

Course 08-801, 08-640, 19-640

Dynamic Network Analysis (Spring 2016)

Instructor

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Wednesdays 4:30-5:20 pm (Lab, Location TBA)

Introduction

Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do these networks evolve? How do network constrain and enable behavior? How can a network be compromised or made resilient? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis and link analysis, is a fast-growing interdisciplinary field aimed at understanding simple & high dimensional networks, from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, & simulation methodologies are used.

An interdisciplinary perspective on network science is provided, with an emphasis on high-dimensional dynamic data. The fundamentals of network science, methods, theories, metrics & confidence estimation, constraints on data collection & bias, and key research findings & challenges are examined. Illustrative networks discussed include social media based (e.g., twitter), disaster response, organizational, semantic, political elite, crises, terror, & P2P networks. Critical procedures covered include: basic centralities and metrics, group and community detection, link inference, network change detection, comparative analytics, and big data techniques. Applications from business, science, art, medicine, forensics, social media & numerous other areas are explored. Key issues addressed: Conceptualization, measurement, comparison & evaluation of networks.

Identification of influential nodes and hidden groups. Network emergence, evolution, change & destabilization.

In this course, the fundamentals of network science, the methods, the theories, the constraints on data collection are examined. This graduate seminar, 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?

Prerequisite: Undergraduate-level statistics course or instructor permission. Linear algebra is recommended but not required. Students are encouraged to bring & use their own data, or to use provided data.

Course Content

Lecture slides and supplemental readings are available in the Course Content section of Blackboard. Weka data mining software is freely available and can be downloaded from <http://www.cs.waikato.ac.nz/ml/weka/downloading.html>.

Software

Required Software

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

Available Software

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/>

Books

Required Books

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

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

Carley, K.M. & Pfeffer, J. 2015 (expected). *Dynamic Network Analysis*.
Available at: http://www.casos.cs.cmu.edu/projects/book/DNA-Book_Draft.pdf

Recommended Books (to be aware of)

Marina Hennig, Ulrik Brandes, Jürgen Pfeffer, and Ines Mergel, 2014, *Studying Social Networks: A Guide to Empirical Research*, University of Chicago Press

Ian McCulloh, Helen Armstrong & Anthony Johnson, 2013, *Social Network Analysis with Applications*, Wiley

Scott J and PJ Carrington, 2011, *The SAGE handbook of social network analysis*, Sage Publications

D. Easley, J. Kleinberg. 2010, *Networks, Crowds, and Markets: Reasoning About a Highly Connected World*. Cambridge University Press.

National Research Council, 2006. *Network Science*

<http://www.nap.edu/catalog/11516.html> or
<http://www.nap.edu/books/0309100267/html/>

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

Carrington PJ, Scott S, and S. Wasserman, 2005, *Models and Methods in Social Network Analysis*. Vol. 28. Cambridge university press

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

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

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.

A.-L. Barabási, 2002, [Linked: The New Science of Networks](#) Perseus, Cambridge, MA,

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

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

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

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

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

[Assignments, Grading, and Late Work Policy](#)

Homework: 5 x 100 point Problem Sets

- **HW1** Issued: 1/13; Due: 11:59 pm 1/24
- **HW2** Issued: 1/28; Due: 11:59 pm 2/7
- **HW3** Issued: 2/10; Due: 11:59 pm 2/21
- **HW4** Issued: 2/24; Due: 11:59 pm 3/6
- **HW5** Issued: 3/16; Due: 11:59 pm 3/27
- **HW6** Issued: 3/30; Due: 11:59 pm 4/10

Course Project: 500 points

- **Project Proposal:** Due 2/21; A brief discussion of your proposed research problem, dataset, methods, and expected challenges. No more than 500 words.
- **Project Draft:** Due 3/27; Intro, Background, and Methodology Sections
- **Project Presentation:** Due 4-18 April, 10-15 minute conference talk discussing your project's methods and key findings
- **Project Write Up:** Due 5/9; Publication style write up of your project. See examples on Blackboard

Late Work Policy: You are expected to turn in all work on time. Because we understand that exceptional circumstances may arise, each student will be permitted to turn in two of their assignments up to 48 hours late with no penalty. Any other late assignments will not be accepted.

Course Outline

Lecture I: Introduction – What is Dynamic Network Analysis

Carley, K.M. & Pfeffer, J. Chapter 1, 6.1

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

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.

Interesting but inaccurate - National Research Council, Chapters 1,2,4,5.

