

Preface

Social systems are the most complex systems we know. They are even more complex than physical or biological systems. Their complexity results not only from multiple interactions of individuals, but also from the complexity of cognitive systems. I, therefore, agree with August Comte that sociology is the queen of science, the ultimate scientific challenge. I furthermore believe that this field will soon be one of the most dynamic scientific areas, not only for its interesting fundamental questions, but also because of the many practical problems humanity is facing in the twenty-first century.

The crucial question is, how one can make substantial progress in a field as complicated and multi-faceted as the social sciences. There are certainly different possibilities, as Chap. 1 discusses. Nevertheless, it seems that many characteristic features of complex social systems can be understood from simple models of social interactions, and I am convinced that a number of challenging scientific puzzles can be solved, using concepts from complexity theory, including self-organization, coevolution, and emergence. Agent-based computational models and behavioral experiments can reveal the mechanisms underlying such phenomena, and the role that different factors play for them.

Complex systems often display a counter-intuitive behavior. For example, as will be shown in this book, the same kinds of social interactions can lead to opposite conclusions, when interactions occur with neighbors, friends, colleagues, or business partners rather than with average interaction partners (see Chaps. 7 and 8). Therefore, a simple nonlinear model may explain phenomena, which even complicated linear models may fail to reproduce. Nonlinear models are expected to shed new light on such social phenomena. They may even lead to a paradigm shift in the way we interpret society.

While part of this book is a compilation of recently published papers, some chapters present variants of previous work or new materials, for example, on the technique and future of agent-based computer simulation and on coordination games in networks (a subject that is interesting to understand the competitive spreading of innovations). The chapters do not need to be read in sequential order, but the organization of this book has a clear logic:

- Chapter 1 discusses the issue of how to describe social systems. It highlights different traditions in the social sciences and the respective advantages and disadvantages of these approaches, stressing their complementary character. The focus of this book, however, will be on simple models of social interactions, explaining various aspects of social self-organization.
- Chapter 2 discusses the method of agent-based computational modeling, how to do it right, and what are future perspectives of this approach. A particular focus is put on the question, how to avoid mistakes and how to derive meaningful results.
- Chapter 3 demonstrates the concept of self-organization for the example of pedestrian crowds. We analyze the spontaneous outbreak of social order under everyday conditions and its breakdown at extreme densities. The chapter illustrates how fundamental research can lead to useful models that enable an understanding of macroscopic outcomes of social interactions. It also summarizes related empirical and experimental work as well as practical applications.
- Chapter 4 provides a second example of agent-based modeling, namely a continuous opinion formation model. It shows why previous models did not solve the puzzle why one finds global diversity in spite of local convergence. Strikingly, it is the tendency of individualization which promotes pluralism through the self-organization of groups.
- Chapter 5 turns the attention from mobility in opinion space to mobility in geographical space. Assuming social interactions with neighboring locations, where the outcome of these interactions is quantified by “payoffs” as this is common in game theory, we find the self-organization of spatiotemporal patterns, when success-driven mobility to neighboring locations occurs. Even when starting with a uniform distribution in space, we observe interesting segregation phenomena and different kinds of agglomeration phenomena, depending on the respective payoff structure. These come about when success-driven mobility increases local differences and thereby destabilizes a homogeneous distribution in space.
- Chapter 6 focuses on the problem of cooperation in social dilemma situations, where it appears more advantageous to selfish individuals to exploit others than to cooperate with them. It is discussed in what ways social mechanisms can effectively change the payoff structure and, thereby, the rules and character of the “game” individuals are playing. It is shown that different mechanisms such as repeated interactions, reputation effects, or social networking can imply different routes to cooperation. The chapter also provides a classification of different kinds of transitions to cooperation and shows that adaptive group pressure can promote cooperation in the prisoner’s dilemma game even without changing the properties of its equilibrium solutions.
- Chapter 7 combines the elements of Chaps. 5 and 6, i.e., it studies individuals facing social dilemma situations in space, considering success-driven mobility. While one would think that social cooperation and mobility are unrelated, it surprisingly turns out that mobility is an important factor supporting human sociality, and that it promotes a co-evolution of social behavior and social environment. This model may shed new light on a number of fundamental

questions such the following: Why do similarly behaving people tend to agglomerate, e.g., form groups or cities (an observation which is often referred to as “homophily”)? How are “social milieus” come about and why do they influence the behavior of people? Why do they persist so long? And why are selfish people more cooperative in reality than expected? What is the role of fluctuations and exploratory behavior for the emergence of cooperation?¹

