Chapter II

An Embodied Logical Model for Cognition in Artificial Cognition Systems

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Abstract

In this chapter we describe a cognitive model based on the systemic approach and on the Autopoiesis theory. The syntactical definition of the model consists of logical propositions but the semantic definition includes, besides the usual truth value assignments, what we call emotional flavors, which correspond to the state of the agent’s body translated into cognitive terms. The combination between logical propositions and emotional flavors allows the agent to learn and memorize relevant propositions that can be used for reasoning. These propositions are represented in a specific format — prime implicants/implicates — which is enriched with annotations that explicitly store the internal relations among their literals. Based on this representation, a memory mechanism is described and algorithms are presented that learn a proposition from the agent’s experiences in the environment and that are able to determine the degree of robustness of the propositions, given a partial assignment representing the environment state.
Introduction

In recent years the interest in logical models applied to practical problems such as planning (Bibel, 1997) and robotics (Scherl et al., 2003) has been increasing. Although the limitations of the sense-model-plan-act approach have been greatly overcome (Giacomo et al., 2002), the gap between the practical ad hoc path to “behavior-based artificial creatures situated in the world” (Brooks, 1991) and the logical approach is yet to be filled.

In this chapter we define a logic-based generic model for a cognitive agent. This model found inspiration in several sources. From the systemic approach (Morin, 1991) and from the Autopoiesis theory (Varela, 1989) came the hypothesis that cognition is an emergent property of a cyclic dynamic self-organizing process. From the theory of evolution (Darwin, 1998) and from the memetics theory (Dawkins, 1976) came the belief that variability and selection is the base of both life and cognition. From (dilettante) neurobiology (Changeux, 1983, 2002; Damasio, 1994, 2000) came the guidelines for pursuing psychological plausibility. From Piaget’s genetic epistemology (Piaget, 1963; Piaget, 2001) came the requirement that learning and cognition should be closely related and, therefore, that the cognitive modeling process should strongly depend on the cognitive agent’s particular history. From the logicist school (Newell, 1980, 1982; Brachman et al., 1985) and the work on cognitive robotics (Levesque et al., 1998; Shanahan, 1993) came the focus on computational logical models. From Wittgenstein (Wittgenstein, 1933) came the intended epistemological status of logic.

Assuming that cognition can be captured by a computational model (Scheutz, 2002) and that this model is somehow based on evolutionary computation (Baum, 2004), in order to model cognition it is necessary to define the elements of an evolutionary environment where such evolutionary computation can take place. In natural evolution, the DNA codes for proteins, but the protein behavior depends on its three-dimensional structure that is not coded in the DNA. The match between code and “good” behavior is computed by selection; staying alive (and reproducing) is the positive feedback to the significant matching. To model cognition using an evolutionary algorithm, we need to define, on the one hand, the code (we propose to adopt a specific logical representation — prime implicants/implicates) and, on the other hand, the necessary feedback modeled in a minimalist approach, only by “good” or “bad” emotions. Finally, we need variability and selection, and time to let them work. Although no particular evolutionary algorithm is described, the chapter formally defines a possible computational framework that supports these necessary features.

The model to be defined is a first approximation. Several aspects of the model could and should be extended to include more complex mechanisms, but this presentation remains as simple as possible in order to stress the solution schema proposed by the model to a specific conceptual problem: how a cognitive agent is to learn and explore meaning in its environment. This problem has wide philosophical, biological, computational and physical implications. This first approximation is restricted to a simple computational context defined through an artificial environment, but the ultimate ambition of the proposed model is to meet Brian Smith’s criteria for a theory of computing (Smith, 1996):