Complex Systems Models in the Social Sciences

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The nonlinear dynamics exhibited by complex systems often pose difficult problems for modelers of those systems, especially when the complex systems are adaptive. This workshop is about modeling complex adaptive systems with an emphasis on agent-based modeling. Agent-based models consist of a number of diverse agents, the behaviors of which are governed by (often simple) decision rules. The dynamic interaction of the agents with one another and with their environment at the micro-level can produce emergent patterns and structures at the macro-level. This workshop provides an introduction to agent-based modeling and compares this approach to more traditional mathematical approaches (e.g., game theory). A variety of applications in the social sciences are used to introduce modeling complex adaptive systems including social/economic/political networks, electoral politics, civil war, and culture. There is a lab session that introduces students to the computer tools used to build agent-based models.

These lectures provide an introduction to recent approaches in computer modeling of complex social systems, comparing them to more traditional mathematical (analytical) approaches and to the previous generation of computer simulations in the social sciences. In addition to describing the methods and techniques of this modeling approach, a number of social science applications will be reviewed and analyzed.

The field of complex systems is extremely diverse and this course is designed to highlight a wide range of theoretical and empirical approaches employed in the literature. Thus, in addition to the study of agent-based modeling, students will be exposed to the leading ideas in network science, natural language processing and machine learning.

This course includes a lab session in which students will be able to run implementations of several of the models discussed in the lectures and learn to build their own computational models. Students will gain sufficient knowledge and experience to plan and build models for their own research. Various software packages and languages will be highlighted including Netlogo (ABM & Networks), Nova (System Dynamics & ABM), R (Statistics and

Network Analysis), and Python (Object-Oriented Programming Language). The lab sessions are conducted by Daniel Katz and Michael Bommarito.

For those seeking a grade in the course, there will be regular assignments in the lab and two options for final evaluation:

1) Updating and running an existing computational model, and writing up the results.

2) Developing an original computational model and writing a short paper.

Students may want to purchase **ONE** of the following books:

Miller, John H. and Scott E. Page. 2007. *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. Princeton, NJ: Princeton University Press.

Page, Scott E. 2011. *Diversity and Complexity*. Princeton, NJ: Princeton University Press.

Mitchell, Melanie. 2009. *Complexity: A Guided Tour*. New York: Oxford University Press.

Downey, Allen B., *Think Complexity*. O'Reilly Press (2012) available for free here: http://www.greenteapress.com/complexity/thinkcomplexity.pdf

Class Schedule

July 20: No Lecture (Course Signup takes place in AM) but Lab will take place at 5:00pm in Helen Newberry Hall

July 21: Introduction to Complex Systems Modeling and Philosophy of Science (Katz)

Holland, John. 1992. "Complex Adaptive Systems." *Daedalus 121*: 17-30.
Axelrod, Robert. 1997. *The Complexity of Cooperation.* Basic Books. Introduction.
Schelling, Thomas. 1978. *Micromotives and Macrobehavior*. Pp. 147-165: Simple models of segregation. Norton, New York, 1978.
Ken Kollman, "The Potential Value of Computational Models in Social Science Research." in Harold Kincaid, ed. *Oxford Handbook in Philosophy in the Social Sciences*. 2012. New York: Oxford University Press.
Miller, John and Scott Page. 2007. *Complex Adaptive Systems.* Princeton, NJ: Princeton University Press. Chs. 5-6.

