Interface for Communication Between Robotic and Cognitive Systems Through the Use of a Cognitive Ontology

Helio Azevedo(1,2) Roseli Aparecida Francelin Romero (1)

(1) ICMC-USP / University of São Paulo
(2) Center for Information Technology Renato Archer (CTI)
São Paulo , Brazil
Email: hazevedo@usp.br , rafrance@icmc.usp.br

***Abstract*—The demand for socially interactive robots has increased annually. In particular, service robots have invaded homes and worked directly with humans who, in general, are not familiar with such devices. Their acceptance is conditioned to the evolution of research in the area of human-robot interaction. This paper contributes towards this acceptance process presenting an ontology that accelerates the implementation of cognitive systems in robots and enables the reproduction of experiments associated with cognitive models and comparison among different implementations. The specific objective is the definition of an ontology that provides a protocol for communication between cognitive and robot part systems.**

***Keywords*–cognitive model; robot; ontology.**

I. INTRODUCTION

The growing use of robots in the modern society is a reality [1]. Only a few decades have passed from a beginning restricted to production environments to the use of service robots in homes. Inside a residence, robots must use similar interaction processes to interact directly with humans.

Such dissemination of robots requires a growth in research on Human-Robot Interactions (HRI), particularly in the subarea defined by Fong [2] as Socially Interactive Robots (SIR). Therefore, the evolution of research into cognitive systems is one of the basic conditions for the consolidation of SIR. However, such research is hindered by the existence of multiple robot platforms, of which many are proprietary, a fact that minimizes the exchange of knowledge and skills among researchers. Moreover several programming frameworks exhibit different architectures and interfaces, which cause the subtraction of resources and delay in the achievement of results.

SIR applications demand more flexible solutions than those offered by hierarchical, reactive and hybrid classical robotic architectures [3]. On the other hand, cognitive architectures have emerged for modeling the cognitive aspects present in processing systems required by the society. They offer an interesting approach. However, there is a question concerning the facilitation of communication between the systems present in these two ”worlds“: robotic and cognitive.

Before delving into such a question, let us recall some definitions. A robot is an agent that acts in the physical world to accomplish one or more tasks. In this work, we assume the robot processing system is organized into two hierarchical systems. The first, named ”cognitive system“, models the cognitive architecture [4], whereas the second, named ”robot part system“, controls the devices attached to the robot [5].

Our hypothesis is there is a gap of communication between the cognitive model and the system that controls the sensors and actuators of robots. As an approach to reduce this gap, we propose defining a set of formally related terms that enables this communication. The strategy for the achievement of such a formalization is the definition of a cognitive ontology, named ”OntCog“, whose benefits involve:

- establishment of a standardized interface between the ”cognitive system“ and the ”robot part system“,
- facilitation of the development of cognitive robotic simulators,
- minimization of laboratory costs for research on cognitive science applied to robotics, and
- facilitation of the construction of reference environments for the development, evaluation and comparison of the performance of cognitive applications.

Few studies have prioritized the development of a protocol for the modeling of cognitive aspects. Novikova et al. [6] designed a platform, named SIGVerse, for the modeling of a robot agent in a 3D environment that interacts with a human avatar controlled by Wii, Kinect and Oculus Rift interfaces. Wii controls the walking movements, Kinect controls the trunk that enables the avatar to pick up objects and perform gestures, and Oculus Rift increases the effect of interaction with the 3D environment. The cognitive aspect is achieved through the recognition of two emotions in interaction, namely surprise and happiness.

On the other hand, some studies have attempted to simulate cognition in humans instead of robots. Faber et al. [7] performed a planning of assembly tasks in a manufacturing system considering the knowledge of human operators. This knowledge is initially absorbed by the analysis of the strategies used by operators during the assembly of mechanical components and then employed in the construction of a knowledge base (production rules) used in the manufacturing planning.

This paper is organized as follows: Section II presents the cognitive ontology proposed and highlights questions that are research subjects; Section III describes the strategies for the validation and verification process of the ontology; finally, Section IV summarizes the conclusions.

