Robot Meets World - Ontologies for Robotic Task & Motion Planning : Extended Abstract

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Abstract

Despite advancements in machine learning and robotics techniques, there still exists a wide range of activities that robots are ill-equipped to perform. This is known as the tail end of edge cases - novel scenarios that The goal of this research project is to identify, design and integrate ontologies for robotic spatial reasoning for use in these unaddressed scenarios. For example, deducing the correct key from the shape of a keyhole, and or determining one's relative size to a hole. The challenge lies in striking a balance between expressivity (the capacity for the ontology to support perception and reasoning) and complexity (a large set of arbitrary axioms can be difficult to verify and maintain over a period of time). We combat this by using a model-based approach, and designing a curated set of competency questions of increasing difficulty that should build upon a shared ontology signature. These ontologies will then be compiled and integrated into a functioning robotic system as a demo. In addition to being a data-efficient approach capable of solving problems that would be intractable via traditional methods, it is more easily regulated due to its explainable nature (there exists a logical train of thought between the ontology axioms and the final proof result).

1. Motivation

For roboticists, we provide a complementary method to machine learning and mechanics, for robotic spatial reasoning. According to our hypothesis, our method would require significantly less data while still being able to generalize to novel scenarios e.g. reasoning about complementary keyhole shapes, or navigating unfamiliar terrain.

For ontologists, a focus on robotics applications can serve as a new guide for practical, expressive, first-order ontologies. In the past 20 years, we have seen widespread adoption of ontologies as a tool for taxonomy and resolving data conflicts. However, we see the potential for ontologies to play a bigger role in a reasoning capacity. Robotics is a good entry point due to its plethora of existing unresolved problems, and relative ease of access to prototyping.

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2. Research Questions

1. *What ontologies are needed for robots to replicate common-sense spatial reasoning?*
2. *What are the minimum axioms needed to represent a physical space?*

3. Objective(s)

1. A curated set of spatiotemporal reasoning problems
2. A set of ontologies representing mereotopologies in space
3. A demo of ontologies working within a holistic robotic system

4. Research Methodology

We use competency questions to verify and validate our ontological choices,

5. Research Results to Date

1. Preliminary set of robotics challenge problems [[1]]
2. Preliminary example of robotic path finding problem modelled as a Process Specification Language (PSL) statement[2]
3. Non-exhaustive ontological framework for robot anatomy, based on Hilbert's Geometry and the Process Specification Language (PSL)[1][2]

References

[1] J. Thai, M. Grüninger, Robot meets world, in: Proceedings of the Joint Ontology Workshops co-located with the Bolzano Summer of Knowledge (BOSK 2020), IOS Press, 2020.

[2] J. Thai, M. Grüninger, Qualitative spatial ontologies for robot dynamics, in: Proceedings of the Joint Ontology Workshops, part of the Bolzano Summer of Knowledge (BOSK 2021), co-located with the 12th International Conference on Formal Ontologies in Information Systems (FOIS 2021) and the 12th International Conference on Biomedical Ontologies (ICBO 2021), IOS Press, 2021.