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## Preface to the Second Edition

Numerous developments have taken place in Computational Social Science (CSS) in the short time since the first edition of this textbook appeared in 2014. They include new university and college programs and curricula, in addition to many exciting research directions offered by big data analytics, advances in social complexity, and innovations in computational modeling tools. Reviews and comments by readers of the first edition have been encouraging, so this second edition provides a number of useful enhancements and corrections to the first.

This edition contains sets of questions, problems, and exercises in each chapter. Their purpose is multifaceted: to test what has been learned; to develop deeper understanding through problem-solving; to exercise critical thinking in support of scientific learning; to test or write code to implement ideas learned or in need of further exploration; or to apply principles in diverse social domains, in different situational contexts, or in particular disciplines.

If you are inclined, send me your responses to exercises and problems. I am happy to acknowledge and select the best for mention in the next edition.

Questions and problems are queries with exact answers, whereas exercises are more open-ended scientific inquiries for exploring and discussing various facets of the material covered in each chapter. Both are intended to solidify and extend knowledge, and to test understanding concerning some of the most important ideas presented in the main content of each chapter. Another function of problems and exercises is to delve deeper into the foundations of CSS, through special topics that could seem to branch off from or interrupt the main flow of the chapter. The answers to most questions and problems are provided in a separate section at the end of the book.

In each chapter, problems and exercises are presented in approximately the same order as the subject matter in the chapter, with very few exceptions. These include cases where knowledge is tested cumulatively, based on a combination of material drawn from two or more sections.

There are many more questions, problems, and exercises than can be assigned in a single semester-long course, or perhaps even in a year-long course. The purpose for this is to allow each instructor some flexibility in selecting the items, and students the opportunity to investigate additional ideas. A number of the exercises also provide ideas for more advanced exams, research papers, or theses. Quite a

number of them can also be used for group assignments to practice collaboration among students and assistance in coordination or mentoring by the instructor. Many exercises also lend themselves to creating interesting posters, which can then adorn a CSS learning environment by integrating research and teaching.

The first draft of these problems and exercises was written during the 2015 Lipari Summer School in Computational Social Science, in the last week of July, and completed during a sabbatical leave in the spring and summer of 2016. I am grateful to colleagues, students, and several readers of the first edition, especially Rob Axtell, Andrew Crooks, Harsh Gupta, Chenyi Hu, František Kalvas, Bill Kennedy, and Dan Rogers for their comments and suggestions.

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## Preface to the First Edition

This textbook provides an introduction to Computational Social Science (CSS), an emerging field at the intersection of traditional social science disciplines, computer science, environmental science, and engineering sciences. CSS is inspired by 20th century pioneers such as Herbert A. Simon, who saw essentially a new way of doing social science enabled by computational science and technology. Scientist and visionary Peter J. Denning once said that “the science of the 21st century will be computational,” so this book is proof of that idea in social science domains.

As a textbook, this is intended as a systematic introductory survey to familiarize the reader with the overall landscape of CSS, including its main concepts, principles, applications, and areas of research. CSS investigates social complexity at all levels of analysis—cognitive, individual, group, societal, and global—through the medium of computation, as we will examine in greater detail in Chap. 1. This book is not intended as an advanced, specialized monograph to develop deep expertise.

The need for this book arose from the lack of unified treatment of the various areas of theory and research in CSS. As a consequence, those of us involved in teaching this new subject have been constrained to use a disparate library of readings without a single, unified framework. This book aims to be both comprehensive (include all major areas of CSS) and scientifically integrated by an overarching framework inspired by the paradigm of complex adaptive systems, as developed by Simon and his contemporaries in what may now be called the Founders’s Generation (described in Chap. 1).

This project originated from the course on Introduction to CSS that has been taught at George Mason University for the past ten years. It is the core course in CSS, required of all students entering our graduate program in the Department of Computational Social Science. Initially, I taught the course, then other colleagues joined. Approximately ten students have taken the course each year, mostly from the CSS program, but also from other departments across the social sciences, computer science, environmental science, and engineering sciences.

