A ROS Multi-Ontology References Service:
OWL Reasoners and Application Prototyping Issues

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Abstract—In this extended abstract, we introduce the AMOR service, a general-purpose and scalable interface between robot architectures and OWL2 reasoners. AMOR addresses synchronisation and communication issues among heterogeneous and distributed software components. As a guiding scenario, we consider a prototyping approach for the use of symbolic reasoning in human-robot interaction applications.

I. INTRODUCTION

The challenge of sharing and communicating information is crucial in complex human-robot interaction (HRI) scenarios. Ontologies and symbolic reasoning are the state of the art approach for a natural representation of knowledge, especially within the Semantic Web domain. In such a context, scripted paradigms have been adopted to achieve high expressiveness [1]. Nevertheless, since symbolic reasoning is a high complexity problem, optimising its performance requires a careful design of the knowledge resolution. Specifically, a robot architecture requires the integration of several components implementing different behaviors and generating a series of beliefs. Most of the components are expected to access, manipulate, and reason upon a run-time generated semantic representation of knowledge grounding robot behaviors and perceptions through formal axioms, with soft real-time requirements.

The Robot Operating System (ROS) is a de facto standard for robot software development, which allows for modular and scalable robot architecture designs¹. Currently, a number of approaches exist to integrate a semantic representation in ROS, such as the KnowRob² support for Allen’s Algebra [2] through a complete framework of useful ontologies, or the native ROS support of MongoDB³, which can be also used to provide a suitable representation for semantic querying. Unfortunately, none of these support the study of advanced reasoning paradigms, and they heavily rely on ad hoc reasoning solutions, significantly limiting their scope. We argue that this fact affects the study of different approaches to semantics in Robotics. For instance, it limits our capability to explore novel semantic representations of perceptions, which offers similar but not equivalent beliefs. We lack a standardized general framework to work with ontologies, natively supporting symbolic logic and advanced reasoning paradigms.

The Ontology Web Language (OWL) is a standard representation supporting several reasoning interfaces, e.g., Pellet [3], and logics approaches [4]. Thus, it can be a solid foundation to a framework for symbolic reasoning in Robotics. OWL is based on the separation between terminological and assertional knowledge, referred to as different boxes. Typically, in Robotics scenarios, we design a static semantics for the beliefs to be represented in the TBox. Then, we populate the ABox through individuals defined using types and properties and, at run-time, we classify knowledge using instance checking. We argue that, due to the high complexity of HRI scenarios, the possibility of a dynamic semantics in the TBox is desirable as well. For instance, it could be used to learn new types for classification. This lead us to a study requiring reasoning heuristics to be compared, components to be shared and different semantics to be adapted.

For this purpose, we propose the ROS Multi Ontology References⁴ (ARMOR in short). ARMOR is an open source service which manipulates and queries OWL2 ontologies. It provides a simple access to a set of dynamic ontologies, handling also the synchronizations among different components in the architecture. Last but not the least, it is a convenient tool to directly assess semantics supported by advanced reasoners.

II. SYSTEM’S ARCHITECTURE

A. Basic ARMOR Concepts

Figure 1 shows a schematic representation of ARMOR. It interfaces the OWL API⁵ through the Java-based Multi Ontology References library (AMOR). Then, ARMOR exposes AMOR functionalities as a service to ROS-based architectures, relying on the support for Java in ROS (ROSJava⁶). ARMOR messages have been designed to accommodate all OWL2 functionalities. Nevertheless, we have implemented only an exhaustive subset of those features so far (i.e., only common run-time operations). Indeed, ontology managers are not distributed across satellite components of a ROS architecture. Instead, dedicated components are in charge of management, while others only provide knowledge axioms, possibly at run-time. With ARMOR, it is possible to inject in the service other symbolic procedures, extending the semantics already provided by AMOR. Static descriptions can be defined with dedicated software, e.g., Protégé⁷.

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²http://www.ros.org/
³http://www.knowrob.org/doc
⁴https://github.com/EmaroLab/ARMOR
⁵http://owlapi.sourceforge.net/
⁶https://github.com/rosjava
⁷http://protege.stanford.edu/
B. AMOR

The core library, referred to as AMOR, contains a map of instantiated ontologies, where the key is a unique name identifier used to access the corresponding ontology in a thread-safe manner. AMOR provides several common operations, such as those to create individuals, assign their properties, make them disjointed and classify them, just to name a few. Furthermore, AMOR ensures complete accessibility to the OWL API features for compatibility and extendability purposes. For example, AMOR allows for invoking reasoning tasks by specifying its OWLReasoner factory, i.e., the unique package of its Java implementation, which assures compatibility with all OWL reasoners.

In the current implementation, we interface several properties that are useful to tune the AMOR behavior, e.g., the buffering of the manipulations or a continuous reasoner update, using the standard ROS Parameter Server, as well as parameters for debugging purposes such as toggling a Graphical User Interface (GUI) for visualising ontology states.

C. ARMOR

The ARMOR service is based on a ROS message structure (i.e., a triple) for the use of the AMOR functionalities from any node in the architecture, even when the development language is different from Java (e.g., Python and C++ are the most common languages in Robotics development). Such a message is composed of: 1) the client name, which is used by the service to identify different callers, 2) the reference name, indicating the operation’s target reference, and 3) the command to execute, i.e., add, remove, replace, query, load, mount, etc. Each of those commands may be further refined by: a) the primary and secondary specifiers, which augment command labels, e.g., add(individual, class) or remove(individual, property), and b) the arguments, a list of entities in the reference parameterizing the command, e.g., {add(class) "Sphere"}, or even {add(property, individual) "hasNorth" "LivingRoom" "Corridor"}. An ARMOR call is based on one or more messages with the same structure. When such a request is sent, the service manipulates or queries the ontology with the given directives. Then, it returns whether the ontology is consistent, eventual error codes with their description, and the names of the queried entities, if requested.

One advanced feature of ARMOR is the possibility of flexibly synchronizing all operations. This follows a mounting/unmounting paradigm, where one or more nodes identified by the same client name can prevent other nodes from manipulating a given ontology, in order to ensure manipulation consistency. On the contrary, queries are always allowed. Calls to busy ontologies will report the issue. The user can choose how to handle this situation.

III. APPLICATIONS

We are currently using ARMOR in different applications. Here we mention only two of them.

The first is aimed at implementing a dynamic PDDL problem generator. This approach uses descriptions of the predicates and objects within a tabletop scenario to infer unsatisfied norms and consequently generate goals [5]. The system has been integrated with ROSPlan [4] by substituting the internal semantic data structure with ARMOR and a suitable OWL ontology. Currently, we are investigating the performance of semantic feedback for re-planning.

The second is a system to learn by experience the arrangement of objects in the robot’s workspace by mapping their properties into the TBox. In this case, we inject a centralised service that scans semantic spatial relations and shapes ontologies, populated by different components in the architecture. Through them, such a service generates a new semantic scene class that the reasoner interprets as soon as it performs hierarchical classification. In this study, we are currently comparing different multi-modal perception modules to generate beliefs indicating relevant properties of a scene as perceived by a robot.

IV. CONCLUSIONS

We introduced the ARMOR service to manipulate OWL ontologies and fully query their reasoners within a ROS architecture. ARMOR is based on a flexible set of messages allowing for the direct access of several OWL features from any component of the architecture. It ensures synchronization between client calls, and flexibility through procedure injection. It also provides an easy interface to OWL2 representations.

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