World Modeling for Autonomous Systems

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Abstract. This contribution proposes a universal, intelligent information storage and management system for autonomous systems, e.g., robots. The proposed system uses a three pillar information architecture consisting of three distinct components: prior knowledge, environment model, and real world. In the center of the architecture, the environment model is situated, which constitutes the fusion target for prior knowledge and sensory information from the real world. The environment model is object oriented and comprehensively models the relevant world of the autonomous system, acting as an information hub for sensors (information sources) and cognitive processes (information sinks). It features mechanisms for information exchange with the other two components. A main characteristic of the system is that it models uncertainties by probabilities, which are handled by a Bayesian framework including instantiation, deletion and update procedures. The information can be accessed on different abstraction levels, as required. For ensuring validity, consistence, relevance and actuality, information check and handling mechanisms are provided.

1 Introduction

Efficient operational autonomous systems require a comprehensive overview on their environment. The present contribution proposes a universal, intelligent system for information storage and management, which is applicable to a wide variety of types of autonomous systems. The primary application of the system is a humanoid robot, designed to help with domestic applications.

The proposed system uses a three pillar information architecture and aims at modeling the environment of an autonomous system. The three pillars represent the main components of the architecture: prior knowledge, environment model, and real world. The first two components can be compared to the long and short term memory of the human brain.

Being the central component of the autonomous system, the environment model acts as an information hub, which stores sensory information and prior knowledge, and delivers it to cognitive processes. The information is represented in the environment model as instances of classes with class specific attributes and
relations. Instances in the environment model correspond to entities in the real world, their classes map object types of the real world. Classes equate concepts in prior knowledge, their realization are instances.

Besides the pillar architecture, the proposed system is characterized by the following features: object oriented representation of information, use of probability distributions in a Degree-of-Belief (DoB) interpretation, information management and fusion based on a Bayesian framework, and information access on different abstraction levels.

Commonly used approaches for the modeling of information comprise semantic nets, predicate logic or formal languages, see e.g. [1]. Recently presented methods involve ontologies, object oriented and probabilistic approaches [2,3]. Current research combines object oriented with probabilistic approaches [4,5,6,7]. The combination of object oriented approaches and ontologies is also being discussed in literature [8]. Probabilistic ontologies are proposed in [9].

The proposed approaches in literature for modeling the environment of autonomous systems are mostly domain specific and not transferable to other applications [4]. [10] proposes an object oriented world modeling approach with the purpose of creating virtual environments for simulation or engineering and for automation of specific tasks, e.g., financial transactions. Some of the main characteristics of the approach are the separation between real world and system objects and the development of the model using class diagrams. [6] proposes a dynamic approach for cooperative intelligent vehicles, which models the relevant environment for neighboring vehicles. Main characteristics are the incorporation of uncertainties for attributes, the modeling of conceptual objects, the inheritance in the object hierarchy, and the development of check and simple inference mechanisms. In robotics, the approaches proposed are generally simple and task specific. They require large amounts of prior information, e.g., the main task of the robot or his context.

This contribution focuses on describing the structure of the proposed system with accent on information management. The main characteristics and their advantages are presented in Sec. 2. Section 3 discusses the information exchange mechanisms and the construction of the environment model. Inference realizations are not part of the proposed architecture and are thus not within the scope of this contribution.

2 Three Pillar Information Architecture

The three pillar information architecture is mainly characterized through the separation and interaction between prior knowledge, environment model, and real world, see Fig. 1.

In the center of the architecture, the object oriented environment model is situated (middle pillar in Fig. 1). It represents the information the autonomous system has about the entities (objects and persons) in its current relevant environment. In the human memory, its correspondent is the short term memory. The information is represented here in form of instances with attributes and