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Future scientific and technological developments in many fields will necessarily depend upon coming to grips with complex systems. Such systems are complex in both their composition – typically many different kinds of components interacting simultaneously and nonlinearly with each other and their environments on multiple levels – and in the rich diversity of behavior of which they are capable.

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UCS will publish monographs, lecture notes and selected edited contributions aimed at communicating new findings to a large multidisciplinary audience.
Sociology and Complexity Science
A New Field of Inquiry
From Castellani: To my wife, Maggie, and my daughter, Ruby

From Hafferty: To my sons, Philip and David
Preface

By now, most academics have heard something about the new science of complexity. In a manner reminiscent of Einstein and the last hundred years of physics, complexity science has captured the public imagination. One can go to Amazon.com® and purchase books on complexification (Casti 1994), emergence (Holland 1998), small worlds (Barabási 2003), the web of life (Capra 1996), fuzzy thinking (Kosko 1993), global complexity (Urry 2003) and the business of long-tails (Anderson 2006). Even television has incorporated the topics of complexity science. Crime shows such as 24® or CSI® typically feature investigators using the latest advances in computational modeling to “simulate scenarios” or “data mine” all possible suspects—all of which is done before the crime takes place. The World Wide Web is another example. A simple search on Google.Com® using the phrase “complexity science” gets close to a million hits! Complexity science is ubiquitous. What most scholars do not realize, however, is the remarkable role sociologists are playing in this new science. Consider the following examples.

0.1 Sociologists in Complexity Science

The first example comes from the new science of networks (Barabási 2003). By now, most readers are familiar with the phenomena known as six-degrees of separation—the idea that, because most large networks are comprised of a significant number of non-random weak-ties, the nodes (e.g., people, companies, etc.) in these networks are generally separated by six or fewer links (e.g., Buchanan 2002, Watts 2004). Readers also may know, from the popular science literature, that the new science of networks is being used to explore a long list of cutting-edge topics, from the global spread of disease to terrorist cells to the human genome project to consumer purchasing behaviors (Buchanan 2002; Newman, Barabási, and Watts 2006). What is noteworthy, however, is that the leading researcher in this field, Duncan Watts, is a professor of sociology at Columbia University (USA). Equally noteworthy, the new science of networks is based, in large measure, on the past twenty years of research in the sociological field of social network analysis (Freeman 2004).
The second example comes from computer simulation, also known as computational modeling (Casti 1999). Over the last decade, computational modeling (the backbone of complexity science method) has made major inroads into science and the market place. From Mathematica® and MATLAB® to RePast® and SWARM®, various software platforms are now used on a regular basis to simulate living cells, state-level policies, disaster scenarios, chemical reactions, water treatment facilities, the collision of black holes, traffic patterns and the dynamics of the stock market (Gilbert and Troitzsch 2005). The list of pioneering scholars in this field includes John Holland, Robert Axelrod, Stephan Wolfram and Joshua Epstein, to name a few. It also includes, right up there at the top, the British sociologist, Nigel Gilbert, editor of the international periodical, Journal of Artificial Societies and Social Simulation (e.g., Gilbert and Abbott 2005; Gilbert and Troitzsch 2005).

The third example comes from the classical era of sociology. Many of the scholars regularly associated with the cannon of sociology—Emile Durkheim, Herbert Spencer and Vilfredo Pareto—were also instrumental in the creation and development of systems thinking. In fact, a variety of cutting-edge ideas in complexity science come from these canonical scholars. The best example is Pareto’s 80/20 rule, which is crucial to understanding the structure of large, complex networks (Buchanan 2002). Another is Durkheim’s concepts of system differentiation, which ties directly to the concepts of system bifurcation and strange attractors (Luhmann 1995).