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II. COGNITIVE ONTOLOGY

This study aims at a protocol for the transfer of information at a higher cognition level. Below are questions that naturally arose in the proposal:

- **What is the desired cognition level?:** The spectrum of cognitive information is wide and ranges from sensations to memory, emotions and creativity. Our initial hypothesis states that the protocol is used as an interface between the cognitive and robot part systems. In this scenario, our interest is on the senses, i.e., sight, hearing, touch, taste and smell. We assume the other abstration levels of cognition are generated by the cognitive system, therefore, the representation of such information in the protocol is not required.
- **How can this information be represented?:** Data stream should not be used in the representation of senses obtained directly from sensors, but rather, a more high-level must be considered. Regarding the "hearing sense", the information would be words, sirens, birds, music, etc. A point for discussion concerns the way "attention focus" information should be aggregated to the message.

The natural way of describing this protocol is by using ontologies. An ontology formally describes objects and their relationships in a knowledge domain and its main advantages include [8]:

- offer of a formally defined vocabulary,
- implementation as a semantic data model,
- possibility of data integration and exchange of information among agents, and
- supply of consistency check tools.

Over the past few years, several ontologies have been proposed for robotic applications, however, according to Prestes [9], they are not generic enough to fully meet the needs of robotics and automation areas. The IEEE offered the *1872-2015 - IEEE Standard Ontologies for Robotics and Automation* [5] in 2015 and defined four ontologies, namely CORA, a core ontology targeted to robotics and automation, Corax, which presents common concepts in robotics and automation, RPARTS, which defines concepts that represent parts of the robot, and POS, which defines general notions of position and orientation.

We are particularly interested in CORA, as it represents the highest level of abstraction under which other groups develop specific ontologies. The ontology proposed in this paper is adherent to CORA, as adherence to international standards minimizes the development efforts and provides better results.

A. Senses Axioms

Our perception of the environment is generated from information gathered by the senses. Sense Axioms (Figure 1) define the objects, properties and relations present in robot sensory information.

The first open question on this topic regards the type of information, i.e., whether it is symbolic or numeric. Concerning the taste sense, the robot sensory information can be classified as sweet, bitter, sour and salty (symbolic types) or ph level (numerical type). Another question is related to the *cognitive information composition that must travel on the established interface*. As an example, rather than notifying the taste and smell perception, we could use flavor.

The treatment to be given to information present only in robots, but not in humans, as magnetism, radioactivity, infrared, etc, must also be taken into account. The ontology modeling can range from a super class definition, named *Generic*, to the inclusion of a class for each sensor type or distribution of information between basic senses. For example, the infrared might be bonded with sight.

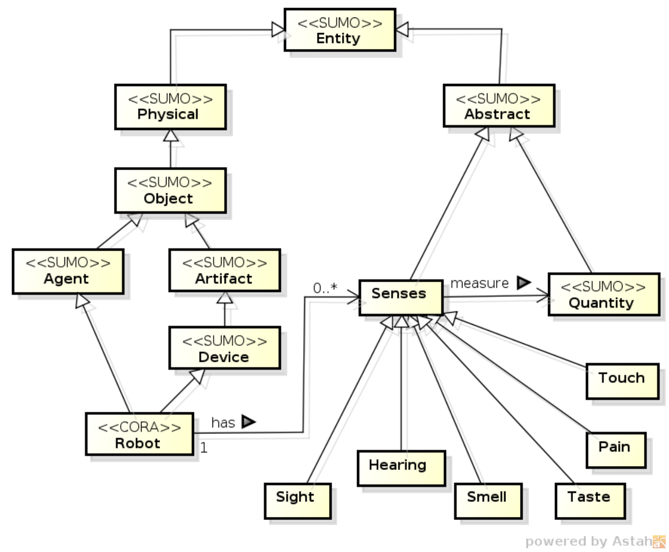

Figure 1. Senses Subclasses.

B. Act Axioms

Another group of information defined in the protocol represents messages from a cognitive system to a robot part system (Figure 2). In this group the central question is at *what level of detail should the action be described?*. For example, the action of picking up an object in the robot visual field can be broken down into the following steps: determination of the object position, size analysis, calculation of mass, identification of the motion sequence of the actuator arm, verification of obstacles in the path of each junction, execution of movements and capture of the object. Another possibility would be the simple sending of a message with the following content: "*Get object X in position Y*".

