

Complex Systems Models in the Social Sciences

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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, individual 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 feedbacks. These local rules produce emergent patterns – equilibria, cycles, long transients, and randomness – and emergent functionalities such as robustness. These lectures will give 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.

This course includes a lab session in which students also 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 your own research in Netlogo (a free ABM platform). The lab sessions are being conducted by Daniel Katz dmartink@umich.edu.

There will be regular assignments in the lab, and then two options for final evaluation:

---updating and running an existing computation model, and writing up the results
or
---developing an original model and writing a short paper on it

Students may want to purchase the following books:

Miller, John and Scott Page. 2007. *Complex Adaptive Systems*. Princeton, NJ: Princeton University Press.

Mitchell, Melanie 2009 *Complexity: A Guided Tour* Cambridge University Press

Class Schedule

July 19: Complex Systems Modeling and Philosophy of Science (Kollman)

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.
Page, Scott (1999). "Computational models from A to Z." *Complexity* 5 (1): 35-41. <http://www.santafe.edu/projects/swarm/swarmfest99/keynote.html>
Miller, John and Scott Page. 2007. *Complex Adaptive Systems*. Princeton, NJ: Princeton University Press. Chs. 5-6.

July 20 Genetic Algorithms, The Evolution of Strategies (Kollman)

Holland, John. 1992. "Complex Adaptive Systems."
Daedalus 121: 17-30.
Holland, John. 1992. "Genetic Algorithms."
Scientific American. July. pp. 66-72.
Axelrod, Robert. 1997. *The Complexity of Cooperation*. Basic Books.
Chapter I.
Kollman, Ken, John Miller, and Scott Page. 1992.
"Adaptive Parties and Spatial Elections."
American Political Science Review 86: 929-937.
Miller, John and Scott Page. 2007. *Complex Adaptive Systems*. Princeton, NJ: Princeton University Press. Ch. 10.

July 21: Models of Markets (Kollman)

Lettau, Martin. 1997. "Explaining the Facts with Adaptive Agents" *Journal of Economic Dynamics and Control*. 21:1117-48.
Arthur, W. Brian, John H. Holland, Blake LeBaron, Richard Palmer, and Paul Taylor. 1997. "Asset Pricing Under Endogenous Expectations in an Artificial Stock Market." In W. Brian Arthur, Steven N. Durlauf, and David A. Lane (Eds). *The Economy as a Complex System II*. Reading, Massachusetts: Addison-Wesley. Pp. 15-44.

July 22: Diversity and Problem Solving (Page)

Hong, Lu, and Scott Page. 2001. "Problem Solving by Heterogeneous Agents," *Journal of Economic Theory*. 97: 123-163.

Hong, Lu, and Scott Page. 2004. "Groups of diverse problem solvers can outperform groups of high-ability problem solvers," Proceedings of the National Academy of Sciences, pp 16385-16389.

July 23: Models of Participation (Kollman)

Bendor, Jonathan, Daniel Diermeier, and Michael Ting, "A Behavioral Model of Turnout." *American Political Science Review*. 2003.

Nathan Collins, Sumil Kamar, and Jonathan Bendor. 2009. "The Adaptive Dynamics of Turnout." *Journal of Politics*. 71:457-472.

July 26: Models of Domestic Political Competition (Kollman)

Kollman, Ken, John Miller, and Scott Page. 1998.

"Political Parties and Electoral Landscapes."

British Journal of Political Science 28: 139-58.

de Marchi, Scott. 2003. "A Computational Model of Voter Sophistication, Ideology and Candidate Position-taking." 2003. In Ken Kollman, John Miller, and Scott Page (editors) *Computational Models in Political Economy*. MIT Press.

Laver, Michael. 2005. "Policy and the Dynamics of Political Competition." *American Political Science Review*. 99(May):263-81.

July 27: Annealing, Sorting, and Institutional Mechanisms (Kollman)

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.

Optional: Chang, Myong-Hun, and Joseph Harrington. 2000. "Centralization vs. Decentralization in a Multi-Unit Organization." *Management Science*. 11(Nov): 1427-1440.

July 28: Models of International Relations (Kollman)

Axelrod, Robert. 1997. *The Complexity of Cooperation*.

New York: Basic. Chapters 4, 6.

Michael Findlay. 2008. "Agents and Conflict: Adaptation and the Dynamics of War." *Complexity*. 14:22-35.

