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## Chapter IV

# Toward a Pragmatic Understanding of the Cognitive Underpinnings of Symbol Grounding

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## Abstract

*We describe a research project investigating symbol grounding, the dynamics by which psychological connections are made between abstract symbols and concrete physical phenomena observed via sense perception and motor action. The project involves the use of a 3D simulated environment (AGI-SIM) as a medium for training, teaching, and developing an integrative, general-intelligence-oriented AI software system (the Novamente AI Engine). Via acting in AGI-SIM, Novamente forms concrete sensorimotor groundings for abstract relationships, such as those expressed in English by prepositions and subject-argument relationships. We describe results obtained using probabilistic-evolutionary learning within*

*Novamente to learn groundings for the concept near, the use of these groundings in practical procedure learning (e.g., learning to play fetch in a simulated world), and then we discuss the correlation of these groundings with linguistic usage of related words and the use of these groundings within analogical and other sorts of inference.*

# Introduction

One may conceive of mind as divided into three categories:

1. Symbol-to-symbol interrelationships
2. Perceptual and motor relationship
3. Symbol grounding relationships binding the symbolic and sensorimotor domains

Each of these categories is critical to intelligence. The first is dealt with by the science of logic; the second by a host of specialized subfields of biology, computer science, psychology, and engineering. Our focus here is on the third: symbol grounding (Harnad, 1990), which is what differentiates embodied, autonomous intelligent systems from purely formal systems on the one hand (i.e., Physical Symbol Systems, as defined by Newell and Simon, 1976) and purely sensorimotor-focused robotics systems on the other (Brooks, 1991).

In this chapter, we take the perspective that the appropriate way to understand the phenomenon of symbol grounding is to consider it in the context of unified, integrated, self-organizing cognition. Toward this end, we review the symbol-grounding problem from the perspective of an ongoing conceptual and technical research project (the Novamente/AGI-SIM project) aimed at creating a cognitive system capable of controlling a variety of embodiments in a variety of environments (including android bodies in physical environments, agents in simulated worlds, and other more adventurous possibilities). The project has many dimensions; the focus of this chapter is on building bridges between the abstract-conceptual and sensorimotor aspects of experiential learning, and the potential for this kind of bridge building to occur inside an AI system. One form that this bridge building takes, we propose, is the automatic learning of procedures that form sensorimotor groundings for abstract relationships such as those represented in English by prepositions and subject-argument relationships. Such groundings play a critical role in the pragmatic fusion of abstract conceptual inference with concrete, low-level sensorimotor procedure learning. And the nature of such groundings is best explored in the context of the particularities of learning and inference algorithms.

The project we describe involves the use of a 3D simulated environment (AGI-SIM) as a medium for training, teaching, and developing an integrative, general-intelligence-oriented AI system (the Novamente AI Engine). After a review of the relevant software systems and concepts, we present the results of some recent computational experiments in which Novamente was used to learn groundings for simple concepts within a simple version of the AGI-SIM world. Specifically, we describe machine learning experiments involving learning groundings for the concept of nearness and using this concept within procedures for carrying