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Recent Trends in Agent-based Computational Research: A Brief Introduction

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Agent-based modeling is becoming increasingly important in most of the behavioral sciences. It is used productively for purely theoretical purposes as well as for empirically oriented analyses in such varied fields as economics (Farmer and Foley 2009), finance (Mathieu, Beaufils, and Brandouy 2005), political science (De Marchi and Page 2014), geography (O'Sullivan 2008), criminology (Birks, Townsley, and Stewart 2012), epidemiology (Auchincloss and Roux 2008), social psychology (Smith and Conrey 2007), demography (Billari and Prskawetz 2003), sociology (Macy and Flache 2009), organizational research (Fioretti 2013), archaeology (Wurzer, Kowarik, and Reschreiter 2015), ecology (Grimm et al. 2005), and biology (Thorne, Bailey, and Peirce 2007). But what is agent-based modeling about and why is it an important tool for social scientists?

In order to isolate the defining characteristics of an agent-based model, it is useful to make a preliminary distinction between "statistical" and "theoretical" models (Skvoretz 1991), the former referring to models that are used for estimation purposes while the latter type of models seek to formally represent a process believed to have generated a specific type of outcome (see Fararo 1969; Boudon 1979; Sørensen 1998 for related distinctions). Agent-based models first and foremost are theoretical models. They simulate the

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behavior of interdependent agents who are endowed with various kinds of attributes and behavioral rules. Typically, simulation is employed to examine the collective outcomes that agents bring about when they act and interact over extended periods of time.

An important reason for the increased use of agent-based modeling is its flexibility and generality. Agent-based models can represent in a clear and precise way (1) a range of different types of agents, (2) their heterogeneity in terms of attributes and behavioral rules, (3) a variety of structural and relational constrains, and (4) the loops that exist between micro behaviors and macro outcomes (see Axtell 2000). Thus, agent-based modeling holds considerable promise for a discipline like sociology because it makes it possible to model certain aspects of social life that other modeling strategies are not able to handle with similar ease. Its strength is that the underlying formalism (i.e., programming and computation) as such does not force the researcher to make assumptions that are known from the very outset to be inappropriate (see Hummon and Fararo 1995).

Although agent-based models primarily are theoretical models in the above-mentioned sense of the term, this does not imply that agent-based models necessarily are far removed from actual data. While the first generation of agent-based modelers indeed tended to rely on very simplified models for exploring theoretical possibilities (for an overview, see Macy and Willer 2002), the field is changing and empirical research is becoming increasingly more important for model calibration as well as model validation (see Bruch and Mare 2006 for one example, and Fagiolo, Windrum, and Moneta 2007 for a general discussion).

Agent-based modelers used to form a community of their own with their own journals and annual meetings. This is gradually changing, however. Researchers using agent-based modeling are no longer "agent-based modelers" but substantively oriented scholars who use the technique when deemed useful for the problem at hand. As a consequence, we now start to see innovative research that uses agent-based models in novel combinations with more traditional methods, as well as new ways of combining empirical or experimental data and agent-based simulations (e.g., see DiMaggio and Garip 2011; Fountain and Stovel 2014; Gonzalez-Bailon and Murphy 2013; Manzo 2013; Mäs and Flache 2013; Wunder, Suri, and Watts 2013).

The Special Issue

The trends described are represented in the contributions to this special issue. The end product is a set of essays that illustrates in various ways the flexibility and power of agent-based modeling.

Bruch and Atwell start off with noting that agent-based modeling so far has had little impact on mainstream quantitative research, and their article discusses how agent-based models can be more firmly integrated within the empirical tradition. To this aim, they discuss techniques to incorporate empirical data within agent-based models, strategies to validate the simulation outcomes, and methods to test the robustness of the simulation outcomes. They also discuss the importance of having access to high-quality and fine-grained data in order to develop empirically grounded agent-based models.

Snijders and Steglich seek to create a bridge between the world of agent-based models focusing on abstract mechanisms for the micro-macro transition, and statistical models aiming at inference and parameter estimation. They focus on a specific class of statistical models for network dynamics, stochastic actor-based models, and show that these models are a specific type of agent-based model. The agent-based model simulates actors' probabilistic choices of (outgoing) ties. These choices are modeled as dependent on mechanisms based on actors' attributes (like homophily) and positions in the network (like the tendency toward reciprocation). Differently from classical agent-based models, stochastic actors-based models for network dynamics contain estimation procedures that allow modelers to empirically assess the relative weight of each postulated mechanism. Snijders and Steglich analyze two networks, a friendship and an advice network, in order to illustrate their approach.

Liu and Bearman's article focuses on the strong and spatially clustered increase in the prevalence of autism diagnoses in California during the last two decades. Liu and Bearman's hypothesis is that the spread of autism in part is driven by social contagion. Parents who are exposed to children with autism are more likely to be aware of the symptoms and thus also more likely to recognize it in their own children. As a consequence, social interactions among parents at focal points like malls and schools are likely to be of importance for both the temporal increase and its spatial configuration. To test this hypothesis, Liu and Bearman build large-scale, empirically calibrated micro-simulation models in which the initial probability of being diagnosed with autism is based on sociodemographic factors only and is then modified as a function of several exposure phenomena relating to the possibility that parents talk. Simulation results show that the temporal and spatial trend is only captured when these sorts of exposure effects are present.

Macy and Tsvetkova's article is the most general in that it deals with a foundational theoretical problem: the consequences of ignoring stochastic components at the micro and network level. To address this issue, they review studies that have compared deterministic and stochastic versions of the same model and observed that the introduction of random

perturbations considerably alters the collective outcomes that are most likely to appear. Macy and Tsvetkova argue that agent-based modeling is ideally suited to study this topic because it allows for the manipulation of stochastic elements without a priori restrictions. Thus, in this article, agent-based modeling is presented as a tool to perform theoretical explorations, which eventually can motivate independent empirical studies, intended to test simulated results.

Manzo and Baldassarri's article closes the issue. It focuses on status hierarchies and employs an agent-based model to improve on the realism of previous mathematical models of status hierarchies. The article shows that the use of an agent-based model makes it possible to relax unrealistic behavioral assumptions concerning deference attributions as well as the interdependence structures within which these attributions take place. The model postulates imitation and reciprocation of others' deference gestures as two basic heuristics that generate counterbalancing dynamics of status inequality at the aggregate level. Compared to previous models, Manzo and Baldassarri's study better shows under which conditions actors' distaste for being snubbed can act as a micro-level force limiting the growth in status inequality. The article also underscores the importance of analyzing an agent-based model by performing proper sensitivity and robustness analyses.

As Coleman (1986:1316), and more succinctly Schelling (1971:147) before him, noted, over the years, we have developed a range of methodological tools for describing how contextual and individual-level properties affect actor-level outcomes. What we largely are lacking, however, are tools for addressing the micro-to-macro link, that is, tools for assessing the macro outcomes individuals are likely to bring about when they act and interact over extended periods of time. Agent-based modeling is destined to become a crucial tool for addressing such questions. In order for the technique to fill this function, however, the simulation models must be firmly anchored in empirical evidence and properly studied by means of sensitivity and robustness techniques. So far most agent-based models have been highly stylized, rather far removed from empirical reality, and their parameter spaces only partially searched. As contributions to this special issue show, the field is changing and through this agent-based modeling is gradually becoming an integral part of the analytical toolbox of the discipline.

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