<http://books.nap.edu/openbook.php?isbn=0309100267>

Lecture II: Network Elite

Carley, K.M. & Pfeffer, J. Chapter 2

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.

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

Lecture III: Groups

Carley, K.M. & Pfeffer, J. Chapter 4

Wasserman & Faust, Chapter 7,8,9,10,12, --- *for reference only*

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.

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

Lecture IV: 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.

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

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

Lecture V: Compare and Contrast Networks

Carley, K.M. & Pfeffer, J. Chapter 6.3

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.

Lecture VI: Issues of Analysis and Inference

Borgatti, Stephen, Kathleen Carley, and David Krackhardt. 2006. "On the Robustness of Centrality Measures under Conditions of Imperfect Data." *Social Networks* 28:124-136.

Anderson, Brigham, Carter Butts, and Kathleen Carley. 1999. "The Interaction of Size and Density with Graph-Level Indices." *Social Networks* 21:239-267.

Banks, David, and Kathleen Carley. 1994. "Metric Inference for Social Networks." *Journal of Classification* 11:121-149.

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.

Lecture VII: Data Discovery, Missing Data, Sampling

Gjoka, M., Butts, C. T., Kurant, M., & Markopoulou, A. (2011). Multigraph sampling of online social networks. *Selected Areas in Communications, IEEE Journal on*, 29(9), 1893-1905.

Gjoka, M., Kurant, M., Butts, C. T., & Markopoulou, A. (2011). Practical recommendations on crawling online social networks. *Selected Areas in Communications, IEEE Journal on*, 29(9), 1872-1892.

Airoldi, E. M., & Carley, K. M. (2005). Sampling algorithms for pure network topologies: a study on the stability and the separability of metric embeddings. *ACM SIGKDD Explorations Newsletter*, 7(2), 13-22

Geeter, Lise, and Nir Friedman. 2002. "Learning Probabilistic Models of Link Structure." *Journal of Machine Learning Research* 3:679-707.

Lecture VIII: Meta-Networks

Carley, K.M. & Pfeffer, J. Chapter 3

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.

L Tang, H Liu, J Zhang, Z Nazeri, 2008, “Community evolution in dynamic multi-mode networks” Proceedings of the 14th ACM SIGKDD international conference on Knowledge discovery and data mining Pages 677-685

[Lecture IX: Link Inference & From Links to Networks](#)

Granovetter, M.S., 1973. The Strength of Weak Ties. *American Journal of Sociology* 78, 1360–1380.

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.

[Lecture X: Network Dynamics I \(Simulation\)](#)

Carley, K.M. & Pfeffer, J. Chapter 7.1, 7.2

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

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

[Lecture XI: Network Dynamics II \(Inference\)](#)

Carley, K.M. & Pfeffer, J. Chapter 6.2,6.4,6.5

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.

Snijders, Tom, Philippa Pattison, Garry Robins, and Mark Handcock. 2006. “New Specifications for Exponential Random Graph Models.” *Sociological Methodology* 36:99-153.

Snijders, Tom, Christian Steglich, and Michael Schweinberger. 2007. “Modeling the Co-Evolution of Networks and Behavior.” Pp. 41-72 in *Longitudinal Models in the Behavioral and Related Sciences*. Mahwah, NJ: Lawrence Erlbaum Associates.

[Lecture XII: Big Data Analytics](#)

Pfeffer, Jürgen & Carley, Kathleen M. 2012. k-Centralities: Local Approximations of Global Measures Based on Shortest Paths. Proceedings of the WWW Conference 2012, 1st International Workshop on Large Scale Network Analysis (LSNA 2012), Lyon, France

Kas, M., Carley, K. M., & Carley, L. R. (2015). An Incremental Algorithm for Updating Betweenness Centrality and k-Betweenness Centrality and Its Performance on Realistic Dynamic Social Network Data. *Social network analysis and mining (SNAM)*. Springer Vienna. Vol. 4, No. 1, pp. 234-256, Jan 9, 2015.

Leskovec, J., & Faloutsos, C. (2007, June). Scalable modeling of real graphs using kronecker multiplication. In *Proceedings of the 24th international conference on Machine learning* (pp. 497-504). ACM.

Lecture XIII: Application: Social Media

Kwak, H., Lee, C., Park, H., Moon, S., 2010. What is Twitter, a social network or a news media?, in: *Proceedings of the 19th International Conference on World Wide Web, WWW '10*. ACM, New York, NY, USA, pp. 591–600.

