Encoding Compositionality in Classical Planning Solutions

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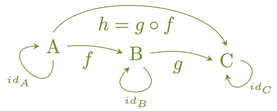
International Joint Conference for Artificial Intelligence (IJCAI) Workshop on Generalization in Planning 2021

MOTIVATION

When trying to understand whether a skill can be transfer, a user may inquire about the purpose each action has in achieving the goal in. To address this, we propose using a structure called string diagrams from category theory to trace literals and predicates and validate compositionality between plans.

CATEGORY THEORY & STRING DIAGRAMS

A category ($\mathbb{C}$) is:



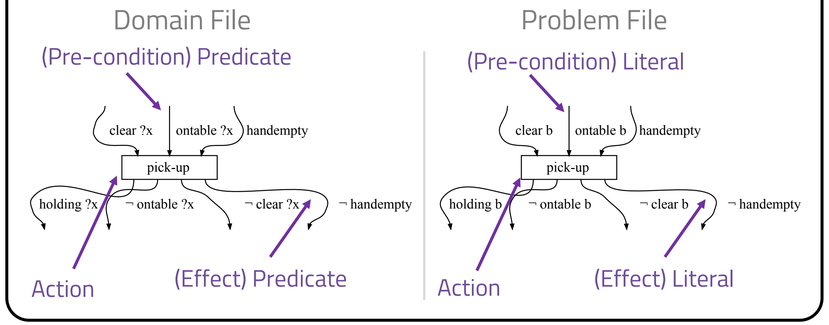
- A set of **objects** $\{A, B, C, \dots\}$
- A set of **morphisms** $\{f, g, h, \dots\}$
  - Where every object has an identity morphism, id_A
- **Composition operator**, $\circ$, that is *associative* with identity morphisms as *unitors*

A symmetric monoidal category ($\mathbb{M}$), adds:

+ **Tensor product**, $\otimes$, which is the product of $\mathbb{M}$ with itself that is *associative* and has *unitor isomorphisms*
+ Braiding isomorphism where $B_{\{X,Y\}}: X \otimes Y \to Y \otimes X$

A string diagram is the graphical syntax for symmetric monoidal categories, where **boxes are morphisms** and **strings are objects**.

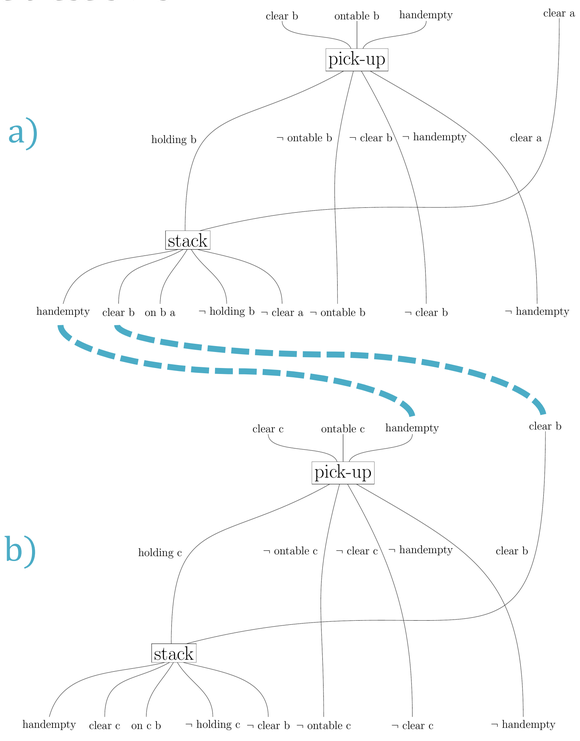
STRING DIAGRAMS FOR PDDL



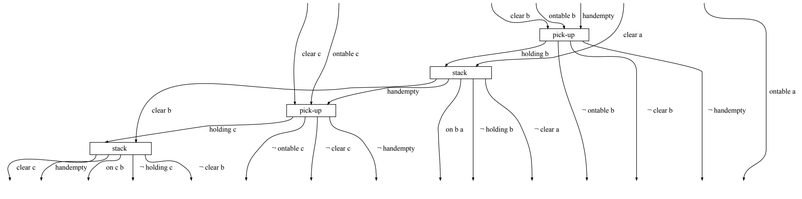
EXAMPLE: BLOCKSWORLD

Can we compose these skills?

stack-block(b, a)



stack-block(c, b)



BENEFITS

- Transferability of skills is a proof-by-construction
- A corresponding graphical syntax for mathematical expressions whose layout is determined by $\circ$ and $\otimes$
- Additional context for how parameters populate the predicates
- Deformation invariance property that allows you to slide boxes to find alternate plans

LIMITATIONS

- PDDL extensions supported are restricted. We have not defined string diagram encodings for quantifiers, equalities, and other extensions.
- We are unable to encode relationships between positive and negated version of a literal. They are currently treated as independent information under the closed world assumption.
- The visualization does not scale effectively to long plans with many actions.

FUTURE WORK

- Functors (maps between categories)
  - Relate composition of actions in domain specific language (e.g. PDDL) to conceptual models of plans to add semantics
  - Relate symbolic plans to geometric plans
- Visualization
  - Sliding boxes along strings to view alternative plans.
  - Scale the length of the strings or the height of the boxes according to some solver metadata, such as cost, or a real-world parameter, such as time to execute.
  - Interactions such as highlighting the strings of a particular literal in order to witness its path through the plan

Use compositionality to validate transferability of skills

Figures generated by TikzIt and AlgebraicJulia (Catlab)