Optional: Epstein, Joshua. 2002. "Modeling Civil Violence: An Agent-Based Computational Approach," *Proceedings of the National Academy of Sciences* (Summer)

July 29: Models of Leadership

Harrington, Joseph. 1999. "Rigidity of Social Systems." *Journal of Political Economy*. 107(Feb):40-64.

Harrington, Joseph. 1998. "Social Selection of Flexible and Rigid Agents." *American Economic Review*. 88(Mar):63-82.

July 30: Multilayered Institutions

Kollman, Ken, John Miller, and Scott Page. 2000. "Decentralization and the Search for Policy Solutions" *Journal of Law Economics and Organization* 16 : 102-28.

Kollman, Ken. 2003. "The Rotating Presidency of the European Council as a Search for Good Policies," *European Union Politics*. 4(Mar):51-71.

August 2: Emergence, power laws, self-organized criticality (Lamberson)

Bak, Per. 1997. *How Nature Works*, Chapter 1.

Newman, Mark. 2004. "Power Laws, Pareto Distributions, and Zipf's Law." Available from: <http://arxiv.org/pdf/cond-mat/0412004>

August 3: Learning, bounded rationality (Lamberson)

Arthur, W. Brian. 1994. "Inductive Reasoning and Bounded Rationality." *American Economic Review*. 84(2): 406-411.

Casti, John L. "Seeing the Light at El Farol." *Complexity*, Vol. 1, No. 5, 1996, pp. 7-10.

Axelrod, Robert. 1997. *The Complexity of Cooperation*. Basic Books. Introduction, Chapters. 3, 7.

August 4: Exploration v. exploitation (Lamberson)

March, James G. 1991. "Exploration and Exploitation in Organizational Learning." *Organization Science*. 2(1): 71-87.

August 5: Path dependence, lock-in, multiple equilibria (Lamberson)

Arthur, W. Brian. 1989. "Competing Technologies, Increasing Returns, and Lock-in by Historical Events." *The Economic Journal*. 99: 116-131.

Page, Scott E. 2006. "Path Dependence" *Quarterly Journal of Political Science*. 1: 87-115.

August 6: Local Increasing Returns (Lamberson)

Lee, Eocman, Jeho Lee and Jongseok Lee. 2006. "Reconsideration of the Winner-Take-All Hypothesis: Complex Networks and Local Bias." *Management Science*. 52(12): 1838-1848.

Anderson, Chris. 2004. "The Long Tail." *Wired*. 12.10. Available from: www.wired.com/wired/archive/12.10/tail.html
<<http://www.wired.com/wired/archive/12.10/tail.html>>

Lamberson, PJ. "Local Increasing Returns"

August 9: Networks (Anderson)

Matthew O. Jackson. 2008. *Social and Economic Networks*. Chapters 1-3

Newman, Mark E. J. 2003. "The Structure and Function of Complex Networks." *SIAM Review*. 45(2): 167-256.

August 10: Community Structure in Social Networks (Anderson)

Santo Fortunato. 2010. "Community detection in graphs." *Physics Reports*. 486: 75-174.

Girvan, M. and M.E.J. Newman. 2002. "Structure in Social and Biological Networks." *Proceedings of National Academy of Sciences*. 99(12): 7821-7826.

August 11: Networks and Diffusion (Anderson)

Centola, Damon and Michael Macy. 2007. "Complex Contagions and the Weakness of Long Ties." *American Journal Of Sociology*. 113(3): 702-734.

Cowan, Robin and Nicolas Jonard. 2004. "Network Structure and the Diffusion of Knowledge." *Journal of Economic Dynamics and Control* 28: 1557-1575.

Golub, Benjamin and Matthew O. Jackson. 2007. "Naive Learning in Social Networks: Convergence, Influence and the Wisdom of Crowds"

August 12: Network Formation (Anderson)

Watts, Duncan J. and Steven H. Strogatz. 1998. "Collective Dynamics of 'Small-World' Networks." *Nature*. 393: 440-442.

Barabasi, Albert-Laszlo and Reka Albert. 1999. "Emergence of Scaling in Random Networks." *Science*, 286: 509-512.

Jackson, Matthew O. and Asher Wolinsky. 1996. "A Strategic Model of Social and Economic Networks." *Journal of Economic Theory*, 71(1): 44-74.

Guimera, Roger, Brian Uzzi, Jarrett Spiro, and Luis A. Nunes Amaral. 2005. "Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance." *Science*, 308: 697-702.

Anderson, Katharine A. 2010. "Collaboration Network Formation and the Demand for Knowledge Workers with Heterogeneous Skills."