Texts in Computer Science

More information about this series at http://www.springer.com/series/3191

Claudio Cioffi-Revilla

Introduction to Computational Social Science

Principles and Applications

Second Edition

Springer

Claudio Cioffi-Revilla
George Mason University
Fairfax, VA
USA

ISSN 1868-0941 ISSN 1868-095X (electronic)
Texts in Computer Science
ISBN 978-3-319-50130-7 ISBN 978-3-319-50131-4 (eBook)
DOI 10.1007/978-3-319-50131-4

Library of Congress Control Number: 2016959534

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To my Lady Jean, L.G.C.H.S.,
on our XLIV *anniversary*

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.

Alexandria, VA, USA Claudio Cioffi-Revilla

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 programing 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.

Washington, DC Claudio Cioffi-Revilla
September 2013

Acknowledgements

During the past four decades I have benefited from scientific discussions with mentors, colleagues, and students who have influenced my research and teaching in Computational Social Science. Much of my original interest in the field came from discussions with Herbert ("Herb") A. Simon and members of the Triple-I Seminar on Complex Systems during the 1980s, including Elinor ("Lin") and Vince Ostrom and Harvey Starr from Indiana University, Dina A. Zinnes, Dick Merritt, Bob Muncaster, Jim Kuklinsky, and Mike Krassa from the Merriam Lab at the University of Illinois at Urbana-Champaign, and Bob Boynton from the University of Iowa. Discussions with Karl Deutsch, Ed Azar, Andy Scott, Harold Guetzkow, Bruce Russett, Hayward Alker, Raoul Narroll, Steve Wolfram, Larry Smarr, Benoit Mandeldrot, Ray Dacey, Martin Shubik, DwainMeford, Jim Rosenau, Pierre Allan, Giorgio Natalicchi, Sam Kotz, and Kurt Johnson from the earlier phase of my academic career are still memorable. Craig Murphy, Doug Nelson, Chuck Taber, Kelly Kadera, Terry Clark, and Paul Pudiate were among my earliest students. When I moved to the University of Colorado at Boulder I learned a great deal from John Rundle and colleagues at the Colorado Center for Chaos and Complexity (C4), especially V.J. Gupta and Liz Bradley.

This textbook grows out of the interdisciplinary Program in Computational Social Science at George Mason University, which I founded in 2002 through joint teamwork with numerous students, faculty, staff, and administrators from the Mason campus. At the risk of unintentionally omitting someone, I wish to thank the many who have helped me in myriad ways: Giorgio Ascoli, Rob Axtell, Peter Balint, Jacquie Barker, Ernie Barreto, Andrea Bartoli, Jeff Bassett, Sheryl Beach, Jim Beall, Pete Becker, Tony Bigbee, Christina Bishop, Kim and Sharon Bloomquist, Gary Bogle, Annetta Burger, Joey Carls, Randy Casstevens, Gabriel Catalin Balan, Debbie Boehm-Davis, Dan Carr, Jack Censer, Guido Cervone, Kai-Kong Chan, Barbara Cohen, Marc Coletti, Jim Conant, Tim Conlan, Chenna Cotla, Julie Christensen, Andrew Crooks, Paul Cummings, David Davis, Ken De Jong, Dan Druckman, Bob Dudley, Debbie V. Duong, Kim Eby, Allan Falconer, Win Farrell, Tatiana Filatova, Kim Ford, Jennifer Fortney, Aaron Frank, Brendon Fuhs, Jim Gentle, Aldona Gozikowski, Omar Guerrero, Cathy Gallagher, Jack Goldstone, Jon Gould, John Grefenstette, Beth Grohnke, Greg Guagnano, Renate Guilford, Tim Gulden, Ates Hailegiorgis, Joey Harrison, Melissa Hayes, Kingsley Haynes, Dee