July 22: Intro to Network Science (Part I) (Katz)

Mark Buchanan, *Nexus: Small Worlds And The Groundbreaking Science Of Networks* (2003)
Duncan J. Watts & Stephen Strogatz, *Collective Dynamics of 'Small World' Networks*, 393 Nature 440 (1998)
Albert-László Barabási & Reka Albert, *Emergence of Scaling in Random Networks*, 286 Science 509 (1999)
Mark Granovetter, *The Strength of Weak Ties*, 78 *American Journal of Sociology* 1360 (1973)

July 23: Intro to Network Science (Part II) (Katz)

Mark E. J. Newman, *The Structure and Function of Complex Networks*. *SIAM Review.* 45(2): 167-256. (2003).
D. J. Watts, P. S. Dodds, & M. E. J. Newman. *Identity and Search in Social Networks*, Science, 296: 1302-1305 (2002).
Peter Sheridan Dodds, Roby Muhamad2 & Duncan J. Watts, An Experimental Study of Search in Global Social Networks, 301 Science 827 (2003).
Aaron Clauset, Cosma Rohilla Shalizi, and M. E. J. Newman, *Power-law Distributions in Empirical Data*, SIAM Review 51, 661-703 (2009).

July 24: On the Path From Micro to Macro-Exploring Mesoscopic Structures (Katz)

Michelle Girvan & Mark E. J. Newman, *Community Structure in Social and Biological Networks,* Proceedings of the National Academy of Science. USA, 99 7821–7826 (2002).
Mason A. Porter, Jukka-Pekka Onnela & Peter J. Mucha, *Communities in Networks*, 56 Notices to the American Mathematical Society 1082 (2009)
Santo Forunato. 2010. "Community detection in graphs." *Physics Reports.* 486: 75-174.
Michael Bommarito, Daniel Katz, Jonathan Zelner & James Fowler, "Distance Measures for Dynamic Citation Networks" 389 Physica A 4201 (2010) available at http://ssrn.com/author=627779
Michael Bommarito, Daniel Katz, Jonathan Zelner, On the Stability of Community Detection Algorithms for Longitudinal Citation Data in Proceedings of the 6th Conference on Applications of Social Network Analysis (ASNA 2009 - ETH Zurich) available at http://ssrn.com/author=627779

July 27: Empirical Complex Systems: The Challenge of Measuring Complexity (Katz)

Mitchell, Melanie. 2009. *Complexity: A Guided Tour (Chapter 7 on Measuring Complexity)*

Daniel Martin Katz & Michael J. Bommarito, Measuring the Complexity of the Law: The United States Code, 22 Artificial Intelligence and Law 337 (2014)
available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2307352

July 28: Empirical Complex Systems: Big Data, Inverse v. Forward Problems, Machine Learning and the Science of Similarity (Katz)

Big Data:
The Data Deluge, The Economist (February 25, 2010) available at
http://www.economist.com/node/15579717?story_id=15579717
Data, Data Everywhere, The Economist (February 25, 2010) available at
http://www.economist.com/node/15557443
All Too Much, The Economist (February 25, 2010) available at
http://www.economist.com/node/15557421
Clicking for Gold, (February 25, 2010) available at
http://www.economist.com/node/15557431

Science of Similarity:
Greg Linden, Brent Smith, and Jeremy York, *Amazon.com Recommendations Item-to-Item Collaborative Filtering*, IEEE Internet Computing (Jan. 2003) *available at*
http://ieeexplore.ieee.org/iel5/4236/26323/01167344.pdf
Clive Thompson, If You Liked This, You're Sure to Love That: The Napoleon Dynamite Problem (NY Times Magazine) available at
http://www.nytimes.com/2008/11/23/magazine/23Netflix-t.html
"Netflix Prize"
available at http://en.wikipedia.org/wiki/Netflix_Prize
From the AT&T Labs: Winning the Netflix Prize
http://www.youtube.com/watch?v=ImpV70uLxyw
The Music Genome Project -- http://en.wikipedia.org/wiki/Music_Genome_Project

Inverse v. Forward Problems:
Inverse Problem
http://en.wikipedia.org/wiki/Inverse_problem
Kepler v. Newton (and the Forward v. Inverse Problem)
http://www.mtholyoke.edu/courses/mdyar/ast223/orbits/orb_lect.html
An Introduction to Inverse Problems
www.gps.caltech.edu/classes/ge193/lectures/Lecture1.pdf
<< Please Skim this Presentation (just ignore the formalism) >>

