Dynamic Network Analysis

08-801
Introduction

M 3:30-5:00 P.M., Spring 2011

Wean Hall Room 4220

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Who knows who? Who knows what? Who is influential? How do ideas and diseases propagate through groups? How do new sciences emerge? Are there patterns of life in the way people interact? Questions such as these and millions of others can be addressed only by looking at networks, at the ties that connect, constrain and enable people, ideas, things, locations. In this course, the fundamentals of network science, the methods, the theories, the constraints on data collection are examined.

The study of networks is integral to numerous fields such as statistics, sociology, organizational science, communication, computer science and forensic science. As a result, many different disciplines provide theories about how these networks form, evolve, and impact behavior; the data used to address network questions; the technologies; the algorithms; the metrics, and so on. Regardless of whether the term link analysis, social network analysis, or network science is used, the discussion hinges on the graph-theoretic based study of dynamic, ubiquitous, and interlocked networks with statistical approaches used for assessing dynamics, information loss, and error. In this course, an interdisciplinary approach to the study of social networks is taken. The relation of social networks to knowledge, communication, activity and other forms of networks are considered. Applications from business, science, art, forensics, and numerous other areas are explored.

This graduate seminar, taught every other year, offers an overview and evaluation of the theory and research on networks broadly defined. Student are encouraged to bring and use their own data, or to use one of the large number of datasets available publicly in this area for assignments. Questions addressed include, but are not limited to: How do we conceptualize, measure, compare and evaluate various types of networks? How do we evaluate the impact of policies and technology on using these networks especially given the fact that these networks are dynamic? What nodes, relations, groups, motifs stand out in or are influential in a network? How do networks emerge, evolve, change? What is the difference in analyzing networks as complete graphs versus networks as emerging from a set of links? How can data on networks be collected and what are the limits of these collection techniques?

Prior courses in linear algebra, graph theory, or social networks are not required.

***Web***

There is a blackboard site for the course.

***Required Software***

**ORA**, available from CASOS - <http://www.casos.cs.cmu.edu/projects/ora/>

**AutoMap**, available from CASOS - <http://www.casos.cs.cmu.edu/projects/automap/>

**Construct**, available from CASOS - <http://www.casos.cs.cmu.edu/projects/construct/>

 *See TAs for latest builds of these tools*

***Useful Software (to be aware of)***

**UCINET**, available from Analytic Technologies - <http://www.analytictech.com/>

**Keyplayer**, from Analytic Technologies - <http://www.analytictech.com/>

**Netdraw**, from Analytic Technologies - <http://www.analytictech.com/>

***Required Books***

Only one book has been ordered at the bookstore – Wasserman and Faust (SNA). The other book is available on-line. However, you may want to pick up the other books listed as supplementary reading.

**Wasserman, S. & K. Faust,** 1994, Social Network Analysis: Methods and Applications. Cambridge University Press.

***Recommended Books (to be aware of)***

**National Research Council**, 2006. *Network Science* <http://www.nap.edu/catalog/11516.html> or <http://www.nap.edu/books/0309100267/html/>

**Linton Freeman,** The Development of Social Network Analysis: A Study in the Sociology of Science. Vancouver: Empirical Press, 2004

**A.-L. Barabási,** 2002, [Linked: The New Science of Networks](http://www.amazon.com/exec/obidos/ASIN/0738206679/complexnetwor-20/qid%3D1063234724/sr%3D1-1/ref%3Dsr_1_1/002-3847067-2891263?v=glance&s=)
(Perseus, Cambridge, MA, 2002)

**Ulrich Brandes and T. Erlebach**, 2005, Network analysis. Methodological Foundations. Springer: Heidelberg (Germany).

**Ronald Breiger, Kathleen M. Carley, and Philippa Pattison (Eds.)**. 2003. Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers. Committee on Human Factors, Board on Behavioral, Cognitive, and Sensory Sciences. Washington, DC: National Academy Press.

**M. Buchanan**, 2002. *Nexus: Small worlds and the groundbreaking science of networks*. New York: W. W. Norton & Company.