III. VERIFICATION AND VALIDATION

After the ontology definition, the results must be verified and validated. The verification (Are we building the product correctly?) is based on the OntoClean methodology [10], which provides a formal basis for the validation of the ontological adequacy of taxonomic relationships. The strategy is to aggregate a set of meta information (Rigidity , Identity, Unity, and Dependence) to the ontology classes and iteratively refine the original taxonomic structure.

Validation (Are we building the right product?) is carried out through the testing of the ontology in a controlled environment, i.e., given a usage scenario, "OntCog" must offer

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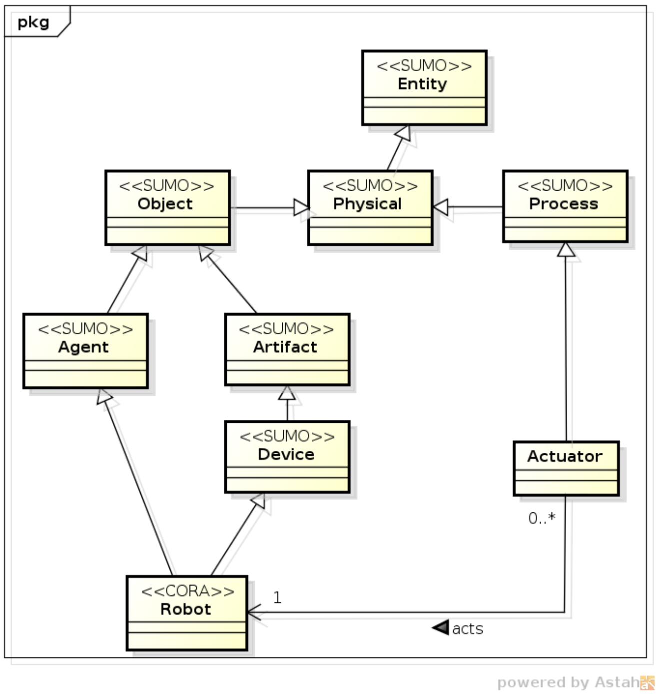

Figure 2. Actuator Subclasses.

resources for the representation of the exchange of information between the cognitive and robot part systems.

Robotics report V.O. [11] proposes the creation of an environment called ”Robot City Environment“, where robots would be inserted and validated through interactions with human actors. The use of validation environments is the basis for a system testing, however, ”Robot City Environment“ incurs a high implementation cost.

We propose an alternative approach based on a simulator rather than emulated cities. Figure 3 shows the architecture for the simulator called Cognitive Model Development Environment (CMDE), which represents an environment for the evaluation of cognitive models. CMDE consists of two processing nodes, of which the first implements a ”cognitive system” to be tested in CMDE environment and the second, called Robot City Simulator (RCS), is a cognitive model simulator. RCS includes the ”robot part system“ and the programming interfaces used in the parameterization of the environment required during a simulation.

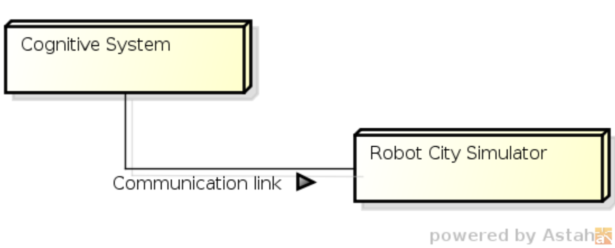

Figure 3. Cognitive Model Development Environment.

IV. Conclusion

This paper has addressed the hypothesis there exists a gap of communication between cognitive and robot part systems that directly impacts on the complexity increase in the cognitive systems development and difficulty of reproducing experiments. The strategy proposed for its minimization is the definition of an ontology that enables the design of a cognitive-level protocol for the development of socially interactive robots.

The expected results are more flexibility to the process of elaboration and validation of robotic cognitive systems by decreasing the researcher efforts and allowing the development of cognitive research in smaller laboratories and with fewer resources through simulators adherent to ”OntCog“ ontology.

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