Complex Systems Models in the Social Sciences

Kyle Joyce
Department of Political Science
University of California, Davis
kjoyce@ucdavis.edu

Daniel Martin Katz
Michigan State University
College of Law
katzd@law.msu.edu

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The nonlinear dynamics exhibited by complex social systems pose challenges and create opportunities. In complex social systems, agents adapt to an environment partially constructed by the actions of other adaptive agents. For example, individuals and organizations adapt their behavior in light of feedback from other individuals and from aggregate variables produced by the collective actions of individuals. Until the advent of agent-based models, including adaptive behavior in all but the starkest of models had been impossible. Agent-based models (ABM) consist of interacting agents. Each agent's behavior is governed by a small set of simple rules, which often depend on local information and feedback. These local rules produce emergent patterns – equilibria, cycles, long transients, and randomness – and emergent functionalities such as robustness.

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), Pajek (Empirical Network Analysis), R (Statistics and Network Analysis), and Python (Object-Oriented Programming Language). The lab sessions are conducted by Daniel Katz (katzd@law.msu.edu) and Kyle Joyce (kjoyce@ucdavis.edu).

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 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.

Class Schedule

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) (Can be purchased on Amazon for ~$10)
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: Intro to Network Science (Part III) (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 Muhamad & Duncan J. Watts, An Experimental Study of Search in Global Social Networks, 301 Science 827 (2003).
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
Daniel Katz & Derek Stafford, *Hustle and Flow: A Social Network Analysis of the American Federal Judiciary*, 71 Ohio State Law Journal 457 (2010)

July 25: On the Path From Micro to Macro-Exploring Mesoscopic Structures (Katz + MJB II)

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 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: Empirical Complex Systems: Big Data and Natural Language Processing (Katz + 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/

July 30: Empirical Complex Systems: 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 (paper will be distributed via email)

<< *Additional Reading TBA* >>

July 31: Theoretical Complex Systems: Models of Preference Aggregation and Sorting (Katz + Kollman)

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.

August 1: 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 4: Models of International Relations (Joyce)

Cederman, Lars-Erik. 2003. "Modeling the Size of Wars: From Billiard Balls to Sandpiles." *American Political Science Review* 97(1): 135-150.

Joyce, Kyle A. "The Cascading Dynamics of War Expansion." Working Paper.

August 5: Models of International Relations (Joyce)

Gartzke, Erik and Alex Weisiger. 2013. "Fading Friendships: Alliances, Affinities and the Activation of International Identities." *British Journal of Political Science* 43(1): 25-52.

Joyce, Kyle A. and Zeev Maoz. "Shocks and International Networks." Working Paper.

August 6: Models of Civil War (Joyce)

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).

August 7: Models of Civil War (Joyce)

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 8: Models of Culture (Joyce)

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 11: Models of American Politics (Joyce)

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 12: Models of Electoral Politics (Joyce)

Laver, Michael and Ernest Sergenti. 2012. Party Competition: An Agent-Based Model. Princeton, NJ: Princeton University Press. (Chapters 1 & 5)

Golder, Matt, Sona N. Golder, and David A. Siegel. 2012. "Modeling the Institutional Foundation of Parliamentary Government Formation." Journal of Politics 74(2): 427-445.

August 13: Computational Models and Empirical Evaluation (Joyce)

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

August 14: Good Practices for Computational Modeling (Joyce)

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)