The fourth example comes from the complexity turn in sociology. As Urry explains, in the last decade, a number of highly influential sociologists have begun to integrate the tools of complexity science into their work. These sociologists include Immanuel Wallerstein (2005), Andrew Abbott (2001), Niklas Luhmann (1995) and Manuel Castells (2000a). Wallerstein, for example, has integrated the work of Prigogine into his world systems theory (2005); Abbott has applied fractals, self-similarity and chaos to the structure and dynamics of the social sciences (2001); Luhmann has constructed a theory of modern society based on the concept of social autoopoiesis (1995); and Castells has developed a theory of globalization using the concept of network. These sociologists are joined by a growing network of sociologists and likeminded scholars, including Duncan Watts, Mark Newman, Albert-László Barabási, Kenneth Bailey, Walter Buckley, Felix Geyer, Phillip Bonacich, David Byrne, Jürgen Klüver, and Christopher Goldspink. What is so exciting about this growing network of scholars is that they are involved in the creation of a new, international, post-disciplinary, highly mobile, intellectual community devoted to the study of sociology and complexity science, or, what we call, SACS for short.
In terms of main street sociology, the value of SACS, among other things, is the incredible new toolkit of theories, concepts, methods and techniques it offers sociologists. Here are some examples:

- In terms of method, SACS offers the following:
  - Agent-based modeling; otherwise known as generative computer simulation.
  - Cellular automata.
  - Neural networking; otherwise known as distributed artificial intelligence, specifically the self-organizing map.
  - Genetic algorithms.
  - Data mining.
  - The new science of networks.
  - Dynamical systems theory; otherwise known as chaos theory.
  - Fractal geometry.
  - New ways to use statistics, such as the Pareto distribution, power laws, regression, and cluster analysis.
  - Nonlinear, dynamic, mathematical modeling.
  - Discrete mathematics.

The strength of these methodological tools—which we discuss more extensively in Chaps. 2, 3 and 5—is their ability to handle the growing complexity of sociological work, such as the massive, electronic databases now regularly studied by sociologists. They also are very helpful in generating theory, testing policy, and conducting social experiments.

- In terms of theory, SACS offers the following:
  - Luhmann’s new social systems theory.
  - Buckley’s theory of society as a complex adaptive system.
  - Byrne’s critical realism.
  - Geyer’s radical constructionism.
  - Watt’s concept of the small-world.
  - Barabási’s concept of scale-free networks.
  - Bak’s concept of self-organizing criticality.
  - Holland’s theory of emergence.
  - Newman’s complex networks.
  - And, the concept of the complex social system.

The last concept listed is, theoretically speaking, the most important tool SACS offers sociologists and likeminded thinkers. By drawing upon the theoretical advancements of complexity science, SACS offers a fresh and innovative approach to sociological systems thinking and its leading concept, the social system. In so doing, SACS not only reinvents the systems tradition in sociology, it provides an empirical, methodological and
theoretical yield that is rather astonishing. To learn more about this astonishing yield, we need to turn to the purpose of our book.

0.2 Purpose of Book

Given all that SACS has to offer, we wrote this book to introduce sociologists to, and provide a thoroughgoing review of, this new intellectual community.

Our book is the first complete overview of the SACS community, including its history, its connection to complexity science, and its five major areas of research: computational sociology, the British-based School of Complexity (BBC), complex social network analysis (CSNA), sociocytbernetics and the Luhmann School of Complexity (LSC). As shown in Map 1 (See Chap. 10 for details about reading this map), these five areas represent the latest advance in sociological systems thinking, offering sociologists a powerful conceptual and methodological toolbox for addressing the growing complexity of their work.

To date, several excellent histories have been written on the larger field of complexity science (e.g., Capra 1996; Cilliers 1998; Waldrop 1992). There is also a growing list of articles and a few books that address the major areas of research in the SACS (e.g., Freeman 2004; Geyer and Zouwen 2001; Gilbert and Troitzsch 2005; Macy and Willer 2002; Rasch and Wolfe 2000). There is even a developing literature, primarily emerging out of the British-based School of Complexity (BBC), that critically examines the theoretical and methodological import of complexity science for sociological inquiry (e.g., Byrne 1998; 2001, 2002; Geyer and Zouwen 2001; Richardson and Cilliers, 2001).

