Introduction

The Simulation of Social Agents

In recent years, a new epistemic culture (see Knorr Cetina, 1999), based on computational models of interacting agents, has been forming in the social sciences. Early exemplars are Schelling (1978), who illustrated that segregation can be an emergent result of interactions among agents that do not themselves prefer segregation, and Axelrod (1984), who explored the ways in which cooperative strategies can survive in iterated Prisoner's Dilemma competitions.[1]

A number of intertwined computational innovations, including object-oriented software design, distributed and parallel processing, mobile online agents, and scientific visualization techniques have greatly enhanced the power and expressiveness of social simulation. As a result, a new generation of influential studies (Axelrod, 1997; Cederman, 1997; Epstein & Axtell, 1996; Resnick, 1997; Young, 1998), and even texts (Axelrod & Cohen, 1999; Weiss, 1999), have appeared.

In this context, in 1999, the University of Chicago and Argonne National Laboratory began cosponsoring an autumn workshop on agent simulation. Although the proceedings of these workshops have been published (see Macal & Sallach, 2000), the *Social Science Computer Review* invited participants in the 2000 workshop to extend their workshop papers into full-length articles that would then be the basis of a special issue of the journal.

The five articles published in this special issue are the result of this invitation. These articles provide a view of the state of the craft of social agent simulation in the early 21st century. Readers are likely to be struck by the range of research topics to which agent simulation topics are being applied.

Specifically, Roberto Pedone and Rosaria Conte provide a unique model of status dynamics in which hierarchy persists, notwithstanding the variability and instability of status symbols. A. Maurits van der Veen, Ian S. Lustick, and Dan Miodownik simulate political identity from a social constructivist perspective. Teresa Satterfield explores the interaction of social and genetic factors in the evolution of creole languages. Harko Verhagen formulates a mechanism designed to emulate how norms spread. Michael J. North describes how models of interdependencies can be used to support infrastructure planning.

Agent simulation research regularly experiences tension between maintaining simplicity, allowing the process and its effects to be clearly understood, versus representing the complexity inherent in the social world. Different research programs address the tension in various ways. The program associated with complex adaptive systems (CASs) strives to achieve clarity through simplicity (Axelrod, 1997; Resnick, 1997). The distributed AI (multiagent systems) program deprecates simplicity in favor of inferential and communicative depth and verisimilitude (Carley & Newell, 1994; Weiss, 1999).

How, and to what extent, empirical detail is incorporated into simulation models defines another way in which the tension between simplicity and complexity is managed. Artificial society research tends to eschew the emulation of empirical patterns in favor of identifying generalized interaction patterns (Gilbert, 2000). In contrast, other research programs strive to reproduce cultural setting in extensive detail. Archeological simulations provide a good

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example of the latter approach (Dean et al., 2000). Such differences are present in the articles presented here as well.

This tension between simplicity and complexity is one aspect of the underlying issue of knowledge representation (see Sowa, 2000), specifically, what social processes and interactions among processes are represented within the simulation. At the core of these representations, there is often an analogy between social and computational processes, which van der Veen et al. make explicit in discussing a repertoire of "strategies, ideas, arguments . . . an agent has at its disposal. Depending on the metaphor we choose, we may say that at any given time, a single strategy is deployed, identity is activated, or argument is articulated only from this repertoire" (p. 265). However, the computational model underlying each is the same; it is only how the analyst chooses to think about the process that changes.

Of course, simulation models do not and cannot emulate societies in all of their multifaceted dynamics. The processes represented within a simulation are selected to represent a particular research focus. In the years to come, the representation of such social entities and processes will be at the heart of an active dialogue between the substantive social sciences and the emerging epistemic community of agent simulators.

The following collection of articles covers some of the main themes addressed by social agent simulation, which include

- origin and persistence of social identity, groups, and structures, and the rise of institutions;
- establishment and proliferation of norms;
- origins of communication and language;
- emergent social and group properties, often counter to the properties of individuals;
- factors of social change emanating at the individual level;
- importance of memory and history in social processes; and
- learning, adaptation, diversity, and mechanisms for change motivated by interactions with a dynamic environment.