Holisky, Bill Honeychurch, Dan Houser, Chris Hyungsik Shin, Bob Jonas, Chris Jones, Mark Katz, Bill Kennedy, Matt Koehler, Maction Komwa, Dorothy Kondal, Raj Kulkarni, Mike Laskofski, Maciej Latek, Randy Latimer, Kate Leonard, Alex Levis, Collette Lawson, Ann Ludwick, Cynthia Lum, José Manuel Magallanes, Julie Mahler, Michelle Marks, David Masad, Steve Mastrofski, Kevin McCabe, Mike McDonald, Hugh McFarlane, Danny Menascé, Alan Merten, Tish Moreno, Michael Naor, Johnny Nelson, Jim Olds, Leslie Painter, Liviu Panait, Dawn Parker, Ann Palkovich, Sean Paus, Nicolas Payette, Carolyn Payne, Kathleen Pérez-López, Bianica Pint, Margaret Polski, Paul Posner, Steve Prior, Denise Quinto, Pris Regan, Cindy Roberts, Suzanne Robbins, Pedro Romero, Tom Rosati, Dave Rossell, Mark Rouleau (our first Ph.D. in CSS), Cathy Rudder, John Sacco, Mickey Satija, Tim Sauer, Laurie Schintler, Paul Schopf, Linda Schwartztein, Jagadish Shukla, Steve Scott, James Snead, Paul So, Arun Sood, Peter Stearns, Roger Stough, Jennifer Sturgis, Keith Sullivan, Burak Tanyu, Rhonda Troutman, Max Tsvetovat, Karen Underwood, Dick Wagner, Nigel Waters, Shandra Watson, Jane Wendelin, Steve Wilcox, Debbie Williams, Sarah Wise, David Wong, Chun-Yi Yang, Carol Zeeve, and Matt Zingraff. Their cumulative efforts have enabled Mason's Graduate Program in Computational Social Science (over a dozen courses in CSS, a Certificate, a Masters in Interdisciplinary Studies/CSS, and a Ph.D. degree), the Department of Computational Social Science, and the generative unit for CSS at Mason: the Center for Social Complexity (CSC).

I have learned much from co-authoring publications, developing new courses and grant proposals, discussing theory and research, and organizing events with a large and stimulating community of colleagues from around the world, including: Tef Abate, Petra Ahrweiler, Guillermo Algaze, Luís Antunes, Aruna Apte, George Atkinson, Fulvio Attinà, Scott Atran, Brent Auble, Tom Baerwald, Bill Bainbridge, Steve Bankes, Mike Batty, Ana Lucia Bazzan, Russ Bernard, Brian Berry, Ravi Bahvnani, Dmitri Bondarenko, Nathan Bos, Peter Brecke, Stuart Bremer, Cathy Cameron, Kathleen Carley, Cristiano Castelfranchi, John Casti, Lars-Erik Cederman, Fahmida Chowdhury, Alfred Cioffi,Wayne Clough, Helder Coelho, Louise Comfort, Rosaria Conte, Chet Cooper, Linda Cordell, Angela Corolla, Nuno David, Guillaume Deffaunt, Hiroshi Deguchi, Christophe Deissenberg, Jerry Dobson, David Dornish, Jim Doran, Massimo Drei, Julie Dugdale, Bruce Edmonds, Giorgio Einaudi, Carol and Mel Ember, Josh Epstein, Mike Fischer, Bill Fitzhugh, Bruno Frohlich, José Manuel Galán, Jianbo Gao, Michele Gelfand, Nigel Gilbert, Gary Goertz, Rebecca Goolsby, Nick Gotts, Ariel Greenberg, Steve Guerin, Alessandro Guidi, George Gumerman, Myron Gutmann, David Hales, Dirk Helbig, Matt Hoffmann, Barry Hughes, Luís Izquierdo, Wander Jager, Eric Jones, Steve Kaisler, Anna Kerttula, Dennis King, Alan Kirman, Jürgen Klüver, Tim Kohler, Nick Kradin, Arie Kruglanski, Larry Kuznar, Steve Lansing, Efraim Laor, Randy Latimer, Steve Lekson, Nicola Lettieri, Mark Lichbach, David Lightfoot, Fred Liljeros, Corey Lofdahl, Urs Luterbacher, Thomas Lux, Patty Mabry, Charles Macal, Ed MacKerrow, Michael Macy, Greg Madey, Artemy Malkov, Joyce Marcus, Jack Meszaros, Manny Midlarsky, Jeff Millstein, Byong Won Min, Harold Morowitz, ScottMoss, Akira Namatame, Dana Nau, Martin Neumann, Michael North, Andrzej