**Sam Leinhardt** (Ed.), 1977, *Social networks: A developing paradigm*. New York, Academic Press.

**Mark Newman, D.J. Watts and A. Barabasi**, 2006, *The Structure and Dynamics of Networks,* Princeton University Press.

**Notin Nohria and Robert Eccles** (eds.) 1992, *Networks and Organizations.* Cambridge, MA: Harvard Business School

**John Scott**, 2000, *Social Network Analysis,* Sage

**Stanley Wasserman and Joseph Galaskiewicz** (eds.) 1994, *Advances in Social Network Analysis: Research in the Social and Behavioral* *Sciences*. Thousand Oaks, CA: Sage.

**Duncan J. Watts**, 2002, *Six Degrees: The Science of a Connected Age,*New York & London: W.W. Norton & Company.

***Lecture I: Introduction – What is Dynamic Network Analysis***

**Wasserman, S. & Faust,** **K**. Chapters 1(1.1,1.2,1.3,1.4), 2 (2.1, 2.2, 2.3) and 3.1 and 3.2

**Linton Freeman, "Social Network Analysis: Definition and History" In A. E. Kazdan, ed. Encyclopedia of Psychology . New York: Oxford University Press, 2000, Vol. 6, pp. 350-351.**

**Borgatti, S.P., Mehra, A., Brass, D. and Labianca, G. (2009). “Network Analysis in the Social Sciences.” Science. Vol. 323. no. 5916, Feb 13, pp. 892 - 895**

**Norman Hummon and Kathleen M. Carley, 1993, “Social Networks: As Normal Science,” Social Networks, 15: 71-106.**

**National Research Council,** Chapters 1,2,4,5. <http://books.nap.edu/openbook.php?isbn=0309100267>

**Carley, K. M.,** 2004, Dynamic Network Analysis. In R. Breiger, K. M. Carley & P. Pattison (Eds.), *Dynamic Social Network Modeling and Analysis: 2002 Workshop Summary and Papers* (pp. 133-45). Washington, DC: National Academies Press.

**Kathleen M. Carley,** 2002, “Smart Agents and Organizations of the Future” The Handbook of New Media. Edited by Leah Lievrouw and Sonia Livingstone, Ch. 12, pp. 206-220, Thousand Oaks, CA, Sage.

**Borgatti & Foster. Borgatti, S.P. and Foster, P.B.** The network paradigm in organizational research: A review and typology.

**Freeman, Linton**. 2000. “Visualizing Social Structure.” *Journal of Social Structure* 1(2). http://www.cmu.edu/joss/content/articles/volume1/

Freeman.html.

**Optional Readings (may be discussed)**

**Barry Wellman**, "Networking Network Analysts: How INSNA (the International Network for Social Network Analysis) Came to Be." Connections 23, 1 (Summer, 2000): 20-31

**Barry Wellman**, "Structural Analysis: From Method and Metaphor to Theory and Substance." Pp. 19-61 in Social Structures: A Network Approach, edited by Barry Wellman and S.D. Berkowitz. Cambridge: Cambridge University Press, 1988.

**Barry Wellman**, "The Network Revolution" chapter in Rainie-Wellman Networked: The New Social Operating System. Not quite finished. MIT PRess, 2011. Network data and measurement. *Annual Review of Sociology* 16:435-63.

**Bernard, H.R., Killworth, P. & Sailer, L**. 1981. Summary of research on informant accuracy in network data, and on the reverse small world problem. *Connections* 4(2):11-25.

**Freeman, L.C., Romney, A.K., & Freeman, S**. 1987. Cognitive structure and informant accuracy. American Anthropologist 89:310-325.

 **Viégas FB, Donath J**. Social network visualization: Can we go beyond the graph. In: *Workshop on Social Networks, CSCW*.Vol 4. Citeseer; 2004:6–10.

This is a reasonable high level primer for social networks <http://faculty.ucr.edu/~hanneman/nettext/>

Good cumulative list of references - <http://www.socialnetworks.org/>

**Further Exploration (read if interested)**

**Stefano Boccaletti et al**. 2006, “Complex Networks: Structure and Dynamics,” *Physics Reports* 424, no. 4-5: 175-308.

**Skyrms, Brian, and Robin Pemantle**. 2004. “A Dynamic Model of Social Network Formation.” *Proceedings of the National Academy of Sciences* 97:9340-9346. http://arxiv.org/abs/math.PR/0404101.

**Alderson, David**. 2008. “Catching the "Network Science" Bug: insight and opportunity for the operations researcher.” *Operations Research* 56:1-36.

