Qualitative Modeling and Cognitive Science

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Motivation

Qualitative reasoning research creates computational models that capture aspects of reasoning about continuous systems, including space, time, and dynamics. It has tackled problems ranging from understanding human mental models of everyday systems to creating systems that can do engineering design and create scientific models. The original motivations for the field came mostly from cognitive science: Creating accounts of human causal reasoning about physical systems. However, over time the fields have grown more separate. This symposium is part of a bridge-building effort, to create more dialogue between these two communities for their mutual benefit.

Gautam Biswas: We have been developing computer-based learning systems where students teach computer agents. These teachable agents provide important structures to help shape the thinking of the *learner-as-teacher*. Each agent manifests a visual structure that is tailored to a specific form of knowledge organization, and has related underlying qualitative reasoning mechanisms that helps the agent interact with the learner, and provide explanations on how well it has understood the material it has been taught. This framework lets us build on well-known teaching interactions that organize student activity (e.g., teaching by "laying out," teaching by example, teaching by telling, teaching by modeling), and keep the start-up costs of teaching the agent very low (as compared to programming). We illustrate the effectiveness of our approach through Betty's Brain, a teachable agent that makes her qualitative reasoning visible through a concept map.

Bert Bredeweg: Conceptual models are an important means for developing and communicating knowledge, particularly concerning the behavior of (physical) systems. But how can the use of such models be facilitated and adapted to the specific needs of people via software? Part of the answers lies in the use of qualitative models and their simulations. Such models provide a rich ontology to capture conceptual models of how humans explain system behavior. Now that these techniques are reasonably well understood interesting questions emerge concerning the automated use of them in aiding learners to develop, share, and communicate knowledge. This requires the design of graphical workbenches to work with such models and the development of smart agents that support a learner in "doing the right thing."

Ronald W. Ferguson: Diagrammatic reasoning is cognitively interesting because it involves the interaction of our powerful and seemingly task-independent visual system with knowledge about culturally-specific cognitive artifacts. Interpretation of new diagram types must be learned, but once learned, take on the character and ease of perception. Recent research in Qualitative Spatial Reasoning (QSR), which examines the development and inferential power of spatial relationships, may help explain why diagrammatic reasoning works this way, and even allow us to characterize what makes a diagram effective. We explore this claim using our GeoRep system as an example of integrating QSR with cognitive models of vision and problem-solving.

Peter Struss: Helping to understand ecological systems, to analyze the reasons for the deterioration of our environment and climate and to propose counteractions provides an important challenge to knowledge-based systems. Modeling artifacts and diagnosing why and how man-made devices fail to perform as expected is an important application area of model-based and qualitative reasoning which is based on a rigorous logical theory. Extending this foundation to natural systems turns out to be not straightforward, emphasizes the needs for conceptual and qualitative modeling formalisms, and the problem solving techniques face a different level of complexity. We will discuss the challenges and directions of potential solutions using an example at the transition between technical and natural systems, namely water treatment processes.

Bruce Sherin: Bruce Sherin's research includes investigations of conceptual change in science and external representations in science and mathematics. Bruce will serve as the discussant for the Symposium.