The AI Revolution:
Rock, Paper, Scissors: You vs. the Computer, (NY Times Interactive) *available at*
http://www.nytimes.com/interactive/science/rock-paper-scissors.html
Steven Levy, *The AI Revolution Is On*, Wired Magazine (January 2011) available at
http://www.wired.com/magazine/2010/12/ff_ai_essay_airevolution/
http://www.wired.com/magazine/2010/12/ff_ai_flashtrading/
Clive Thompson, *What Is I.B.M.'s Watson?* NY Times Magazine (June 14, 2010) available at
http://www.nytimes.com/2010/06/20/magazine/20Computer-t.html

July 29: Prediction v. Causal Inference in Complex Systems - SCOTUS

Daniel Martin Katz, Michael Bommarito & Josh Blackman, *Predicting the Behavior of the United States Supreme Court: A General Approach* (2014) available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2463244

Martin, A. D., Quinn, K. M., Ruger, T. W., and Kim, P. T. (2004). Competing approaches to predicting supreme court decision making. Perspectives on Politics, 2(04):761–767.

Blackman, J., Aft, A., and Carpenter, C. (2012). Fantasyscotus: Crowdsourcing a Prediction Market for the Supreme Court. Northwestern Journal of Technology and Intellectual Property, 10(3).

July 30: Theoretical Complex Systems: Models of Preference Aggregation and Sorting (Katz)

Kollman, Ken, John Miller, and Scott Page. 1998. "Political Parties and Electoral Landscapes." *British Journal of Political Science 28:* 139-58.
Kollman, Ken, John Miller, and Scott Page. 1997. "Political Institutions and Sorting in a Tiebout Model." *American Economic Review 87:* 977-92.
Elizabeth Bruch and Robert Mare. 2006. "Neighborhood Choice and Neighborhood Change." *American Journal of Sociology*. 112: 667-709.

July 31: Theoretical Complex Systems: Path Dependence, Lock-in, Multiple Equilibria, Exploitation/Exploration, and Neutral Landscapes (Katz)

March, James G. 1991. "Exploration and Exploitation in Organizational Learning." Organization Science. 2(1): 71-87.
Fontana, Walter. 2003. "Topology of the Possible." Santa Fe Working Paper. http://tuvalu.santafe.edu/~walter/Papers/top.pdf
Page, Scott E. 2006. "Path Dependence" Quarterly Journal of Political Science. 1: 87-115.
Arthur, W. Brian. 1989. "Competing Technologies, Increasing Returns, and Lock-in by Historical Events." The Economic Journal. 99: 116-131.
Miller, John and Scott Page. 2007. *Complex Adaptive Systems.* Princeton, NJ: Princeton University Press. Ch. 10.
Axelrod, Robert. 1997. *The Complexity of Cooperation.* Basic Books. Chapter 1.

August 3: Empirical Complex Systems: NLP & Structured v. Unstructured Data (MJB II)

Advancing Social Science Research by Applying Computational Linguistics
http://terpconnect.umd.edu/~oard/pdf/asist08cheng.pdf

William Li, et. al., Using Algorithmic Attribution Techniques To Determine Authorship in Unsigned Judicial Opinions, Stanford Technology Law Review 16 (2013)
http://www.argentumlux.org/~andrewlo/documents/StanfordTechLawRev2013.pdf

Survey of Text Mining:
http://www.kde.cs.uni-kassel.de/hotho/pub/2005/hotho05TextMining.pdf

Jean-Baptiste Michel, et. al., Quantitative Analysis of Culture Using Millions of Digitized Books, Science 14 January 2011: 176-182 available at
http://www.sciencemag.org/content/331/6014/176.abstract

Additional Optional Canonical Texts:
Chris Manning & Hinrich Schütze, Foundations of Statistical Natural Language Processing
http://nlp.stanford.edu/fsnlp/

Trevor Hastie, Robert Tibshirani & Jerome Friedman, Elements of Statistical Learning
http://www-stat.stanford.edu/~tibs/ElemStatLearn/

August 4: Models of Culture (MJB II)

Axelrod, Robert. 1997. "The Dissemination of Culture: A Model with Local Convergence and Global Polarization." Journal of Conflict Resolution 41(2): 203-226.

