A System Layout for Cognitive Service Robots

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Abstract—In this paper we discuss a system layout for cognitive service robots. The goal is to sketch components and their interplay needed for cognitive robotics as introduced by Ray Reiter. We are particularly interested in applications in domestic service robotics where we focus on integrating qualitative reasoning and human-robot interaction. The overall objective is to build and maintain a knowledge-based system and agent specification.

I. INTRODUCTION

In this work, we are concerned with a system layout for what is often called *cognitive robotics*. Cognitive robotics as introduced by the late Ray Reiter is to be understood as "the study of the knowledge representation and reasoning problems faced by an autonomous robot (or agent) in a dynamic and incompletely known world" [5]. Our application domain is domestic service robotics [15]. It deals with socially assistive robots that perform helpful tasks for humans in and around the house. These robots must be able to engage in communication with the humans around them. What is more, when a robot needs to assist humans with complex and cognitively challenging tasks, it must be endowed with some form of reasoning that allows to take decisions on the course of action in complex scenarios. In addition, autonomous operation for extended periods of time is only possible if the robot can handle certain variations and unavoidable errors by itself. Also, it should be flexible in dealing with human fallibility. We refer to such a robot as a cognitive service robot system.

II. A COGNITIVE SERVICE ROBOT SYSTEM LAYOUT

We now discuss a system layout for such a cognitive service robot in domestic applications. Figure 1 shows an overview of the elements that we think are necessary and useful for a cognitive robotic system. The particular focus here is on integrating qualitative reasoning and human-robot interaction [7], [8] for applications in domestic domains [11].

The blue elements are components that provide basic capabilities like collision avoidance and localization. The green boxes represent high-level components, that is, components featuring a sophisticated reasoning mechanism. We use a logic-based high-level language called ReadyLog [4] which, among other things, features decision-theoretic planning in the spirit of [2]. The orange components bridge between the high-level and the human or extend the high-level with mechanisms to facilitate intuitive interaction. The yellow box finally, is an optional but desirable component to enable



Fig. 1: A cognitive service robot system layout

enduring autonomy. It is an extension of the high-level control that has tight connections to the basic components.

A. Basic Human-Robot Interaction Modules

Our domestic service robot is supposed to interact with laymen. Hence, it needs to be operable by such laymen and the interaction between the human and the robot needs to be as *natural* and intuitive as possible. This is why we argue for extending the basic capabilities with modules for three important human-robot interaction components, namely speech, face, and gesture recognition. Examplary solutions for such components tailored for the particular application scenarios can be found in [3], [1], and [9] respectively. We consider these components since they represent (perhaps the most) important modalities in human-robot interaction. Human-robot interaction can be made even more natural and affective with additional components such as text-to-speech and an animated visual appearance.

B. High-level Reasoning

A domestic service robot that needs to assist humans with complex and cognitively challenging tasks, must be endowed with some form of reasoning that allows it to take decisions in such complex scenarios. This high-level reasoning abstracts from the details of lower levels and provides mechanisms to come up with a dedicated course of action for a robot to reach a particular goal. Our robot features a logic-based high-level reasoning component for that purpose. It allows for flexibly combining programming and planning in the behavior specification of the robot.

C. Qualitative Representations and Control

One of the issues in developing a robotic system that interacts with humans is the difference in representations with humans and machines. A technical system mostly uses numbers to represent things like speed, distance, and orientation while humans use imprecise linguistic notions. A robotic system that assists humans in their daily life, must be equipped with means to understand and to communicate with humans in terms and with notions that are natural to humans. The qualitative representations and reasoning with them should be available especially for positional information (e.g. as proposed in [12]) since these are very frequent in domestic settings, for example, with references to objects and places.

D. Semantic Annotations

Another building block to mediate between the raw sensor data and the numerical information that the base components of a cognitive robot work with are semantic annotations. In our cognitive robot system, for instance, we allow for generating semantically annotated maps [10]. This attaches semantic information to places like functions of a room or where it is likely to find people in an apartment. Another example could be part of the object recognition [6], where objects are described by a set of (semantic) attributes. This way, one can dynamically build classes of objects, for example, all objects with a specific color.

E. Natural Language Interpretation

Humans tend to be imprecise and imperfect in their natural spoken language. Therefore, when natural language is used to give instructions to a robot, the robot is potentially confronted with incomplete, ambiguous, or even incorrect commands. Aiming for a robust and flexible system a method for natural language interpretation that can account for handling such fallibility is beneficial. We present such a system [13] that uses decision-theoretic planning in the spirit of DT-Golog [2] to interpret the instruction given to the robot. It is able to account for imprecise and missing information and initiates steps for clarification accordingly.

F. Self-Maintenance

A robotic system that is capable of planning and executing complex tasks is a complex system itself. That is why such a system is itself vulnerable to errors. These errors are not restricted to action execution but span to internal system errors as well. As an additional component in the system layout we proposed a system for self-maintenance [14] that is able to detect and circumvent certain errors. Thus we increase the system's robustness and enable longer-term autonomous operation.

III. CONCLUSION

In this paper, we discussed the layout of a cognitive service robotic system that integrates qualitative reasoning and human-robot interaction for applications in domestic service robotics. The system layout features components that allow for implementing a capable service robotic system. The layout addresses bridging the gap between the robot and the human with several measures, making available the qualitative notions that humans commonly use in the robot system, in general, and in the high-level reasoning, in particular. This allows for natural interaction and with its advanced reasoning the robot can assist its human users with complex and cognitively challenging tasks. This is especially useful with disabled or elderly people.

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