Representation, Execution, and Interaction for Human-Robot Cognitive-Enabled Handover Tasks

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Abstract— **Robots presence increases to help reduce workers fatigue in factories. They are anticipated to become companions in households. Both environments can be widely different but in order to bring value to humans they need to be able to carry out tasks together with us. Teaming up with robots requires us to change our approach to building autonomous systems. A fundamental difference is the need for a form of cognition to adopt collaborative behaviors and adapt to situations while performing actions. This article focuses on human-robot handovers and describes a semantic model of the task as well as its integration in the robot reasoning, decision making, and interaction processes.**

I. INTRODUCTION

As wide as the range of applications for collaborative robots can be, it comes down to the ability of building a system that is able to work in a human environment. As such, the robot capacity to act as a partner and carry out joint actions is essential[1]. An important source of inspiration to develop these new systems lies in the way humans, collaborate with each other. Specifically how actions are coordinated. If several strategies can be thought of, both active and passive mechanisms rely on our capacity to build and maintain a common understanding and representation, of the tasks we undertake [2]. Specifically, in the case of handovers, share notions related to spatial concepts [3]. Those high level representations need to be linked to corresponding low level commands [4].

Furthermore, another important factor for effective collaboration is communication, which humans do naturally, but represents a real challenge for a machine [5], [6]. This can be partly explained by the fact that machines lack common sense reasoning [7]. And communicating intentions or expectations in particular, is a crucial component of joint actions to account for uncertainties regarding teammates decisions [8].

Following previous works [9], this paper proposes (i) a symbolic model to represent a handover task, (ii) an approach to generate arm and gripper motions based on the generic model and observations in the real world, and (iii) interacting mechanisms participating in making sure that the task is carried out successfully.

II. COGNITIVE-ENABLED HANDOVER

The following section first describes the design of the concepts network, then gives an overview of the reasoning process and finally presents the interaction mechanisms (see Figure 1).

A. Model of a handover

The handover model is twofold. On one hand the physical aspects of the task need to be represented, and the robot needs to understand of how to coordinate its actions with the human on the other hand. The proposed taxonomy is built using ontological knowledge stored in an Apache Jena Fuseki Server[1] and manipulaetd via SPARQL queries[2]. It provides a framework for the robot to compare with the real world, which can then make rule-based inferences to link information provided by the environment and action goals. They allow the robot to interpret commands and bring domain-specific common sense reasoning regarding manipulation actions, such as, to pass something it is first needed to be holding it. Note those rules are not one sided, they can also be used to anticipate what the human is possibly going to do next.

B. Executing a handover

Sending a command to perform a handover triggers the creation of the corresponding goal in the knowledge base. A goal the robot might not be able to satisfy, if for instance it does not hold the object. To account for that the set of reasoning rules is able to grasp the inconsistencies and generate intermediate goals. Inherent properties of an object such as its size can be stored, however poses are calculated only when required. The result of an action is determined from observations rather than anticipating the result of a command. Therefore, as the creation of intermediate goals is predicated upon the current state of the robot beliefs, they are generated one at a time. A semantic controller interprets high level decisions and translate them into messages for the Robot Operating System[3] (ROS).

C. Interaction

The robot can extract information about the environment through conversation with its partner. Based on human input the robot can judge the handover successful or not and decide to release the object or put it back. Those commands are interpreted as an (action, target) compound after three steps [5]. First the received signal is converted into individual symbols, then a syntax check to separate actions and objects and finally a semantic analysis to verify whether the meaning of the action can be understood and the object of the manipulation identified. After interpreting the command a new entry in the knowledge base is created.

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[1]https://jena.apache.org/documentation/fuseki2/
[2]https://www.w3.org/TR/sparql11-overview/
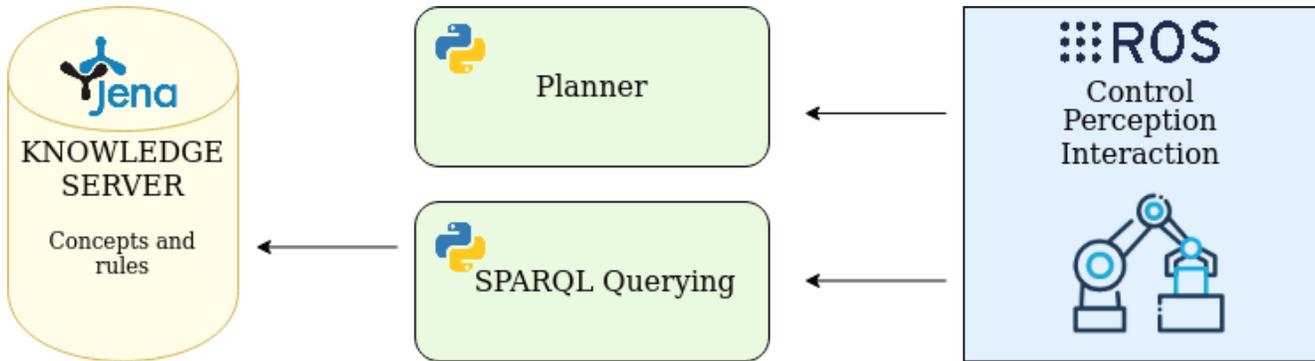[3]https://www.ros.org/

Fig. 1. Software architecture. Composed of 4 parts. An ontology server based on Apache Jena Fuseki where are defined concepts and rules linking them together. A planner modelling the problem as a graph. A library to create queries and send them to the server endpoint. ROS packages for translating this into actions that the robot can execute.

III. DISCUSSION

Stirring the aim from traditional automation to collaborative executions brings to light challenges that are related to manipulation tasks in general.

A. Planning about expectations

It is understood that to successfully collaborate human and robots need to share, at least to some extent, mental models of the environment and each other, allowing anticipation. However, if the robot is programmed to do just that it also seems inevitable that the human will modify his behavior according to what the robot next action or motion trajectory is thought to be [10]. In consequence, on one hand the human could be seen as an agent acting on its own, or reacting to the actions of the robot on the other hand. Back to our handover example and the proposed method, one way to improve and get the most natural trajectories would be to acknowledge that, in this case, the human will also estimate the robot trajectory to calculate the meeting point. Therefore making both agents able to move simultaneously when, by imposing where to receive the object, the actions are naturally more sequential.

B. Innate knowledge and learned knowledge

To model a manipulation task and the reasoning that the robot should apply is challenging because the list of edge cases that could fall out of what the rules comprise is virtually endless. Nonetheless, they remain a good base and prove to be useful to develop interactions with a human partner. It is thus important for the future that the robot would have ways to build on top of its existing rules, or in other words, build concepts on its own. Future work will aim at finding human-robot collaboration in establishing concepts themselves as well.

IV. CONCLUSION

This paper describes a cognition-enabled approach to perform handover tasks between a robot and a human[4]. Based on the proposed conceptual model, the robot can reason and generate an adequate semantic event chain. It does so comparing the model with information gathered from the environment either visually or interactively, during conversation acts with a human partner. Converting human inputs to object-action complexes allows to make a bridge with the symbolic knowledge.

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