Defining Research and Development Directions for Modeling and Simulation of Complex, Interdependent Adaptive Infrastructures

Appendix A: Our Course of Study

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Appendix A: Our Course of Study

A large component of our R&D effort this year was focused on an examination of the scientific literature in Complexity Science. This literature is extremely diverse and is rapidly encompassing almost every field of scientific investigation. The sorting of this literature to first identify the critical set of topics, and then to find the critical papers in each, took a significant effort (and made all our heads spin from time to time!). We covered these critical papers in a series of Sessions where participants would first read the assigned papers and then come together to discuss them in a 2 hour period. Below we list these readings by session and topic. We also include some 'additional reading' that might also be of benefit to fill out the topic a bit more. Note that a CD that contains copies of all the research papers listed below is available from the Infrastructure Complexity R&D Group. Books must be purchased separately.

Preliminary: Background and Overview

Buchanan, M., *Ubiquity: the science of history… or why the world is simpler than we think*, Crown Publishers: New York, 2001.

Additional Reading and Reference:

Jensen, H.J., *Self-Organized Criticality: Emergent complex behavior in physical and biological systems*, Cambridge lecture notes in Physics, Cambridge University Press, 1998.

Waldrop, M.M., *Complexity: The emerging science at the edge of order and cha*os, New York: Penguin, 1992.

Bak, P., *How Nature Works: The science of self-organized criticality*, Copernicus, Springer-Verlag New York, Inc., 1996.

Bar-Yam, Y., *Dynamics of Complex Systems*, Studies in Nonlinearity, The Advanced Book Program, Perseus Books: Reading, Massachusetts, 1997.

Stauffer, D., and A. Aharony, *Introduction to Percolation Theory*, Second Edition, Taylor & Francis: London, 1992.

Gleick, J, *Chaos: Making of a new science*, Viking: New York, 1987.

Lorenz, E. N., Deterministic nonperiodic flow. J. Atmos. Sci. Vol. 20, pp 130-141, 1963.

Nicolis, G., 'Physics of far-from-equilibrium systems and self-organization', in P. Davids (ed.), *The New Physics*, Cambridge University Press, 1989.

Binney, J.J., N.J. Dowrick, A.J. Fisher, and M.E.J. Newman, *The Theory of Critical Phenomena*, Oxford, UK: Oxford University Press, 1992.

Session 1: Self-Organized Criticality… From Physical to Social Sciences

Bak, P., C. Tang, and K. Wiesenfeld, Self-Organized Criticality: An explanation of 1/f noise, Physical Review Letters, 59:4:381-384, 1987.

Sakhtjen, M.L., B.A. Carrerras and V.E. Lynch, Disturbances in a power transmission system, Physical Review E, 61:5:4877-4882, 2000.

Watts, D.J., A simple model of global cascades on random networks, Proc. Of the National Academy of Sciences, 99(9); 5766-5771; 2002, www.panas.org/cgi/doi/10.1073/pnas.082090499.

Additional Reading:

Bak, P., C. Tang, and K. Wiesenfeld, Self-Organized Criticality, Physical Review A, 38:1:364-374, 1988.

Session 2: Beyond SOC… and what about model validation?

Carlson, J.M, and J. Doyle, Highly optimized tolerance: A mechanism for power laws in designed systems, Physical Review E, 60:2:1412-1427, 1999.

Willinger, W., R. Govindan, S. Jamin, V. Paxon, and S. Shenker, Scaling phenomena in the Internet: Critically examining criticality, PNAS, 99:suppl. 1:2573-2580, 2002. www.pnas.org/cgi/doi/10.1073/pnas.012583099.

Session 3: Introduction to Complex Networks

Albert, R., H. Jeong, A.-L. Barabasi, Error and attack tolerance of complex networks, Nature, 406:378-382, 2000.

Strogatz, S.H., Exploring Complex networks, Nature, 410:268-276, 2001.

Additional reading:

Buchanan, M. Nexus: Small Worlds and the Groundbreaking Science of Networks. W. W. Norton & Company Inc., NY NY, 2002.

Callaway, D.S., M.E.J. Newman, S.H. Stogatz, and D.J. Watts, Network Robustness and Fragility: Percolation on Random Graphs, Physical Review Letters, 85:25:5468-5471, 2000.