**Borgatti, Stephen, Ajay Mehra, Daniel Brass, and Giuseppe Labianca**. 2009. “Network Analysis in the Social Sciences.” *Science* 323(February 13):892-895.

***Lecture II: Network Elite***

**Wasserman & Faust,** Chapter 5

**Borgatti, S. P.** (2004). The Key Player Problem. In R. Breiger, K. M. Carley & P. Pattison (Eds.), *Dynamic Social Network Modeling and Analysis: 2002 Workshop Summary and Papers* (pp. 241-52). Washington, DC: National Academies Press.

**Philip Bonacich**, Power and Centrality: A Family of Measures, American Journal of Sociology, 1987, 92(5):1170-82.

**Martin Kilduff and David Krackhardt**, Bringing the Individual Back In: A Structural Analysis of the Internal Market foe Reputation in Organizations, Academy of Management Journal, 1994, 37:87-108.

**Brass, D. and Burkhardt, M.** 1992. Centrality and power in organizations. Pp. 191-215

**Freeman, L.C.** 1979. Centrality in social networks: Conceptual clarification. Social Networks. 1: 215-239

**Optional Readings (may be discussed)**

**Brass, D.J. & Krackhardt, D.** 1999. The social capital of 21st century leaders. In J.G. Hunt, G.E. Dodge, & L. Wong (Eds.), Out-of-the- box leadership, 179-194. Stamford, CT: JAI Press.

**Cook, K., Emerson, R., Gillmore, M. & Yamagishi, T.** 1983. The distribution of power in exchange networks ... American Journal of Sociology 89: 275-305.

**Markovsky, B., Willer, D. and Patton, T.** 1988. Power relations in exchange networks. American Sociological Review 53: 220-236.

**Leavitt, H.** 1951 Some effects of certain communication patterns on group performance.

**Further Exploration (read if interested)**

**Everett, Martin, and Stephen Borgatti**. 2005. “Ego Network Betweenness.” *Social Networks* 27:31-38.

**Watts, Duncan, and Peter Sheridan Dodds**. 2007. “Influentials, Networks, and Public Opinion Formation.” *Journal of Consumer Research* 34:441-458.

**La Due Lake, Ronald, and Robert Huckfeldt**. 1998. “Social Capital, Social Networks, and Political Participation.” *Political Psychology* 19.

**Knoke, David**. 1990. “Networks of Political Action: toward theory construction.” *Social Forces* 68:1041-1064.

**Valente, Thomas**. 1996. “Social Network Thresholds in the Diffusion of Innovations.” *Social Networks* 18:69-89.

**Latkin, Carl et al**. 1995. “Personal Network Characteristics as Antecedents to Needle-Sharing and Shooting Gallery Attendance.” *Social Networks* 17:219-228.

***Lecture III: Groups***

**Wasserman & Faust**, Chapter 7,8,9,10,12

**Newman, M**. 2004. “Detecting Community Structure in Networks.” *European Physics B*:321-330.

**Breiger, Ronald, Scott Boorman, and Phipps Arabie**. 1975. “An Algorithm for Clustering Relational Data with Applications to Social Network Analysis and Comparison with Multidimensional Scaling.” *Journal of Mathematical Psychology* 12:328-383.

**Lorrain, Francois, and Harrison White**. 1971. “Structural Equivalence of Individuals in Social Networks.” *Journal of Mathematical Psychology* 1:49-80.

**Davis, George, and Kathleen Carley**. 2008. “Clearing the FOG: fuzzy overlapping groups for social networks.” *Social Networks* 30:201-212.

**Kubica, Jeremy, Andrew Moore, and Jeff Schneider**. 2003. “K-groups: tractable group detection on large link data sets.” in *Third IEE International Conference on Data Mining*.

**Neville, Jennifer, Micah Adler, and David Jensen**. 2003. “Clustering Relational Data Using Attribute and Link Information.” in *Proceedings of Text Mining and Link Analysis Workshop*. Eighteenth International Joint Conference on Artificial Intelligence.

**Optional Readings (may be discussed)**

**Lu, Qing, and Lise Getoor**. 2003. “Link-Based Classification.” *Proceedings of the 20th International Conference on Machine Learning*.

**Karrer, Brian, Elizavetta Levina, and Mark Newman**. 2008. “Robustness of Community Structure in Networks.” *Physics Review E* 77(046119).

