Polyscheme and Cognitive Substrate Tutorial

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The Cognitive Substrate and Polyscheme

This tutorial describes a research program that aims to explain the breadth and power of human intelligence by creating a parsimonious computational model with these abilities. The approach is based on the Cognitive Substrate Hypothesis and the Polyscheme theory of cognitive architecture. These theories aim to explain two key properties of human intelligence: (1) it can operate in a broad range of situations, many of which never occurred when human cognitive mechanisms evolved and (2) it can simultaneously integrate several forms of perception, knowledge and reasoning.

The Cognitive Substrate Hypothesis (Cassimatis 2006) states that 1. A modest set of relations (involving, for example, time, causality, identity and space) are sufficient to encode knowledge about most or all domains and that 2. Once cognition involving these relations is understood, explaining the rest of cognition can proceed by characterizing problems using these substrate relations. This hypothesis is motivated in part by work into lexical semantics (Talmy 1988; Jackendoff 1990) and cognitive development (Carey and Spelke 1994) suggesting that a core set of representations and mechanisms from physical reasoning and/or perception underlie cognition in many domains.

The Polyscheme theory of cognitive architecture is intended to explain how mechanisms for reasoning over the substrate relations can be integrated and it thereby motivates an implementation of a cognitive substrate that people can use to model human intelligence in a wide array of domains. It is based on the belief that much human reasoning can be explained in terms of simulations using "lower-level" processes. Three of the ways Polyscheme differs from traditional production-system architectures are: (1) the extent of its focus on the breadth and power of human reasoning abilities, (2) its commitment to richer, more specialized primitive representational elements and (3) its inclusion of multiple representational formalisms and computational mechanisms (including, for example, neural networks, quantified probabilistic and logical constraints, temporal constraint graphs and category hierarchies).

Much work has demonstrated Polyscheme's ability to implement a cognitive substrate that supports models of reasoning in many domains. This work often proceeds by providing *mappings* between cognitive structures that occur in one domain and those in the cognitive substrate. For example, the structures in modern formal grammatical theories can be mapped onto the structures in physical reasoning (Cassimatis 2006); reasoning about people's beliefs can be reduced to reasoning about categorical, identity and counterfactual relations (Bello, Bignoli et al. 2007); many difficult linguistic reference resolution problems can be resolved by using substrate relations to encode and jointly reason over both linguistic and non-linguistic constraints (Cassimatis 2008).

Objectives of Tutorial

The objectives of this tutorial are to (1) introduce participants to results from linguistics and cognitive development that motivate that Cognitive Substrate Hypothesis (2) to explore the ramifications of this work for theories of cognitive architecture, development and evolution and (3) to enable them to use the Polyscheme architecture to develop, refine and apply models using substrate relations. Models of infant physical reasoning, children's metacognition, syntactic parsing, reference resolution and spatial reasoning will be used as examples. Applications discussed will include robotics, natural language processing and human-computer interaction.

Background of Participants

Participating in the tutorial will only require some familiarity with basic notions in cognitive science and a comfort with simple formal notation. Anyone able to read a basic production rule or a formula in introductory logic will be able to follow the tutorial. No programming apart from the use of Polyscheme's input format will occur during the tutorial.

References

Bello, P., P. Bignoli, et al. (2007). Attention and Association Explain the Emergence of Reasoning About False Belief in Young Children. 8th International Conference on Cognitive Modeling, Ann Arbor, MI.

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Cassimatis, N. L. (2006). "A Cognitive Substrate for Human-Level Intelligence." Artificial Intelligence Magazine 27(2).

Cassimatis, N. L. (2008). Resolving Ambiguous, Implicit and Non-Literal References by Jointly Reasoning over Linguistic and Non-Linguistic Knowledge, LONDIAL 2008: 12th Annual SEMDIAL Workshop on Semantics and Pragmatics.

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