

Chapter 4

Exploring Emergence within Social Systems with Agent Based Models

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ABSTRACT

In this chapter, the authors examine manifestations of emergence or apparent emergence in agent based social modeling and simulation, and discuss the inherent challenges in building real world models and in defining, recognizing and validating emergence within these systems. The discussion is grounded in examples of research on emergence by others, with extensions from within our research group. The works cited and built upon are explicitly chosen as representative samples of agent-based models that involve social systems, where observation of emergent behavior is a sought-after outcome. The concept of the distinctiveness of social from abiotic emergence in terms of the use of global parameters by agents is introduced.

INTRODUCTION

This chapter explores agent based modeling (ABM) of social systems that involve or demonstrate aspects of emergence. Although many real world social systems display emergence, the modeling of an agent based social system that may demonstrate emergence is fraught with difficul-

ties, as emergence is inherently ethereal and/or ephemeral - that is, difficult to capture objectively. If one has explicitly coded for emergent behavior, then it is really *not* emergent as it is an expected or anticipated result. In this chapter, several instances of real and modeled emergence are illustrated and discussed, with a focus on the difficulties in identifying and defining true emergence that arises

DOI: 10.4018/978-1-4666-5954-4.ch004

unpredictably and not from modelers' decisions. In this work, emergences are conceptualized as agent- and/or group-level phenomena that are not specifically encoded by the modeler. While emergence is often thought of as a behavioral whole that is greater than the sum of its parts, in our conceptualization, emergence can manifest at large or small scales, may be a complex or a simple phenomenon, and may be counterintuitive or not. Emergence begins when the outcomes of a simulation cannot be tied back directly to the encoded agent behavioral rules and profiles.

Agent based modeling is 'bottom-up' systems modeling from the perspective of constituent parts. Systems are modeled as a collection of agents (in social systems, most often people) imbued with properties: characteristics, behaviors (actions), and interactions that attempt to capture actual properties of individuals. In the most general context, agents are both adaptive and autonomous entities who are able to assess their situation, make decisions, compete or cooperate with one another on the basis of a set of rules, and adapt future behaviors on the basis of past interactions. Agent properties may be conceived by the modeler or may be derived from actual data that reasonably describe agents' behaviors – i.e. their movements and their interactions with other agents. The emergence of a data culture, also called 'big data' and associated 'big data analytics', offers new opportunities to use real world data, even in real time, as inputs into ABMs. The modeler's task is to determine which data sources best govern agent profiles in a given ABM simulation. There are alternative ABM approaches that attempt to introduce even greater levels of agency, including other-regarding behaviors and social dilemmas (Goldstone & Janssen, 2005; Helbing, Yu, & Rauhut, 2011). The ABMs considered here are considerably simpler, but their interactivity in terms of agent contact and mobility is often more detailed.

The foundational premise and the conceptual depth of ABM is that simple rules of individual behavior will aggregate to illuminate complex

and/or emergent group-level phenomena *that are not specifically encoded by the modeler*, and this is the key characteristic of emergence within an ABM. Emergent behavior may be counterintuitive, and may be a simple or complex behavioral whole that is greater than the sum of its parts (Swan, Gordon, & Seckbach, 2012). However, we do not regard "surprise" as an essential component of emergence (Ronald, Sipper, & Capcarrère, 1999; Gordon, 2000; Ronald & Sipper, 2001), if only because experience with emergent systems reduces one's sense of surprise.

There are a number of modeling efforts which imply or reference emergence within social systems. Often, the evidence for emergence is an observation that is unexpected, anecdotal, or circumstantial. As defined in (Wikipedia, 2013c): "In philosophy, systems theory, science, and art, emergence is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions." While asserting that emergent behavior does not necessarily need to be complex, we propose that when it *is* complex, the complex behavior may also arise from relatively complex interactions, as would more likely be the case with biological systems. In either case, the modeling community likely displays a bias, tending to overload the term 'emergence' and/or to identify outcomes as emergent that are not truly emergent. Although not a bibliographic survey, a Google search of the phrase "modeling emergence" reports just over 5 million results. A Web of Knowledge search "Title=(model* emergen*) NOT Title=(emergency)" yielded nearly 1300 publications. We have also been guilty of this bias, and in this chapter we attempt to objectively add to the evolving modeling framework of emergent phenomena. More specifically, there is no doubt that there are considerable emergent phenomena; it is the modeling of such which is problematic or at least embryonic. Indeed, the phrase 'modeling emergence' is an oxymoron in that we are adhering to the premise that emergence cannot be explicitly modeled. The ability of system-level outcomes

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