- Chapter 8 looks at a further mechanism that has been suggested to promote cooperation, namely “costly punishment.” It is shown that the consideration of neighborhood interactions can resolve the so-called second-order free-rider puzzle that wonders why people would invest into the punishment of uncooperative behavior, if they can profit from other people’s sanctioning efforts. The chapter also suggests that the spreading of morals and double moral behavior can be understood with concept of evolutionary game theory. The related system dynamics shows quite a number of surprising features.²
- Chapter 9 studies effects of network interactions and transaction costs in coordination games. Developing a percolation theoretical description for the related system dynamics allows one to analytically understand the competitive spreading of innovations, opinions, or products from a new scientific angle. Furthermore, we point out that system-wide coordination is a double edge sword.
- Chapter 10 focuses on the implications of heterogeneity in the inclinations of individuals. For this, we study the interaction of several populations with incompatible preferences. This implies a large variety of different system behaviors, such as the outbreak or breakdown of cooperation, the formation of commonly shared norms, the evolution of subcultures, or the occurrence of conflicts which may cause “revolutions”. Despite its richness, the model is simple enough to facilitate an analytical understanding of the possible system behaviors.³ It would be highly desirable to test the predictions of the model by behavioral experiments.⁴

¹The following related paper may interest the reader as well: D. Helbing, W. Yu, and H. Rauhut (2011) Self-organization and emergence in social systems: Modeling the coevolution of social environments and cooperative behavior. *Journal of Mathematical Sociology* **35**,177–208.

²The reader may be interested in the related follow up work as well: D. Helbing, A. Szolnoki, M. Perc, and G. Szabó (2010) Punish, but not too hard: how costly punishment spreads in the spatial public goods game. *New Journal of Physics* **12**, 083005; D. Helbing, A. Szolnoki, M. Perc, and G. Szabó (2010) Defector-accelerated cooperativeness and punishment in public goods games with mutations. *Physical Review E* **81**(5), 057104.

³D. Helbing and A. Johansson (2010) Evolutionary dynamics of populations with conflicting interactions: Classification and analytical treatment considering asymmetry and power. *Physical Review E* **81**, 016112.

⁴Recently, the emergence of social norms has been further investigated, and the related study may be interesting for the reader as well: D. Helbing, W. Yu, K.-D. Opp, and H. Rauhut (2011) The emergence of homogeneous norms in heterogeneous populations. Santa Fe Working Paper 11-01-001, see <http://www.santafe.edu/media/workingpapers/11-01-001.pdf>.

- Chapter 11, therefore, discusses ways in which social experiments should and could be done in the future, using the help of computers.
- Chapter 12 focuses on the example of a route choice experiment, in which a sudden transition to turn-taking behavior is found after many interactions, and it is shown that this transition can be understood with a reinforcement learning model.
- Chapter 13 analyzes the same route choice game for the case of several participating players. It is found that, rather than applying probabilistic strategies, experimental participants develop specialized and almost deterministic strategies over time. There is strong evidence of social differentiation. Furthermore, we show how an individualized information system can be developed that supports social adaptation and avoids a self-defeating prophecy effect.
- Chapter 14 then looks at social systems from a complex systems perspective. In this way, it analyzes systemic socioeconomic risks and the underlying mechanisms. In particular, it discusses factors that have probably contributed to the current financial crisis.
- Chapter 15 addresses the question, how to manage the complexity of social systems, considering that classical control concepts are known to fail.
- Chapter 16 finally tries to identify fundamental and real-world challenges in economics, thereby suggesting questions and approaches for future research.⁵

Although these contributions have originally not been written as chapters of a book, they are largely complementary to each other and follow a common approach that tries to understand macroscopic behavioral patterns from interactions between many individuals. All models pursue an agent-based approach, and for many chapters, supplementary video animations are available at <http://www.soms.ethz.ch>. Most of the models furthermore follow an evolutionary game theory perspective and are mutually consistent. In fact, the wide spectrum of phenomena that can be described by evolutionary game theoretical models, ranging from coordination and cooperation over social norms and conflict up to revolutions, suggests that this theoretical framework may be flexible enough to form the basis of a future integrated theory of socioeconomic interactions. With this vision in mind, I hope the reader will find this book inspiring.

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⁵Beyond proposing research questions, the Visioneer White papers “From Social Data Mining to Forecasting Socio-Economic Crises,” “From Social Simulation to Integrative System Design,” and “How to Create an Innovation Accelerator” make suggestions how to foster scientific progress in the socioeconomic sciences, see <http://www.visioneer.ethz.ch>. These are published in *EPJ Special Topics* **195**, 1–186 (2011).

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