The Next Generation of Cognitive Modeling Tools: Opportunities, Challenges and Basic Needs

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In the past twenty or so years the scientific community has made impressive advancements in the modeling and simulation of general human cognition. This progress has led to the beginnings of wide-spread applications and use. In fact, we are now at a point where the community can begin to make fairly accurate predictions as to how this technology will be used in the next twenty–plus years. Accordingly, the purpose of this panel is to engage the community at large regarding the future needs and requirements associated with building cognitive models for various scientific and engineering endeavors. Specifically, this panel will discuss and make recommendations with regard to the future functionality of cognitive modeling that could be encompassed in next-generation capabilities. To do this, we will concentrate on four different domain areas. These are: academic use of cognitive modeling, cognitive model development, neuroscience-related issues, and practical applications of cognitive modeling.

Introduction to Discussion

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Cognitive modeling has become a fundamental activity for professionals within a variety of domains. Within academic psychology, it is often expected that theoretical proposals will be accompanied by a computational formalization. Furthermore, simulation provides a basis for establishing the correspondence between human experimentation and theoretical beliefs. Cognitive modeling has also been adopted by human factors professionals as a component of engineering analysis. Whether the intent is design analysis or system verification, cognitive modeling often provides a basis for human performance modeling. Finally, within the field of cognitive systems, cognitive models of users, experts or others, are embedded within systems and provide a framework to support and extend human-computer interactions.

While current frameworks enjoy extensive application and are supported by communities of academic and professional scientists and engineers, one may reasonably ask what the next generation of cognitive modeling tools will entail. Will they be elaborations of current frameworks such as ACT-R and Soar, with the look and feel of the upgrades common with computer operating systems or popular software applications? Or, will cognitive modeling tools enable users to employ models in fundamentally different ways that change how professionals think about cognitive modeling and its application in science and engineering, as well as education?

The panel seeks to look into the future to glimpse the functionality that may be encompassed in hypothetical and not so hypothetical next generation of cognitive modeling tools. This will be accomplished by first asking panelists representing current application domains to briefly discuss the issues that arise in their domain. These issues may entail fundamental limitations, practical considerations, opportunities for broadened application, capabilities enabled through integration with new and developing technologies, etc. Following these discussions, the panel will transition to a moderated discussion focused on thoughts and insights of audience members. The objective will be to have the audience expand on the thoughts of the panelists and to have them contribute ideas based on needs currently unfulfilled in current modeling tools, as well as to speculate concerning the functions they would like to see in future modeling tools.

Panelists will represent major application domains for cognitive modeling tools. First, an academic psychologist will address the use of cognitive modeling within cognitive science both as research tools and as a basis for enhancing education for undergraduate and graduate cognitive psychology, and related disciplines. The latter discussion may be expanded to address use of cognitive modeling in education across disciplines and spanning K12 to advanced degree programs. The second panelist will provide a perspective from the cognitive modeling development community that will encompass the development, elaboration, application, and verification and validation of cognitive modeling tools. The third panelist will discuss the practical application of cognitive modeling within engineering design and analysis. Finally, the fourth panelist will focus on the incorporation of cognitive models within various products. These products will encompass current applications such as intelligent tutoring systems and synthetic entities for simulation and gaming environments, as well as potential applications and products that may or may not have precedents within current technologies.

The overall objective is to gain insights from a diverse cross-section of the community that will benefit those working toward development of the next generation of cognitive modeling tools. The inputs collected from this session will be documented in a summary report that will be made available to the community at large through web-based, and potentially other avenues for publication.

Cognitive Modeling in Basic Research and Student Training

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University of Notre Dame

Cognitive modeling has a long and successful history in understanding basic human cognitive processes in academic research. It is one of the core methodological tools available to cognitive psychologists working on basic theoretical issues. Cognitive models lay one's assumptions bare, pointing out logical inconsistencies, and counterintuitive predictions with great clarity. While many cognitive models are developed with the aim of explaining known phenomena, there are also cases where models have predicted findings that would otherwise go undiscovered without the models. Some examples of each of these cases are provided within the context of human memory retrieval.

