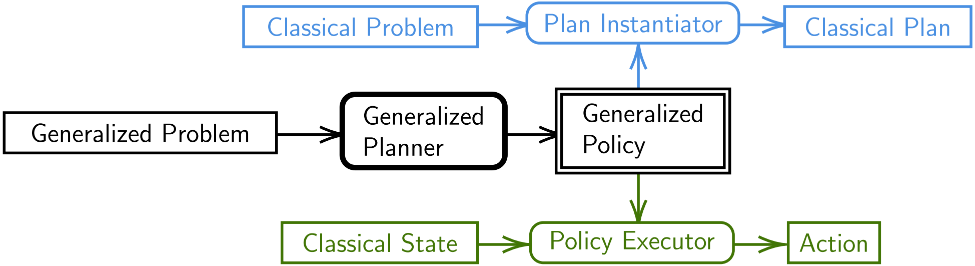
[3] Bonet et al. 2017.

[4] Illanes and McIlraith 2017.

[5] Bonet and Geffner 2018.

Generalized Planning

Workflow overview



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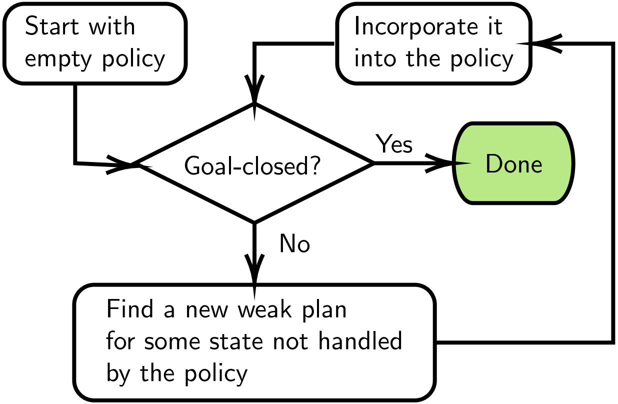
The LOOM Algorithm

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

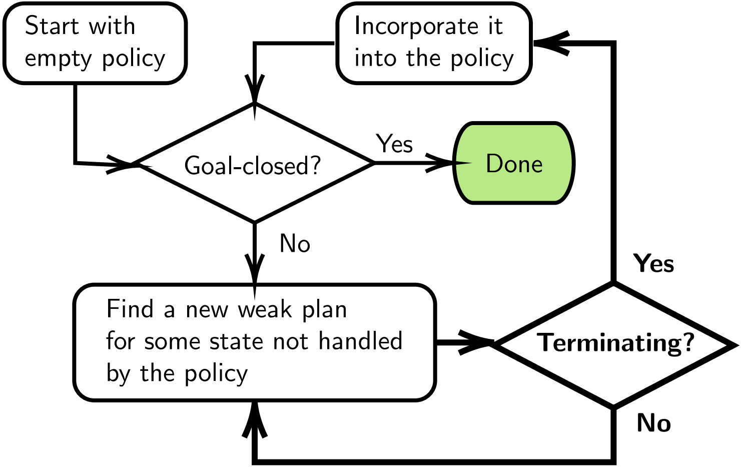
[6] Muise, McIlraith, and Beck 2012.

[7] Srivastava et al. 2011.

Background: Idealized Version of PRP


Start with empty policy
Incorporate it into the policy
Goal-closed?
Yes
Done
No
Find a new weak plan for some state not handled by the policy

Idealized Version of Loom



Start with empty policy

Goal-closed?

Yes

Done

No

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

Terminating?

Yes

Incorporate it into the policy

No

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 Loom

Small overhead in most cases

Domain	Time to generalized solution (s)
Recycling	0.03
Logistics	0.53
Hamburger	0.03
Construction	0.17
Roundabout	297.89

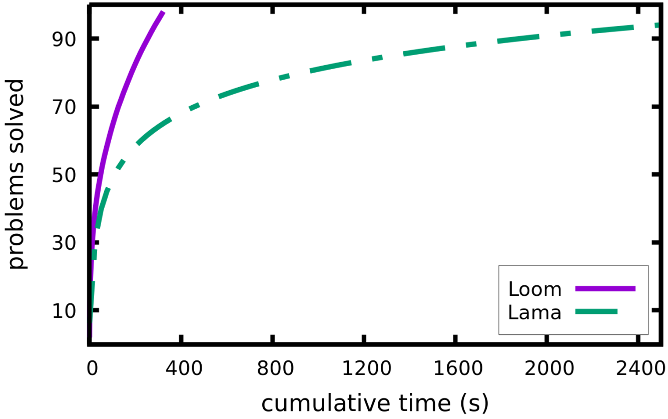
Executing generalized solutions

Significant improvements in most cases

Domain	Loom Execution time (s) (normalized average)	Lama-First Planning time (s) (normalized average)	Relative
Recycling	5.39	11.99	**45%**
Logistics	0.04	0.03	**133%**
Hamburger	0.05	0.26	**19%**
Construction	0.10	1.47	**7%**
Roundabout	0.004	0.006	**67%**

Problems solved over time

Construction domain



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

Bonet, Blai and Hector Geffner (2018). "Features, Projections, and Representation Change for Generalized Planning". *IJCAI.*

Bonet, Blai et al. (2017). "Generalized Planning: Non-Deterministic Abstractions and Trajectory Constraints". *IJCAI.*

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

Illanes, León and Sheila A. McIlraith (2017). "Numeric Planning via Abstraction and Policy Guided Search". *IJCAI.*

Muise, Christian J., Sheila A. McIlraith, and J. Christopher Beck (2012). "Improved Non-Deterministic Planning by Exploiting State Relevance". *ICAPS.*

Riddle, Patricia J et al. (2015). "Automated transformation of PDDL representations". *SoCS.*

Srivastava, Siddharth et al. (2011). "Qualitative Numeric Planning". *AAAI.*

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