Nowak, Sean O'Brien, Paul Ormerod, John Padgett, Mario Paolucci, Domenico Parisi, Peter Peregrine, Peter Perla, Gary Polhill, Brian Pollins, Denise Pumain, Rodolfo Ragionieri, Bill Rand, Dwight Read, Colin Renfrew, Bob Reynolds, Fred Roberts, J. Daniel Rogers, Juliette Rouchier, Dieter Ruloff, Jerry and Paula Sabloff, John Salerno, David Sallach, Lena Sanders, Todd Sandler, Antonio Sanfilippo, Dez Saunders-Newton, Vittorio Scarano, Steve Schlosser, Phil Schrodt, Lee Schwartz, Frank Schweitzer, Payson Sheets, Andrew Sherratt, Carl Simon, Ian Skoggard, Ricard Solé, Jim Spohrer, Detlef Sprinz, Flaminio Squazzoni, Gene Stanley, John Sterman, Christina Stoica, Rick Stoll, Gary Strong, Lee Schwartz, David Sylvan, Rein Taagepera, Keiki Takadama, John Tangney, Takao Terano, Pietro Terna, Rita Teutonico, Jim Thomas, Qing Tian, Klaus Troitzsch, Peter Turchin, Alex Vespignani, MitchWaldrop, DavidWarburton, PaulWerbos, JonWilkenfeld, and Peyton Young.

A graceful invitation from my colleague and friend, Shu-Heng Chen, to deliver the 2011 Herbert A. Simon Lecture Series in Computational Social Science at National Chengchi University in Taipei, Taiwan, provided a unique opportunity to organize my ideas for this textbook. A preview of this textbook was provided in March 2012 at the invitation of the Center for the Study of Complex Systems at the University of Michigan. I am grateful to Robert Axelrod, John Holland, Scott Page, Rick Riolo, and their students for sharing their insights and suggestions.

Some of the examples or modeling applications discussed in this book originated or came into focus through discussions with members of the government policy and analytical community. None of them bears any responsibility for my interpretations or inferences.

Students from the Fall 2012 session of CSS 600—Introduction to CSS—helped as I finalized the outline of this textbook. I am especially grateful to Gary Bogle, Tom Briggs, Annetta Burger, Paul Cummings, José Manuel Magallanes, and Dan Pryce. Several chapters of this textbook were also used while lecturing at the Lipari International Summer School in Computational Social Science, now in its 5th year. I am grateful to students and invited faculty, including David Beaver, Kathleen Carley, Alfredo Ferro, Giovanni Giuffrida, Carlo Pennisi, Alessandro Pluchino, Kalev Leetaru, Roy Lindelauf, Huan Liu, Roel Popping, Raghu Ramakrishnan, Marc Smith, Philip Schrodt, V.S. Subrahmanian, Alberto Trobia, and Calogero Zarba.

I am especially grateful for input on various chapters received from Dan Rogers, Linda Cordell, Sean Luke, Nazli Choucri, Bill Kennedy, Siggy Scott, and Joey Harrison. I also wish to thank Jean N. Cioffi, Dorothy Kondal, and Nancy Turgeon for careful editing and assistance with proofreading.

Support received from the US National Science Foundation and the Office of Naval Research, as well as from the Center for Social Complexity and the Provost's Office at George Mason University, especially intellectual support received from Provost Peter Stearns, is gratefully acknowledged.

I also wish to thank Wayne Wheeler and Simon Rees, my editors at Springer, for their encouragement and patience. They are among the most professional, persevering, and pleasant editors I have worked with.

Images used in this textbook were produced by me or obtained from NASA, PublicDomainPictures.net,Wikipedia, Malteser International, and faculty webpages without copyrights.

Contents

Acronyms

ABM	Agent-based model
ACE	Agent-based computational economics
ACM	Association for Computing Machinery
AI	Artificial intelligence
AND	Boolean conjunctive operator
BDI	Beliefs, desires, intentions
CA	Cellular automaton or automata
CAMEO	Conflict and Mediation Event Observations
CAS	Complex adaptive system
CASOS	Center for Computational Analysis of Social and Organizational Systems, Carnegie Mellon University
CCDF	Complementary cumulative density function (also c.c.d.f.)
CDF	Cumulative density function (also c.d.f.)
CIDCM	Center for International Development and Conflict Management, University of Maryland
CIKM	Conference on Information and Knowledge Management of the ACM
CMU	Carnegie Mellon University
COA	Course of action
COPDAB	Conflict and Peace Data Bank
CPU	Central processing unit
CSC	Center for Social Complexity, George Mason University
CSS	Computational Social Science
CSSN	Computer-supported social networks
CSSSA	Computational Social Science Society of the Americas
DARPA	Defense Advanced Research Projects Agency
DDR3 SDRAM	Double-data-rate three synchronous dynamic random access memory
DYNAMO	DYNAmic MOdels
EC	Evolutionary computation
ECPR	European Consortium for Political Research
ECML-PKDD	European Conference on Machine Learning and Principles and Practices of Knowledge Discovery in Databases

