Chapter X
Construction of Meanings in Biological and Artificial Agents

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ABSTRACT

In this chapter, we focus on the issue of understanding in various types of agents. Our main goal is to build up notions of meanings and understanding in neutral and non-anthropocentric terms that would not exclude preverbal living organisms and artificial systems by definition. By analyzing the evolutionary context of understanding in living organisms and the representation of meanings in several artificially built systems, we come to design principles for building "understanding" artificial agents and formulate necessary conditions for the presence of inherent meanings. Such meanings should be based on interactional couplings between the agents and their environment, and should help the agents to orient themselves in the environment and to satisfy their goals. We explore mechanisms of action-based meaning construction, horizontal coordination, and vertical transmission of meanings and exemplify them with computational models.

INTRODUCTION

Different kinds of agents—bacteria, animals, humans, some computer programs and robots—have something in common: they all are achieving some goals by sensing and acting in certain (real or virtual) environments (Kelemen, 2003). Some of them can communicate among themselves or even with humans. To what extent can we say that they understand what they do? If they attribute some meanings to situations and events in their environments, what is the nature of these meanings? Do they use the same meanings when they communicate? Where do these meanings come from? Are they innate (pre-programmed) or learned? These questions are the central focus of this chapter.

Some people may be reluctant to use the terms "understanding" and "meaning" in association with other than human agents. Notions of understanding often presuppose intentionality or consciousness.

However, such notions either exclude some types of agents from consideration by definition, or at least obfuscate the matter even more by reducing the problem to a harder one (as detecting/proving intentionality or consciousness in non-human agents is very problematic). Our approach is different. We will look for as neutral and non-anthropocentric characterizations of meaning and understanding as possible, applicable to preverbal living organisms and artificial agents as well. This is in line with similar efforts to define life and consciousness in such a general way that the human life and human consciousness are just their possible instantiations (Langton, 1989; Holland, 2003).

After providing a formal background, we will start our quest for meaning by drawing lessons from preverbal stages of phylogeny and ontogeny and by studying sensorimotor intelligence of animals and infants. Then we will introduce basic problems with understanding in artificially constructed systems and analyze several examples. The main issue that we will elaborate on is that of the origin of meanings. We will explore possibilities and limits of constructivist approach to meaning by the computational modeling methodology glossed as "understanding by building" (Pfeifer & Scheier, 1999).

The contribution of such an approach is threefold. First, we live in times when human-computer and computer-computer interaction is no longer a science fiction, but a practical engineering problem. We need to design representational formalisms that will allow us to endow machines with ontologies necessary for their successful solving of given tasks and for their mutual coordination/communication. The representation must be sufficiently complex to capture peculiarities of physical and social environments, including their dynamical character. In open environments, the ability to learn and autonomously construct useful representation of relevant meanings is crucial. Second, operationalization of Semantic theories and building relevant computational models can help clarify the notion of "understanding" in artificial systems that has been a source of controversy in Artificial Intelligence for a long time, and provide mechanisms for symbol and language grounding. Last but not least, the computational models can help us better understand ourselves. They can have a backward impact on theories of learning and language development, and on cognitive science in general.

THEORIES OF MEANING

Philosophers and linguists have studied the big question of "what does it mean to mean something" for many centuries. Nowadays, the study of meaning is mainly in the realm of Semantics and semiotics. In denotational Semantics, linguistic meanings are some objects. Concerning the nature of these objects, the fundamental distinction should be made between the *realist* and *cognitive* (or *conceptualist*) approaches. In the realist approach, meanings are some entities "out there" in the world. In the cognitive approach, meanings are mental entities "in the head". Gärdenfors (2000) characterizes cognitive Semantics by the following six tenets:

1. Meaning is a conceptual structure in a cognitive system (not truth conditions in possible worlds).
2. Conceptual structures are embodied (meaning is not independent of perception or bodily experience).
3. Semantic elements are constructed from geometrical or topological structures (not symbols that can be composed according to some system of rules).
4. Cognitive models are primarily image-schematic (not propositional). Image schemas are transformed by metaphoric and metonymic operations (Lakoff & Johnson, 1980).
5. Semantics is primary to syntax and partly determines it (syntax cannot be described independently of Semantics).
6. Contrary to the Aristotelian paradigm based on necessary and sufficient conditions, concepts show prototype effects (Rosch, 1978).

The first two tenets imply that language understanding cannot be managed by any isolated *language module* (in the sense of Fodor, 1983), but it is an integral part of the very same conceptual system that serves reasoning, orientation and acting in the world (Lakoff, 1987; Barsalou, 1999).

Gärdenfors (2000) represents meanings in

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