Chapter XI
Cognitively Based Modeling of Scientific Productivity

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ABSTRACT

This chapter advocates a cognitively realistic approach to social simulation. based on a model for capturing the growth of academic science. Gilbert's (1997) model, which was equation based, is replaced in this work by an agent-based model, with the cognitive architecture CLARION providing greater cognitive realism. Using this agent model, results comparable to human data are obtained. It is found that while different cognitive settings may affect aggregate productivity of scientific articles, generally they do not lead to different distributions of productivity. It is argued that using more cognitively realistic models in social simulations may lead to novel insights.

SOCIAL SIMULATION AND COGNITIVE MODELING

A significant new trend in social sciences has been that of agent-based social simulation (ABSS). This approach consists of constructing models of societies of artificial agents. Agents are autonomous entities with well-defined rules of behavior. Running such a model entails instantiating a population of agents, allowing the agents to run, and observing the interactions between them. It thus differs from traditional (equation-based) approaches to simulation, where relationships among conceptual entities (e.g., social groups and hierarchies, or markets and taxation systems) are expressed through mathematical equations. Agent-based modeling has a number of advantages over equation-based modeling (Axtell, 2000; Sun 2006).

Interestingly, the evolution of simulation as a means for computational study of societies has been paralleled by developments in computational modeling at the individual level. Whereas earlier models of cognition tended to emphasize one of the aspects of cognition (for instance, memory or learning), some recent approaches have been more integrative, with a focus on putting the pieces together. The result of this integrative approach is *cognitive architectures*, which are essentially models that capture different aspects of cognition and their interaction. Such models tend to be generic and task independent. Cognitive architectures have greatly grown in expressive power in recent years, and now capture a variety of cognitive phenomena, including various types of memory/representation, modes of learning, and sensory-motor capabilities (e.g., Anderson & Lebiere 1998; Sun 2002).

So far, however, the two fields of social simulation and cognitive architectures have developed in near-isolation from each other (with some exceptions; e.g., Carley & Newell, 1994; Sun 2006; Naveh & Sun, in press). Thus, most of the work in social simulation assumes very rudimentary cognition on the part of the agents. At the same time, while the mechanisms of individual cognition have been the subject of intensive investigation in cognitive science and cognitive architectures (e.g., Anderson, 1983; Rumelhart & McClelland 1986; Sun, 2002), the relationships between sociocultural forces and individual cognition remain largely unexplored (again with some exceptions).

We believe, however, that the two fields of social simulation and cognitive architectures can be profitability integrated. As has been argued before (Sun & Naveh, 2004; Moss, 1999; Castelfranchi, 2001), social processes ultimately rest on the choices and decisions of individuals, and thus understanding the mechanisms of individual cognition can lead to better theories describing the behavior of aggregates of individuals. So far, most agent models in social simulation have been extremely simple (in the form of very simple automata with a few ad-hoc assumptions) or entirely absent (in the case of equation-based modeling). However, we believe that a more realistic cognitive agent model, incorporating realistic tendencies, inclinations, and capabilities of individual cognitive agents can serve as a more realistic basis for understanding the interaction of individuals (Moss, 1999). Although some cognitive details may ultimately prove to be irrelevant, this cannot be determined *a priori*, and thus simulations are useful in determining which aspects of cognition can be safely abstracted away.

At the same time, by integrating social simulation and cognitive modeling, we can arrive at a better understanding of individual cognition. By studying cognitive agents in a social context, we can learn more about the sociocultural processes that influence individual cognition.

In this chapter, we first describe the model proposed by Gilbert (1997) for capturing the growth of academic science. Gilbert's model lacks agents capable of meaningful autonomous action. We then describe a cognitive architecture, CLARION, that captures the distinction between explicit and implicit learning. This architecture has been used to model a variety of cognitive data (see Sun, Merrill, & Peterson, 2001; Sun, 2002; Sun, Slusarz, & Terry, 2005). We demonstrate how Gilbert's simulation can be redone in an enhanced way with CLARION-based agents (Sun & Naveh, in press). We argue that the latter approach provides a more cognitively realistic basis for social simulation.

PREVIOUS MODELS OF ACADEMIC SCIENCE

Science develops in certain ways. In particular, it has been observed that the number of authors

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