Furthermore, two excellent books have been written about complexity science for a sociological audience. There is Eve, Horsfall and Lee’s edited *Chaos, Complexity and Sociology: Myths, Models, and Theories* (1997) and Byrne’s *Complexity Theory and the Social Sciences* (1998). Along with being over a decade old, these books focus on the history of complexity science and its implications for sociology. The current book, in contrast, focuses on the last decade of research integrating complexity science with sociology—something that the above two books, in many ways, helped to initiate and develop. Byrne’s work, in particular, played a significant role in the development of the BBC.
As such, to date, while a significant amount of work has been done to develop, assess and review the new science of complexity and its implications for sociology, the community of SACS as a whole has yet to be empirically identified, defined or reviewed, let alone treated as a formal scientific system for study. Providing such an overview, however, is not the only reason we wrote this book.

0.3 SACS Toolkit

In addition to reviewing the community of SACS, our book has a second purpose. We want to introduce readers to our new toolkit for modeling social systems, which we call, appropriately enough, the SACS Toolkit. Toolkits are designed to accomplish a task. They come with blueprints, guidelines, supplies, tools, techniques, information overviews, maps, figures, case studies, and so forth. The SACS Toolkit is designed for modeling social systems. The SACS Toolkit is comprised of the following:

- It has a theoretical framework, called social complexity theory, which provides researchers a set of working concepts and a practical framework for organizing their empirical inquiries into the structure and dynamics of most social systems. Related, the SACS Toolkit can be used with (rather than against) existing concepts and theories in sociology.

- It has a procedural algorithm, which we call assemblage, that provides researchers a step-by-step method for building from the “ground-up” a working model of a social system.

- It has a recommended list of methods and techniques best suited for studying social systems. While the SACS Toolkit can be used with just about any sociological method or technique, researchers will find the following toolset somewhat indispensable: cluster analysis, neural networking (specifically, the self-organizing map), social network analysis, grounded theory method, Foucault’s genealogical method, fractal geometry, chaos theory, computational modeling, and data mining.

- An accompanying website comprised of additional reviews, case studies, graphics and so forth to help researchers learn about complexity science, SACS and the Toolkit. See www.personal.kent.edu/~bcastel3.
Chapters 2 and 3 provide a detailed overview of the SACS Toolkit. They also explain why we applied this toolkit to the study of SACS. Our study of SACS is a combination of historical and quantitative data. It also includes our usage of a variety of methodological techniques, such as historiography, grounded theory, statistics, social network analysis and the new science of networks. To handle the complexity of our data and related techniques, we turned to the SACS Toolkit. The strength of the SACS Toolkit is its ability to handle such a wide variety of data and techniques, all in the effort to model a complex social system.

Our application of the SACS Toolkit to the study of SACS resulted in the third reason we wrote this book.

0.4 Applying the Toolkit to SACS

The third purpose of our book is to demonstrate the utility of complexity science for sociological inquiry by applying the SACS Toolkit to our review of the SACS community. As the old adage goes, there is no learning like doing. The structure and dynamics of the SACS community are (no pun intended) rather complex. We therefore decided that the best way to handle this complexity was to employ the SACS Toolkit. Our book is therefore as much a handbook in SACS method as it is an introduction to SACS. In addition to Chaps. 2 and 3, throughout the book we provide the reader a number of methodological pauses, which address various issues related to the particular analysis in which we are engaging. To follow these pauses, the index has two major headings: SACS Toolkit and Methodological Issues in Book.

0.5 Outline of Book

Our book follows the traditional academic format: introduction (Chap. 1), method (Chaps. 2 and 3), summary of results (Chap. 4), detailed overview of results (Chaps. 5 through 8), and conclusion (Chap. 9).

