Symbolic reasoning about unseen objects from multimodal sensory feedback for manipulation

Arthur N. Helsloot, Mert Imre, Carlos Hernandez Corbato, and Jens Kober

Object manipulation is a challenging problem for robots when the environment cannot be fully observed, e.g., in environments that are physically and visually accessible from only a single side. It becomes crucial to exploit the resources to get as much information as possible to operate robustly in such environments. For this purpose, we propose Symbolic Reasoning for Partially Observable Environments (SyRePOE), that combines an ontology to maintain its world model and symbolic reasoning to infer information about the environment. Although methods based on Behavior Trees [1] or Planning Domain Definition Language (PDDL) [2] can provide solutions to such tasks, they remain task specific as they are limited in reasoning over and updating the current state, and changing the task would require major modifications in the structure. As SyRePOE has logic rules and ontology classes defined in the knowledge base, independent of the reasoning procedure, the cost of modifications is relatively low, as most of the rules and knowledge base will remain the same, and makes it scalable.

We investigate how SyRePOE can use multimodal sensory feedback and symbolic reasoning together for drawing conclusions that would allow the model of the environment to be more accurate, for example, by inferring the existence of an object that has not been observed. The proposed system is composed of four main software components: perception module, reasoner module, ontology module, and planning module. The perception module extracts information from the sensory input, and passes that information to the reasoner module. The planning module receives a PDDL description, that includes the most up-to-date world model and task to extract the next action and its parameters. The main responsibility of the ontology is to maintain the world model. The ontology, implemented in OWL [3], has been modeled under the PMK [4] and automatically under SUMO [5]. The ontology is initialized with fixed knowledge about the environment and object types it can expect to find in the environment. SyRePOE reasoner is implemented in Prolog, acts as an common interface for other modules to communicate and updates the world model through inference. The reasoner uses the fixed information of the environment, force readings during action application and visual inference in order to keep the world model in ontology updated with the changes. It provides an interface for other modules, asserts effects of actions, solves the possible conflicts and infers presence of objects.

We proposed SyRePOE for solving manipulation tasks in a visibly and operationally limited environments. Combining ontology and symbolic reasoning SyRePOE is able to retrieve more accurate model of the environment using multimodal sensory information. The proposed system is tested and validated on both simulated and real environments.

REFERENCES