**Clauset, Aaron, Mark Newman, and Christopher Moore**. 2008. “Finding Community Structure in Very Large Networks.” *Physics Review E* 77:1-6

**Further Exploration (read if interested)**

**Winship, Christopher, and Michael Mandel**. 1983. “Roles and Positions: a critique and extension of the blockmodeling approach.” *Social Methodology* 14:314-344.

**Kubica, Jeff, Andrew Moore, and David Cohen**. 2003. “Finding Underlying Connections: a fast graph-based method for link analysis and collaboration querries.” in *Proceedings of the 2003 IJCAI Text-Mining & Link Analysis Workshop*.

**Borgatti, Stephen, and Martin Everett**. 1992. “Notations of Position in Social Network Analysis.” *Social Methodology* 22:1-35.

**Magdon-Ismail, Malik, M. Goldberg, W. Wallace, and D. Siebecker**. 2003. “Locating Hidden Groups in Communication Networks Using Hidden Markov Models.” Pp. 126-137 in *Intelligence and Security Informatics*, vol. 2665/2003. Springer-Verlag.

***Lecture IV: From Links to Networks***

**Skillicorn, David**. 2006. *Knowledge Discovery for Counterterrorism and Law Enforcement*. 1st ed. Boca Raton, FL: CRC Press.  Chapters 1 and 6.

 **Park, Han Woo, and Mike Thelwall**. 2003. “Hyperlink Analyses of the World Wide Web: A Review.” *Journal of Computer Mediated Communication* 8.

 **S. Lehman and A.D. Jackson,** 2005, Live and Dead Nodes. Computational and Mathematical Organization Theory. 11(2): 161-170.

**L. Getoor, N. Friedman, D. Koller, B. Taskar,** 2002. Learning Probabilistic Models of Link Structure. Journal of Machine Learning Research 3: 679-707.

 **Krackhardt D.** Simmelian ties: Super strong and sticky. In: *Power and influence in organizations*.; 1998. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:simmelian+ties#2.

**Optional Readings (may be discussed)**

**Y. Zhang, M. Roughan, C. Lund, and D. Donoho.** An information-theoretic approach to traffic matrix estimation. In Proceedings of SIGCOMM, 2003

**Jennifer Neville, David Jensen,** Dependency Networks for Relational Data. Proc. IEEE International Conference on Data Mining (ICDM). 2004:170-177.

**Klein, Malcolm, and Lois Crawford**. 1967. “Groups, Gangs, and Cohesiveness.” *The Journal of Research in Crime and Delinquency* 4:63-75.

**Brin, Sergey, and Lawrence Page**. 1998. “The Anatomy of a Large-Scale Hypertextutal Web Search Engine.” in *Proceedings of the 7th World Wide Web Conference*.

**Further Exploration (read if interested)**

**Bellair, Paul**. 1997. “Social Interaction and Community Crime: examining the importance of neighbor networks.” *Criminology* 35:677-704.

**Sampson, Robert J., Jeffrey D. Morenoff, and Thomas Gannon-Rowley**. 2002. “Assessing "Neighborhood Effects": social processes and new directions in research.” *Annual Review of Sociology* 28:443-478.

**Wilson, John**. 2000. “Volunteering.” *Annual Review of Sociology* 26:215-240.

**Faloutsos, Christos**. 1999. *Searching Multimedia Databases by Content*. Kluwer Academic Publishers.

# **Lecture V: Network Text Analysis and AutoMap**

**Richard Klimoski and Susan Mohammed**, 1994, Team Mental Model: Construct or Metaphor?, *Journal of Management*, 20(2):403-437.

**Carley, Kathleen**, 1997, Network Text Analysis: the network position of concepts. In Carl W. Roberts (Ed.), Text Analysis for the Social Sciences, (pp. 79-102). Mahwah, NJ: Lawrence Erlbaum Associates.

**Carley, Kathleen,** 1994, “Extracting Culture through Textual Analysis.” Poetics, 22: 291-312.

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**Diesner Jana and Kathleen M. Carley**, 2005, “Revealing Social Structure from Texts:Meta-Matrix Text Analysis as a novel method for Network Text Analysis,” In V.K. Narayanan & D.J. Armstrong (Eds.) Causal Mapping for Information Systems and Technology Research: Approaches, Advances, and Illustrations, Chapter 4, Harrisburg, PA: Idea Group Publishing.