EOS	Evolution of Organized Society project, University of Essex
EPA	Evaluation, potency, activity. Dimensions of Osgood's semantic space
ERG	Exponential random graph
EU	European Union
FEARLUS	Framework for the Evaluation and Assessment of Regional Land Use Scenarios
FIFO	First-in-first-out
FILO	First-in-last-out
FORTRAN	FORmula TRANslation
GB	Gigabyte
GCM	General Circulation Model
GDELT	Global Data on Events, Location, and Tone
GeoMASON	Geospatial MASON
GHz	Gigahertz
GIS	Geographic Information System
GPU	Graphic processing unit
GUI	Graphic user interface
HMM	Hidden Markov model
HPC	High-performance computing
HRAF	Human Relations Area Files, Yale University
I/O	Input–output
ICPSR	Interuniversity Consortium for Political and Social Research
ICR	Institute for Communications Research, University of Illinois at Urbana-Champaign
IEEE	Institute of Electrical and Electronic Engineers
INSNA	International Network for Social Network Analysis
IPCC	Intergovernmental Panel on Climate Change
ISIMADE	International Symposium on Intelligent Multimedia and Distance Education
ISS	International Space Station
JVM	Java virtual machine
KWIC	Keywords in context
KWOC	Keywords out of context
kya	Thousands of years ago
LEO	Low Earth orbit
LIFO	Last-in-first-out
LILO	Last-in-last-out
LISP	LISt Processing
LOC	Lines of code
LRD	Long-range dependence
LUCC	Land-Use and Cover Change
M2M	Model-to-model
MAS	Multi-agent system or systems
MASON	Multi-Agent Simulator of Networks or Neighborhoods

MC	Monte Carlo
MDIVVA	Motivate-design-implement-verify-validate-analyze
MDS	Multi-dimensional scaling
MINUIT	Numerical minimization computer program
MIT	Massachusetts Institute of Technology
MLE	Maximum likelihood estimate, estimator, or estimation
NAACSOS	North American Association for Computational Social and Organizational Sciences
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NER	Named entity recognition
NIST	National Institute of Standards and Technology
NRR	Normal relations range
NSF	National Science Foundation
NVAC	National Visualization Analytics Center, PNNL
OCR	Optical character recognition
OMG	Object Management Group
ONR	Office of Naval Research
OO	Object-oriented
OOM	Object-oriented model or modeling
OOP	Object-oriented program or programming
OR	Boolean disjunctive operator
ORA	Entity extraction algorithm by CASOS
PDF	Probability density function (also p.d.f.)
PNAS	Proceedings of the National Academy of Sciences of the USA
PNNL	Pacific Northwest National Laboratory, Department of Energy
PPNB	Pre-Pottery Neolithic B period
PRNG	Pseudo-random number generator
RAM	Random access memory
RNG	Random number generator
SAS	Statistical Analysis System
SD	System dynamics
SDC	Size, development, and capability
SEQAND	Boolean sequential conjunctive operator
SES	Socioeconomic status
SIAM	Society for Industrial and Applied Mathematics
SIGKDD	Special Interest Group on Knowledge Discovery and Data Mining of the ACM
SIMPEST	Simulation of Political, Economic, Social, and Technological Systems
SIMPLE	Simulation of Industrial Management Problems with Lots of Equations
SIMPOP	SIMulation of POPulation project, University of Paris-Sorbonne
SNA	Social network analysis

SOCPAC	A FORTRAN IV program for structural analysis of sociometric data
SPSS	Statistical Package for the Social Sciences
SSRC	Social Science Research Council
SSRN	Social Science Research Network
STELLA	System dynamics simulation system
TABARI	Textual Analysis by Augmented Replacement Instructions
TBJ	Truth, beauty, and justice
TRIAL	Technique for Retrieval of Information and Abstracts of Literature
UAV	Unmanned autonomous vehicle
UCINET	University of California-Irvine social network analysis software
UCLA	University of California-Los Angeles
UML	Unified Modeling Language
UN	United Nations
URL	Uniform resource locator
US	United States
USSR	Union of Soviet Socialist Republics
VENSIM	System dynamics simulation system
WWW	World-Wide Web
XOR	Boolean exclusive disjunctive operator

List of Figures

List of Tables