Pedone and Conte, taking their lead from Simmel, simulate the interaction between two processes: imitation and distinction making. Those high in the status hierarchy distinguish themselves from low-status members, whereas those low in the hierarchy imitate high-status members. As their study elegantly demonstrates, cultural symbols are unstable, but the diffusion of symbols does not efface the underlying hierarchical order.

Whereas Pedone and Conte explore the dynamic interactions of high- and low-status actors, van der Veen et al. study the acquisition and activation of strategies, from repertoires of varying sizes, in response to environmental changes. The latter may vary randomly or by patterns that are predictable in the short term. In addition, the effects of potential mobilizing agents of two types (entrepreneurs and innovators) are investigated.

Satterfield's simulation is grounded in the empirical patterns of Sranan Tongo. In this sense, it is culturally explicit, similar to the archeological studies described above. However, it is also designed to explore the interaction between two competing theories. One holds that innate blueprints are an automatic source of generic structures for natural language. The other minimizes a priori linguistic knowledge in favor of social and environmental conditions. The preliminary results reported here suggest a complementarity between the two processes.

Verhagen models the interaction of individual and group decision trees in the spreading and internalization of group norms. The degree of agent autonomy, relative to the group, is varied during the exploration of these micro-macro dynamics.

North provides another type of empirically driven simulation. Inasmuch as they are motivated by pragmatic policy considerations, validation and calibration of energy and market factors comprise an essential aspect of North's methodology.

Policy implications provide an additional way in which the dialogue between substantive issues and simulation results may come into focus. North notes that his model of infrastructure markets predicted price spiking in California. Indeed, in a paper presented in March 2000, North (2000) wrote, "SMART II indicates that certain transmission line configurations tend to encourage price spikes. The transmission system in Southern California . . . has one of the price line configurations that encourage price spikes" (p. 4). North would not maintain that rolling blackouts in California during the winter of 2000-2001 were caused entirely by the configuration problems he identified. Nonetheless, the example illustrates how policy applications of agent simulation technology (see Scharpf, 1997) can be an essential part of the broader dialogue between simulative and substantive research programs.

These articles suggest a common framework for constructing and applying social agent simulations, an approach not altogether different from the traditional context of computational simulation:

1. Define hypothesis and/or theory(ies).
2. Represent and implement the theoretical constructs in the context of the simulation, that is, define norm, status, identity, performance, "innovative" and "entrepreneurial" agents, "stable" and "risky" environments, and so forth.
   How do we define and interpret norms and other terms that may not have been defined previously to the extent necessary for computational simulation? In this regard, there are questions of scope covered by the operational definitions, that is, if a norm is used, does it represent all norms or does it merely demonstrate a single case of a norm? If multiple norms are represented, are they intended to span the space of all norms?
3. Set up an agent simulation model environment, consisting of (a) a simulation "landscape," which defines allowable agent interaction patterns, for example, a two-dimensional grid as in CA or network, and so on; (b) agent attributes and behavior (decision) rules; and (c) systematic simulation experiments to study the effect of changes in variables.
4. Set up global (system) measures for comparison of simulation results. Examples are diversity, variability, distinctiveness, population performance, and clustering.
   Conduct large numbers of simulation experiments across the parameter space. The choice of, and application or development of, a simulation tool is a major aspect of the simulation process.
5. Interpret simulation results by mapping them back into the theory space. Identify patterns in the results and partition the result space into broad categories.

Close study of these articles will reveal alternate ways in which social processes can be represented, some suggested by the authors, others identified by the reader. The systematic exploration of these types of possibilities will help frame the focus and social impact of this emerging epistemic culture in the years and decades to come.

NOTE

1. This is not to suggest that there is a consensus about Axelrod's claims for particular strategic outcomes. In particular, see Binmore (1994).

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