**Nigam, Kamal, Andrew McCallum, Sebastian Thrun, and Tom Mitchell**. 2000. “Text Classification from Labeled and Unlabeled Documents using EM.” *Machine Learning* 39:103-134.

**Optional Readings (may be discussed)**

**Carley, Kathleen, Dave Columbus, Matthew DeReno, and Jana Diesner**. 2008. *Automap User's Guide 2008*. Carnegie Mellon University School of Computer Science: Carnegie Mellon University.

**Diesner, Jana**. 2007. *AutoMap Help Manual*. Organizational Risk Analyzer Help Files. Carnegie Mellon University.

**Carley, Kathleen,** 1997, “Extracting Team Mental Models Through Textual Analysis.” Journal of Organizational Behavior, 18: 533-538.

**Further Exploration (read if interested)**

**Skillicorn, David**. 2006. *Knowledge Discovery for Counterterrorism and Law Enforcement*. 1st ed. Boca Raton, FL: CRC Press.  Chapter 2 (hard copy available in CASOS lab upon request).

**Carley, Kathleen**. 1986. “An Approach for Relating Social Structure to Cognitive Structure.” *Journal of Mathematical Sociology* 12:137-189.

**Lecture VI: Topics in Dynamic Network Text Analysis**

**Skillicorn, David**. 2006. Chapter 7: Knowledge Discovery From Public Data. *Knowledge Discovery for Counterterrorism and Law Enforcement*. 1st ed. Boca Raton, FL: CRC Press.

**Landauer, Thomas, Peter Foltz, and Darrell Laham**. 1998. “An Introduction to Latent Semantic Analysis.” *Discourse Processes* 25:259-284.

**Malin, Bradley, Edoardo Airoldi, and Kathleen Carley**. 2005. “A Network Analysis Model for Disambiguation of Names in Lists.” *Computational and Mathematical Organization Theory* 11:119-139.

**Diesner, Jana, Terril Frantz, and Kathleen Carley**. 2005. “Communication Networks from the Enron Email Corpus.” *Computation and Mathematical Organization Theory* 11.

**Corman, Steven, Timothy Kuhn, Robert McPhee, and Kevin Dooley**. 2002. “Studying Complex Discursive Systems: Centering Resonance Analysis of Organizational Communication.” *Human Communication Research* 28(2):157-206.

**Hoffman, Robert, and Gavan Lintern**. 2006. “Eliciting and Representing the Knowledge of Experts.” in *Cambridge Handbook of Expertise and Expert Performance*, Ericsson, K. A., Charness, N., Feltovich, P., & Hoffman, R. (Eds.). New York, NY: Cambridge University Press.

**Keila, Parambir, and David Skillicorn**. 2005. “Structure in the Enron Email Dataset.” in *SIAM International Conference no Data Mining*. Workshop on Link Analysis, Counterterrorism, and Security.

**Chapanond, Anurat, Mukkai Krishnamoorthy, and Bulent Yener**. 2005. “Graph Theoretic and Spectral Analysis of Enron Email Data.” *Computational and Mathematical Organization Theory* 11(3).

**Optional Readings (may be discussed)**

**Kubica, Jeremy, Andrew Moore, David Cohn, and Jeff Schneider**. 2003. “cGraph: A Fast Graph-Based Method for Link Analysis and Queries .” in *Proceedings of the 2003 IJCAI Text-Mining & Link-Analysis Workshop*.

**Tong, Hanghang, Brian Gallagher, Christos Faloustos, and Tina Eliassi-Rad**. 2007. “Fast Best-Effort Pattern Matching in Large Attributed Graphs.” in *Proceedings of the 2007 Knowledge and Data Discovery Conference*.

**Further Exploration (read if interested)**

**TBA**

**Lecture VII: Network Topology**

**Newman, Mark**. 2003. “The Structure and Function of Complex Networks.” *SIAM Review* 45:167-256.

**Borgatti, Stephen, and Martin Everett**. 1999. “Models of Core/Periphery Structures.” *Social Networks* 21:375-395.

**Erdos, Paul, and Alfred Renyi**. 1959. “On Random Graphs I.” *Publicationes Mathematicae Debrecen* 6:290-297.

**Frantz, Terrill, and Kathleen Carley**. 2005. *A Formal Characterization of Cellular Networks*. Carnegie Mellon University School of Computer Science, Technical Report CMU-ISRI-05-109.