Chapter 1 provides an overview of the systems tradition in sociology, focusing on its three major eras: the classical era of Marx, Spencer, Pareto and Durkheim; the functional era of Parsons, Merton and the new fields of cybernetics and systems science; and the complexity turn era, which includes the new scholars of SACS.

Chapters 2 and 3 introduce readers to the SACS Toolkit, including why we chose to use it to study the SACS community.
Chapter 4 summarizes the results our study. In fact, upon completion of this chapter, the reader has a basic working knowledge of SACS.

The next four chapters explore the SACS community in further detail. Chapter 5 discusses the major environmental forces impacting SACS, including the growing complexity of sociological work and the emergence of complexity science. Chapter 5 (along with Map 1) also provides a formal (albeit brief) review of the new science of complexity, including its major traditions, key areas of study and methods, and leading figures. Chapter 5 therefore constitutes the fourth reason we wrote this book. It helps readers new to complexity science gain a basic sense of the field, along with directions for future research.

Chapter 6 provides a detailed overview of the five areas of research in SACS such that a given reader could begin to pursue research in any one of them.

Chapter 7 goes back to the late 1990s to see if there is some formal tipping point after which SACS emerges as a legitimate area of inquiry. From there, the last decade of development in SACS is explored.

Chapter 8 focuses on the structure and dynamics of SACS today, including its major hubs, authorities, gatekeepers and household names. This chapter also explores the fractal dynamics of SACS and its major intellectual trajectories.

Chapter 9 is our conclusions chapter. In addition to summarizing, in non-technical terms, the findings of our study, this last chapter examines the impact the SACS community is having on sociology today.

Chapter 10: Mapping Complexity. This final chapter constitutes the fifth reason we wrote our book: to provide readers a visual tour of complexity science and the new community of SACS. The SACS Toolkit is a highly visual method for modeling social systems. As such, our book relies upon, rather extensively, a series of images—maps, figures and graphs. Given our repeated usage of these images, we created Chap. 10.

Chapter 10 provides the reader a full-scale version of each image in the book, along with a basic introduction on how to read it, as well as directions about where in the book the image is first used and explained. This way, as the reader moves through the chapters, the images we repeatedly use, can be easily found.

Nevertheless, we do still provide a thumbprint of our images in the text. During the course of reading the book, the first time an image is used, it will be included in the text.

As a final note, all of the images in Chap. 10 are available, in color, at our website, for easy download. Maps 1 and 2 are also available electronically, with links to the internet so that teachers and readers can use the web to explore further the major scholars, topics, or fields of study in SACS and complexity science (See www.personal.kent.edu/~bcastel3/).
0.6 Ways to Read Book

We used the traditional format so that readers with different purposes and backgrounds could make effective use of our book. This book can be read four different ways:

*The Quick Read:* For readers looking to gain a quick overview of the book, we recommend reading the conclusion (Chap. 9) first and then Chaps. 4 and 1, which provide a more detailed review of the SACS community and its connection to the history and current challenges of organized sociology and the sociological systems tradition.

*The How-To Read:* For those primarily interested in an in-depth understanding of the SACS Toolkit we recommend reading our method chapters first (Chaps. 2 and 3), followed by Chap. 4, which summarizes how we employed the SACS Toolkit to study the SACS community. From here, the reader can explore Chaps. 6 through 8 to see detailed examples of how we used the SACS Toolkit, along with Chap. 10, our visual tour.

*The Sociological Read:* For those interested in the sociological side of complexity science, we recommend reading Chaps. 1 through 4, followed by Chap. 9. This approach provides a good review of the systems tradition in sociology and the community of SACS, as well as our new toolkit for modeling social systems as applied to SACS.

*The Full-Read:* For those interested in a full review of the SACS community, complexity science and the SACS Toolkit, we recommend the following reading. Read the Chaps. 1, 2 and 3, then the conclusion, following by Chap. 4. From here, proceed to read Chaps. 5 through 8.

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