Session 4: Adaptive Networks

Feitelson, E., and I. Salomon, The implications of differential network flexibility for spatial structures, Transportation Research Part A, 34:459-479, 2000.

Dorogovtsev, S.N., and J.F.F. Mendes, Evolution of Networks, Advances in Physics, 51:4:1079-1187, 2002.

Sessions 5, 6 and 7: In-depth Graph Theory as relevant to Complex Networks

Albert, R., and A.-L. Barabasi, Statistical mechanics of complex networks, Reviews of Modern Physics, 74:1:47-97, 2002.

Additional Reading:

Watts, D.J., Small Worlds: *The dynamics of Networks between Order and Randomness, Princeton Studies in Complexity*, Princeton University Press: Princeton, New Jersey, 1999.

Barabasi, A.-L., *Linked: The new science of networks*, Perseus Publishing: Cambridge Massachusetts, 2002.

Session 8: Starting to dig into Social Behavior and Agent-Based Models

Axtell, R., Why Agents? On the varied motivations for agent computing in the social sciences, Center on Social and Economic Dynamics, The Brookings Institution, Working Paper #17, 2000.

Berry, B.J.L., L.D. Kiel, and E. Elliot, Adaptive agents, intelligence, and emergent organization: Capturing complexity through agent-based modeling, PNAS, 99:suppl. 3:7187-7188, 2002. www.pnas.org/cgi/doi/10.1073/pnas.092078899. (Overall introduction to special PNAS issue of the same name)

Additional Reading:

Epstein, J.M., and R. Axtell, *Growing Artificial Societies: Social Science from the bottoms up*, Brookings Institution Press: Washington, D.C., 1996.

Session 9: Modeling Social Behavior

Epstein, J.M., Modeling civil violence: An agent-based computational approach, PNAS, 99:suppl. 3:7243-7250, 2002. www.pnas.org/cgi/doi/10.1073/pnas.092080199.

Danielson, P., Competition among cooperators: Altruism and reciprocity, PNAS, 99:suppl. 3:7237-7242, 2002. www.pnas.org/cgi/doi/10.1073/pnas.082079899.

Additional reading:

Axelrod, R., *The complexity of cooperation: Agent-based models of competition and collaboration*, Princeton Studies in Complexity, Princeton University Press: Princeton, New Jersey, 1997.

Session 10: Modeling Financial Behavior

Tesfatsion, L., Economic agents and markets as emergent phenomena, PNAS, 99:suppl. 3:7191-7192, 2002. www.pnas.org/cgi/doi/10.1073/pnas.072079199.

LeBaron, B., Short-memory traders and their impact on group learning in financial markets, PNAS, 99:suppl. 3:7201-7206, 2002. www.pnas.org/cgi/doi/10.1073/pnas.072079699.

Additional Reading:

Eguiluz, V.M., and M.G. Zimmermann, Transmission of information and herd behavior: An application to financial markets, Physical Review Letters, 85:26:5659-5662, 2000.

Session 11: Modeling Policy

Lempert, R., Agent-based modeling as organizational and public policy simulators, PNAS, 99:suppl. 3:7195-7196, 2002. www.pnas.org/cgi/doi/10.1073/pnas.092078899.

Moss, S., Policy analysis from first principles, PNAS, 99:suppl. 3:7267-7274, 2002. www.pnas.org/cgi/doi/10.1073/pnas.092080699.

Carley, K.M., Computational organization science: A new frontier, PNAS, 99:suppl. 3:7257-7262, 2002. www.pnas.org/cgi/doi/10.1073/pnas.082080599.

Session 12: Artificial Chemistry

Dittrich, P., Jens Ziegler, Wolfgang Banzhaf. 2001. Artificial Chemistries – A Review, Artificial Life, Vol. 7 No. 3, pp 225-275.

Additional Reading:

Kauffman, S. A. 1993. The origins of order: Self-organization and selection in evolution. New York, Oxford University Press.

Fontana, W., and L. W. Buss. 1996. The barrier of objects: From dynamical systems to bounded organization. In Boundaries and Barriers (pp 56-116). Redwood City, MA, Addison-Wesley.

Ziegler, J. and Wolfgang Banzhaf. 2001. Evolving Control Mechanisms for a Robot, Artificial Life, Vol. 7 No. 2, pp 171-190