**Kleinberg, Jon**. 1999. *The Small World Phenomenon: an algorithmic perspective*. Cornel Computer Science Department: Cornel University.

**Watts, Duncan, and Steven Strogatz**. 1998. “Collective Dynamics of "Small World" Networks.” *Nature* 393:393-395.

**Barabasi, Albert-Laszlo, and Eric Bonabeau**. 2000. “Scale-Free Networks.” *Scientific American* 288(5):50-59.

**Airoldi, Edoardo, and Kathleen Carley**. 2005. “Sampling Algorithms for Pure Network Topologies: a study on the stability and separability of metric embeddings.” *ACM SIGKDD Explorations Newsletter* 7(2):13-22.

**Optional Readings (may be discussed)**

**Leskovec, Jurij, Deepayan Chakrabarti, Jon Kleinberg, and Christos Faloutsos**. 2005. “Realistic, Mathematically Tractable Graph Generation and Evolution, Using Kronecker Multiplication.” Pp. 133-145 in *Proceedings of the 2005 Conference on Knowledge and Data Discovery*, vol. 3721/2005.

**Barabasi, Albert-Laszlo, Reka Albert, and Hawoong Jeong**. 2000. “Scale-Free Characteristics of Random Networks: the topology of the wold-wide web.” *Physica A* 281(1-4):69-77.

**Malone, Thomas**. 1987. “Modeling Coordination in Organizations and Markets.” *Management Science* 33(10):1317-1332.

**1. Rattigan MJ, Maier M, Jensen D**. *Graph clustering with network structure indices*. New York, New York, USA: ACM Press; 2007:783-790.

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**Dunbar, Robin**. 1998. “The Social Brain Hypothesis.” *Evolutionary Anthropology* 6:178-190.

**Hirshman, Brian, and Jesse St. Charles**. 2009. “Simulating Emergent Multi-Tierd Social Ties.” in *Proceedings of the 2009 Human Behavior and Computational Intelligence Modeling Conference*. Oak Ridge National Laboratory, TN.

**Hoff, Peter, Adrian Raferty, and Mark Handcock**. 2002. “Latent Space Approaches to Social Network Analysis.” *Journal of the American Statistical Association* 97:1090-1099.

**Lecture VIII: Compare and Contrast Networks**

**Wasserman & Faust**, Chapter 15

**Krackhardt, David**. 1988. “Predicting with Networks: Nonparametric Multiple Regression Analysis of Dyadic Data.” *Social Networks* 10:359-381.

**Anderson, Carolyn, Stanley Wasserman, and Bradley Crouch**. 1999. “A P\* Primer: logit models for social networks.” *Social Networks* 21:37-66.

**Robins, Garry, Pip Pattison, Yuval Kalish, and Dean Lusher**. 2007. “An Introduction to Exponential Random Graph (p\*) Models for Social Networks.” *Social Networks* 29:173-191.

**Dekker, David, and David Krackhardt**. 2007. “Sensitivity of MRQAP Tests to Collinearity and Autocorrelation Conditions.” *Psychometrika* 72:563-581.

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**Hoffman, Donna, and George Franke**. 1986. “Correspondence Analysis: graphical representation of categorical data in marketing research.” *Journal of Marketing Research* 23:213-227.

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**Wasserman, Stanley, and Philippa Pattison**. 1996. “Logit Models and Logistic Regressions for Social Networks.” *Psychometrika* 61:401-425.

**Wasserman, Stanley, and Philippa Pattison**. 1996. “Logit Models and Logistic Regressions for Social Networks.” *Psychometrika* 61:401-425.

**Further Exploration (read if interested)**

**Batchelder, William, and A. Kimball Romney**. 1988. “Test Theory Without an Answer Key.” *Psychometrika* 53:71-92.

**Lecture IX: Network Dynamics I (Simulation)**

**Friedkin, Noah and Eugene Johnsen**. 1999. Social Influence Networks and Opinion Change. *Advances in*  *Group Processes* 16: 1-29.

**Monge, P. R. and Contractor, Noshir**. 2001. Emergence of communication networks. In F. M. Jablin & L. L. Putnam (Eds.), *The New Handbook of Organizational Communication: Advances in Theory, Research, and Methods* (2nd ed., pp. 440-502). Thousand Oaks, CA: Sage.