This book is intended for two types of readers, which reflect the diverse student communities who have taken this course over the years. Some students will use it as a one-time, comprehensive exposure to the field of CSS. Other students might use it as foundation for further study through more advanced, specialized work in one or more of the areas surveyed here. This book should also be helpful to students

preparing for their doctoral examination in CSS, as a review of basic ideas and a way to integrate knowledge.

The background assumed of the reader consists of some familiarity with one or more of the social sciences at a level equivalent to undergraduate study, basic knowledge of programming in any language (nowadays Python has become quite popular and is an excellent language for learning about computation), and some ability to follow mathematical modeling using logic, elementary probability, and basic calculus. Higher mathematics are unnecessary for introducing CSS.

The plan of the book is as follows: Chapter 1 provides an introduction, focusing primarily on the meaning of complex adaptive systems in social domains, including the significance of Herbert A. Simon's seminal theory and the paradigm it provides for CSS. This initial chapter also explains the main areas of CSS covered in this textbook, which are taken up in Chaps. 3 to 10. Chapter 2 provides a review of basic ideas in computing from a social science perspective, or computation as a paradigm for developing social science; it is *not* intended as a substitute for formal instruction on computation and programming for social scientists.

The following chapters cover major areas of CSS, corresponding to four distinct methodological approaches, as summarized in Sect. 1.6:

- Automated information extraction (Chap. 3)
- Social networks (Chap. 4)
- Social complexity:
  - Origins and measurement (Chap. 5)
  - Laws (Chap. 6)
  - Theories (Chap. 7)
- Social simulation:
  - Methodology (Chap. 8)
  - Variable-based models (Chap. 9)
  - Object-based (Chap. 10)

Each chapter contains a brief opening section introducing and motivating the chapter. This is followed by a section summarizing some of the history of CSS in the chapter's area, based on significant milestones. The purpose of these historical chronologies associated with each chapter's theme is to make the reader aware of significant scientific roots of the field of CSS, including its braided development with related disciplines; it does not provide a systematic history. Each chapter also includes a list of Recommended Readings, primarily intended as a guide for deepening understanding of each chapter, not as exhaustive bibliographies.

The style of the textbook attempts to strike a balance between an informal, reader-friendly, narrative tone, and a more formal tone that is necessary for highlighting rigorous concepts and results. Concept formation is a major emphasis, as is the statement of laws and principles from theory and research in quantitative social science, especially formal theory and empirically validated models. Along these lines, an effort is made, beginning in Chap. 2, to provide CSS with systematic,

scientific, graphic notation that has been so sadly lacking in traditional social science. This is done by adopting the Unified Modeling Language (UML) as a viable system for describing social complexity through graphic models that have powerful analytical meaning, as well as having direct correspondence with computation and code. Mathematical notation used in this book is standard and aims at maintaining consistency across chapters.

Finally, in terms of possible uses of this textbook, instructors may consider the following options. The ten chapters of this textbook are normally more than sufficient for a one-semester course, because some chapters will require more than one week to work through. Chapter 1 is best covered in a single session. Chapter 2 can easily be covered in two sessions, by dedicating the second session to UML. Chapters 4, 5, 6, 7, 9, and 10 can also each be covered in two sessions, by dividing the material into the main sections composing each chapter. Hence, another option is to use this textbook for a two-semester sequence, as is done in many other fields. This extended format would also permit more use of Recommended Readings, supplemented by additional bibliography, and spending more time analyzing examples to deepen understanding of concepts and principles. Readers are strongly encouraged to use the list of Recommended Readings to study the classic works, which are highlighted in the historical section at the beginning of each chapter.

This book has benefited from significant feedback from students, so I welcome future suggestions for corrections and improvements. I hope you, the reader, enjoy learning from this book at least as much as I have enjoyed writing it.

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