Cognitive models are also useful in explaining cognitive processes to students learning various topics in cognitive science. Cognitive models provide the students with a concrete instance that demonstrates otherwise abstract principles of human thought. The cognitive model also allows the student to manipulate variables of interest, if incorporated into the model, to make predictions about various outcomes, thereby enhancing their investigative training in a relatively short period of time compared to traditional data collection techniques.

A High-Level Behavior Representation Tool Based On Software Engineering

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There has only been a short history of high level languages to model human cognition based on cognitive architectures. One early example showed a large (3x) speed increase over plain modeling, but it was not widely adopted. It is time again to consider high-level behavior representation languages. Cognitive models and intelligent agents are becoming more complex and pervasive. This is driving the need for development environments that make it easier to create, share, and reuse cognitive models. Several high level modeling languages have recently been created and a summary has been recently presented at the International Cognitive Modeling Conference (Ritter et al., 2006). These languages are each different, but they have a common goal of making modeling human data easier to perform. We can now see some generalities and common lessons. I will identify lessons for the development of these languages as well as for their users.

For example, The Herbal tool set (Cohen, Ritter, & Haynes, 2005) consists of a high-level behavior representation language and its integrated development environment, which provides explanations of intelligent agent purpose, structure, and behavior. Herbal structures the programming process by using an explicit class ontology. Although the Herbal tool set allows designers to create models by directly programming in the Herbal high-level language, the Herbal IDE makes it possible for the designer to interact with this language visually. The Herbal IDE reduces the learning required by making it a visual task, yet appears to not reduce expressivity, both of which are important. The ontology leads to models that can explain themselves. The explanation patterns are based on a study of what questions users ask of models (Councill, Haynes, & Ritter, 2003).

Practical Application of Cognitive Modeling

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The design and acquisition process for large scale military systems is a cumbersome and tedious one, but, ironically, one that moves too quickly to allow the full set of associated human factors issues to be addressed. The challenge this timeline creates is compounded by the fact that, for maximum impact, human factors issues should first be addressed *before* a system is built, when it is still in the concept development stage. Further, early consideration of human factors increasingly requires the consideration of cognitive factors at a fairly high level of specificity. Modeling tools offer promise both with respect to speed and to how early they can be applied; however, before modeling tools, especially cognitive modeling tools, can be offered as the right approach for answering design and acquisition questions they must be fast, easy-to-use, easy-to-interpret, and valid across a wide range of domains.

The military community is investing in tools that meet these criteria and is eager to see a good return on investment (e.g., Lotens, et al., 2005). The U.S. Army has invested in tool development and in application (e.g., Allender, Archer, Kelley, & Lockett, 2005). The tool development approach heavily leverages existing modeling tools and established cognitive architectures, including the integration of task and cognitive modeling approaches. Several case examples of modeling tools and applications—ranging from evaluation of helmet-mounted-display utility to understanding commander decision making on a dynamic battlefield—illustrate the progress made to date as well as the requirements for the next steps in cognitive modeling tool development.

From Kinematics to Cognition: What are we really looking for in a model of human performance?

Joseph Cohn, Ph.D.
Naval Research Laboratory

Significant effort has been devoted to developing models that accurately reflect human behavior in terms of kinematics, perception, physiology, and cognition. Typically, these efforts proceed independently of each other, with efforts in one domain having little impact on other domains. However, as evolving theories of cognition suggest, there are in fact complex interactions—dynamic couplings—between these domains which are clearly present in, and have significant impact on, human behavior.

Consequently, any attempt at modeling cognition must tap into these other domains if it is to truly reflect that which it purports to represent. In this presentation, we discuss some of the cutting edge work developing in these different domains, and identify different areas of intersection where much sought after couplings between models should be developed.

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