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Companion Cognitive Systems: An Overview

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Introduction

This talk will describe work in progress on *Companion Cognitive Systems*, a new cognitive architecture whose goal is modeling large-scale learning of conceptual knowledge.

Keywords: Analogy, cognitive architecture.

Motivation

Existing cognitive architectures, such as ACT-R and SOAR, tend to focus on skill learning. While important, we believe that it is equally important to understand how conceptual knowledge is learned, and organized for effective use. Moreover, models based on ACT-R and SOAR tend to be focused on specific tasks, and often are run in isolation, for short periods, rather than treated as organisms that must survive for extended periods of time. With Companions, we are exploring a very different set of issues. Our goal is to create computational systems that can be treated like sentient beings, handling conceptual knowledge in human-like ways, without pre-built domain limitations, over extended periods of time. This includes continually adapting and learning about the domains they are working in, the people working with them, and themselves.

Assumptions of the Architecture

Our working hypothesis is that the flexibility and breadth of human common sense reasoning and learning arises from analogical reasoning and learning from experience (Forbus & Gentner, 1997). Within-domain analogies provide rapid, robust predictions. Analogies between domains can yield new insights and facilitate learning from instruction. First-principles reasoning emerges slowly, as generalizations created from examples incrementally via analogical comparisons. This hypothesis suggests a very different approach to cognitive architecture than is typically used. Reasoning and learning by analogy are central, rather than exotic operations undertaken only rarely. Accumulating and refining examples becomes central to learning and adaptation. We are using Gentner's (1983) structure-mapping theory as our account of analogy and similarity, and using components based on it as building blocks for Companions. This includes SME for analogical matching, MAC/FAC for analogical retrieval, and SEQL for generalization. We are using hand-drawn sketches as one of the primary interaction modalities, to explore how qualitative representations provide a bridge between perception and cognition (cf. Forbus *et al* 2004).

Some aspects of the current implementation diverge from psychological fidelity, due to limitations of today's technology. For instance, we are using a distributed agent architecture hosted on a cluster to provide the necessary

computational power. While we make the visual and conceptual representations produced by our sketching software as cognitively plausible as we can, some specific aspects of the processing are dictated by expediency and the need for interactive performance on today's technology, rather than theoretical bets about those aspects of human processing, since our modeling interest lie elsewhere.

Experiments

We are using several domains to explore these ideas. This talk will focus on *everyday physical reasoning*. No existing AI system handles the breadth and flexibility of the kinds of reasoning that people do about the everyday physical world around them. While progress in qualitative reasoning has provided a powerful collection of representations to work with, the QR community has focused more on narrow engineering domains, rather than reasoning broadly. To provide a clear progress metric, we are using the kinds of problems found on the Bennett Mechanical Comprehension Test as a corpus. The BMCT is extremely broad, including for example statics, dynamics, heat flow, and electricity. However, the reasoning demanded is qualitative in nature, and understanding spatial inputs (diagrams in the exam, which we approximate via sketching) is essential.

To better understand the contributions of different aspects of analogical reasoning, we have started with a baseline model, basically a single pass of retrieving examples and applying them to solve new problems. This has led to some promising results already. This includes learning visual/conceptual mappings and conventions for depicting everyday objects, modeling assumptions (e.g., how parts of everyday objects map into qualitative mechanics formalisms), and causal models (e.g., that tall things with narrow bases tend to be less stable). We summarize these results and describe other experiments in progress.

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