**Johnson, Jeff, Palinkas, Lawrence, and Boster, James**.2004. Informal social roles and the evolution and stability of social networks. In R. Breiger, K. M. Carley & P. Pattison (Eds.), *Dynamic Social Network Modeling and Analysis: 2002 Workshop Summary and Papers* (pp. 121-32). Washington, DC: National Academies Press.

**Watts, Duncan**. 1999. Networks, dynamics, and the small world phenomenon. *American Journal of Sociology*, *105*(2), 493-527

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**Carley, Kathleen**. 1991. “A Theory of Group Stability.” *American Sociology Review* 56:331-354.

**Optional Readings (may be discussed)**

**Watts Duncan and Strogatz Stephen**. 1998. Collective dynamics of 'small-world' networks. *Nature* 393, 440-442.

**Friedkin, Noah**. 1998. *A Structural Theory of Social Influence*. New York: Cambridge University Press (hard copy available in CASOS lab).

**Skyrms, Brian, and Robin Pemantle**. 2004. “A Dynamic Model of Social Network Formation.” *Proceedings of the National Academy of Sciences* 97:9340-9346.

**Hirshman, Brian, Michael Martin, Michael Bigrigg, and Kathleen Carley**. 2008. *The Impact of Educational Interventions on Real and Stylized Cities*. Techincal report number CMU-ISR-08-114. Carnegie Mellon University School of Computer Science: Carnegie Mellon University, Pittsburgh PA.

**Hill a L, Rand DG, Nowak MA, Christakis NA**. Emotions as infectious diseases in a large social network: the SISa model. *Proceedings of the Royal Society B: Biological Sciences*. 2010;(July):3827-3835.

**Hill AL, Rand DG, Nowak MA, Christakis NA**. Infectious Disease Modeling of Social Contagion in Networks Bergstrom CT, ed. *PLoS Computational Biology*. 2010;6(11):e1000968.

**Centola D**. The Spread of Behavior in an Online Social Network Experiment. *Science*. 2010;329(5996):1194-1197.

**Further Exploration (read if interested)**

**Macy, Michael, James Kitts, and Andreas Flache**. 2003. “Culture Wars and Dynamic Networks: a hopfield model of emergent structure.” Pp. 1-6 in *First Conference of the European Social Simulation Association*.

**Carley, Kathleen et al**. 2006. “BioWar: scalable agent-based model of bioattacks.” *IEEE Society, Man, and Cybernetics Part A* 3:1-12.

**Lecture X: Network Dynamics II (Inference)**

**Wasserman & Faust,** Chapter 17(17.2)

**McCulloh, Ian, and Kathleen Carley**. 2008. *Social Network Change Detection*. Technical report number CMU-CS-08-116. Carnegie Mellon University School of Computer Science: Carnegie Mellon University, Pittsburgh PA.

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**Optional Readings (may be discussed)**

**Snijders, Tom**. 2004. “Models for Longitudinal Network Data.” in *Models and Methods in Social Network Analysis*. New York: Cambridge University Press.

**Doreian, Patrick, and Frans Stokman**. 1997. *Evolution of Social Networks*. Amsterdam, The Netherlands: Gordon and Breach Publishers (hard copy available in CASOS lab upon request).

**Moon, Il-Chul, and Kathleen Carley**. 2006. “Estimating the Near-Term Changes of an Organization with Simulations.” Pp. 1-8 in *AAAI Fall Symposium*. Arlington, VA.

**Further Exploration (read if interested)**

**Cataldo, Marcelo, Patrick Wagstrom, James Herbsleb, and Kathleen Carley**. 2006. “Identification of Coordination Requirements: implications for the design of collaboration and awareness tools.” in *Proceedings of the 2006 Conference on Computer Supported Cooperative Work*. Banff, Alberta.

**McCulloh, Ian, and Kathleen Carley**. 2008. *Detecting Change in Human Social Behavior Simulation*. Technical report number CMU-ISR-08-135. Carnegie Mellon University School of Computer Science: Carnegie Mellon University.

 **Hamming, Richard**. 1950. “Error Detecting and Error Correcting Codes.” *The Bell System Technical Journal* 29:1-14.

**Lecture XI: Issues of Analysis and Inference**

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