Flache, Andreas and Michael W. Macy. 2011. "Local Convergence and Global Diversity: From Interpersonal to Social Influence." Journal of Conflict Resolution 55(6): 970-995.

August 5: Models of American Politics (MJB II)

Kollman, Ken, John H. Miller, and Scott E. Page. 1992. "Adaptive Parties in Spatial Elections." American Political Science Review 86(4): 929-937.

Ensley, Michael, Michael Tofias, and Scott de Marchi. 2009. "District Complexity as an Advantage in Congressional Elections." American Journal of Political Science 53(4): 990-1005.

August 6: Models of Civil War (MJB II)

Epstein, Joshua M. 2002. "Modeling Civil Violence: An Agent-Based Computational Approach." Proceedings of the National Academy of Sciences 99(90003): 7243-7250.

Bennett, D. Scott. 2008. "Governments, Civilians, and the Evolution of Insurgency: Modeling the Early Dynamics of Insurgencies." Journal of Artificial Societies and Social Simulation 11(4).

Findley, Michael G. and Joseph K. Young. 2007. "Fighting Fire with Fire? How (Not) to Neutralize an Insurgency." Civil Wars 9(4): 378-401.

Weidmann, Nils B. and Idean Salehyan. 2013. "Violence and Ethnic Segregation: A Computational Model Applied to Baghdad." International Studies Quarterly 57(1): 52-64.

August 7: Collective Action and Resource Management (MJB II)

Agrawal, A., Brown, D.G., Rao, G., Riolo, R., Robinson, D.T., and M.J. Bommarito. Interactions between Organizations and Networks in Common-Pool Resource Governance, Environmental Science & Policy 25, 138-146.

Daniel Brown, Riolo, Rick, Robinson, Derek T., North, M., and William Rand (2005) "Spatial Process and Data Models: Toward Integration of Agent-Based Models and GIS" Journal of Geographical Systems, Special Issue on Space-Time Information Systems 7(1): 25-47.

Elinor Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action (Political Economy of Institutions and Decisions), Cambridge University Press (1990) Chapter 1, 6

August 10: Social Epidemiology / Information Diffusion – Part1 (MJB II)

Downey, Allen B., *Think Complexity*. O'Reilly Press (2012) Chapter 11 http://www.greenteapress.com/complexity/thinkcomplexity.pdf

Daniel Katz, Joshua Gubler, Jon Zelner, Michael Bommarito, Eric Provins & Eitan Ingall, *Reproduction of Hierarchy? A Social Network Analysis of the American Law Professoriate*, 61 J. of Legal Educ. 76 (2011) available at http://ssrn.com/author=627779

Keeling, M.J. and Rohani, P. Modeling Infectious Diseases in Humans and Animals. Princeton University Press. (2007) Chapter 2 available at http://homepages.warwick.ac.uk/~masfz/ModelingInfectiousDiseases/Chapter2/index.html

August 11: Social Epidemiology / Information Diffusion – Part II (MJB II)

Allen LJ1, Burgin AM., *Comparison of deterministic and stochastic SIS and SIR models in discrete time*. 163 Math Biosci. 1 (2000) http://www.ncbi.nlm.nih.gov/pubmed/10652843

August 12: Computational Models and Empirical Evaluation (MJB II)

de Marchi, Scott. 2005. Computational and Mathematical Modeling in the Social Sciences. New York: Cambridge University Press. (Chapters 1-3)

August 13: Good Practices for Computational Modeling (MJB II)

Miller, John H. and Scott E. Page. 2007. Complex Adaptive Systems: An Introduction to Computational Models of Social Life. Princeton, NJ: Princeton University Press. (Appendix B)

Axelrod, Robert. 1997. The Complexity of Cooperation. Princeton, NJ: Princeton University Press. (pages 210-214)