IGI PUBLISHING **ITJ 4571**

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This paper appears in the publication, International Journal of Agent Technologies and Systems, Volume 1, Issue 1
edited by **Goran Trajkovski © 2009, IGI Global**

Cognitive Robotics and Multiagency in a Fuzzy Modeling Framework

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ABSTRACT

Fuzzy algebraic structures are a useful and flexible tool for modeling cognitive agents and their societies. In this article we propose a fuzzy algebraic framework where the valuating sets are other than the unit interval (lattices, partially ordered sets or relational structures) . This provides for a flexible organization of the information gathered by the agent (via interactions with the environment and/or other agents) and enables its selected use when different drives are active. Agents (Petitagé, ANNA, POPSICLE and Izbushka), which are instantiations of our model, are also given in order to illustrate the use of this framework, as well as its possible extensions.

Keywords: *cognitive agents; fuzzy algebraic structures; L-fuzzy structures; multiagent systems; P-fuzzy structures; R-fuzzy structures*

INTRODUCTION

Powerful tools, capable of capturing relevant parts of the world, as well as flexible enough to enable customized views of behaviors, are necessary when observing and calibrating cognitive agents in single and multiagent environments. This need becomes even more apparent when observing the interaction between the agent and the environment, the agents themselves, and while studying the emergence of new phenomena in such setups. Due to the extension of ranks, fuzzy structures enable for a more flexible and anthropomorphic toolset for frameworks

within which we study the agents, environment, interaction, and other related phenomena.

When fuzzifying crisp algebraic and relational structures, we usually change the rank of the characteristic function of either the carrier of the structure, or of the operations/relations of the systems (observed as sets themselves) from the two-element set $\{0, 1\}$ to the unit interval $[0, 1]$. For our modeling purposes, we introduce further generalizations. The unit interval is a special case of a lattice, every lattice a partially ordered set (poset), and each poset a relational structure. For our cognitive model, we utilize algebraic structures valued by lattices (L-fuzzy structures), posets (P-fuzzy structures), and relational structures (R-fuzzy structures).

Within these efforts, in this article we observe fuzzy algebraic structures as a base for our interactivist model of agency. Based on their experiences from the stay in an initially unknown environment, our agents build associations of expectancies of the general form $percept_1$-$action_0$-$percept_2$ (meaning that if it perceives $percept_1$ and applies $action_0$ it expects to see $percept_2$) and attribute to them drive-related emotional contexts. The exploration of the environment is governed by a Piagetian inborn scheme, a sequence of actions that an agent aims to execute in its search for a place where it can satisfy its active drive(s).

We will be presenting the below consideration using language as if applied to an autonomous mobile agent in a 2D environment, executing actions like forward, left, etc. This simplification does not hurt the exposition on the approach when applied to other types of environments (3D, cyberspace etc.), and actions (different from actual physical movements from one spot in the environment to another).

The article is organized as follows. Section 2 gives the cognitive agency and fuzzy algebraic preliminaries needed for the presentation of the cognitive agent in Section 3. Section 4 gives examples of cognitive agents within the fuzzy algebraic framework: Petitagé, our first complete cognitive agent, and its implementation in PYRO; ANNA, a cognitive agent with a neural network approach to learning; POPSICLE, as an environment for harvesting information from human subjects for the purpose of calibrating the simulation models; Izbushka, an agent-environment that couples with users, defining its goals via the interaction with the human partner. The last section overviews the article and gives directions for further research.

PRELIMINARIES

Below we present our view on agency and multiagency, as well as the fuzzy algebraic structure preliminaries necessary to introduce our new fuzzy algebraic definition of the cognitive agent.

Cognitive Agency

Crucial to the agent's performance is the intrinsic representation of its environment that it builds when it interacts with the environment (or other agents). Due to perceptual resolution, problems such as perceptual and/or cognitive aliasing arise (Trajkovski 2007). For example, two locally distinct places of the environment might be perceived the same way by the agent. All that the agent can rely on at that point is the context of the place it is in, as (unlike approaches in traditional Artificial Intelligence) it is not being spoon-fed the whole environment. The term context here refers to experiences that the agent has had immediately preceding its arrival at its present position. The agent enters the environment as a blank slate, and proceeds to build a functional representation of it. The agent's behavior depends on the inborn scheme of action that it tries to execute, and it notes the percepts that result from the execution of a subpart of its scheme, as inspired by the infant development studies of Jean Piaget (1973).

In our analyses, we distinguish between two distinct classes of perspectives in observing a given environment: ontology (ALF - Agent Learning Framework), as the view of the designer (meta-observer), and gnoseology, the view of the individual agent, as formalized below (Trajkovski & Vincenti 2005). Due to