Carley, Kathleen M. & Pfeffer, Jürgen & Liu, Huan & Morstatter, Fred (2014). Embassies Burning: Toward a Near Real Time Assessment of Social Media Using Geo-Temporal Dynamic Network Analytics. In: *Social Network Analysis and Mining* 4(1). 1-23.

Lecture XIV-XV: Application: Organizations

Krackhardt, David, and Daniel Brass. 1994. "Interorganizational Networks: the micro side." Pp. 207-229 in *Advances in Social Network Analysis: research in the social and behavioral sciences*, S. S. Wasserman & J. Galaskiewicz (Eds.). Thousand Oaks, CA: Sage.

Burt, Ronald. 1992. "The Social Structure of Competition." Chapter 2 in *Structural Holes*. Harvard University Press, Boston MA (pp. 57-89).

Cross, R. L., & Parker, A. (2004). *The hidden power of social networks: Understanding how work really gets done in organizations*. Harvard Business Press.

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual review of sociology*, 415-444.

Lecture XV: Application: TBD

Lecture XVI: Application: Counter-Terrorism

http://www.slate.com/articles/news_and_politics/searching_for_saddam/2010/02/searching_for_saddam.html

Carley, Kathleen, Ju-Sung Lee, and David Krackhardt. 2002. "Destabilizing Networks." *Connections* 24:79-92.

Enders, Walter, and Paan Jindapon. 2010, "Network externalities and the structure of terror networks." *Journal of Conflict Resolution* 54(2): 262-280.

John Horgan, Michael Kenney, Cale Horne, Peter Vining, Kathleen M. Carley, Michael Bigrigg, Mia Bloom, and Kurt Braddock, 2014, "Competitive Adaptation in Terrorist Networks: Preliminary Findings From an Islamist Case Study," in *Counter-terrorism & Hostile Intent: Human Factors Theory and Application*, edited by Alex Stedmon, Glyn Lawson & Rose Saikayasit (London: Ashgate, 2014).

Lecture XVII: Application: Health

Christakis, N. A., & Fowler, J. H. (2007). The spread of obesity in a large social network over 32 years. *New England journal of medicine*, 357(4), 370-379.

Scanfeld, D., Scanfeld, V., & Larson, E. L. (2010). Dissemination of health information through social networks: Twitter and antibiotics. *American journal of infection control*, 38(3), 182-188.

Jacqueline A. Merrill, Kathleen M. Carley, Mark G. Orr, Christie Y. Jeon and Jonathon Storricks, 2012, "Patterns of Interaction Among Local Public Health Officials and the Adoption of Recommended Practices," *Frontiers in Public Health Services and Systems Research*, 1:1, Article 6. Available from: <http://uknowledge.uky.edu/frontiersinphssr/vol1/iss1/6>

Lecture XVIII-XIX: Application: Diffusion

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

D López-Pintado, 2008. Diffusion in complex social networks. *Games and Economic Behavior*

Granovetter, M., 1978. Threshold Models of Collective Behavior. *American Journal of Sociology* 83, 1420–1443.

Lecture XX-XXI: Network Text Analysis

Carley, K.M. & Pfeffer, J. Chapter 8

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

Diesner, J., Frantz, T.L., Carley, K.M., 2005. Communication Networks from the Enron Email Corpus "It's Always About the People. Enron is no Different". *Comput. Math. Organ. Theory* 11, 201–228.

Somers, M.R., 1994. The narrative constitution of identity: A relational and network approach. *Theory and society* 23, 605–649.

Corman, S.R., Kuhn, T., Mcphee, R.D., Dooley, K.J., 2002. Studying Complex Discursive Systems. *Human Communication Research* 28, 157–206.

Lecture XXII-XXV: Final Presentations

Lecture XVI LAST: The Future of Network Science

Carley, K.M. & Pfeffer, J. Chapter 9

Carley, Kathleen, and Allen Newell. 1994. "The Nature of the Social Agent." *Journal of Mathematical Sociology* 4:221-262.

Kenneth Joseph, Kathleen M. Carley, David Filonuk, Geoffrey P. Morgan, and Jürgen Pfeffer, to appear. Arab Spring: From News Data to Forecasting. *Social Networks and Mining*.

Butts, Carter, and Kathleen Carley. 2000. *Spatial Models of Large-Scale Interpersonal Networks*. Thesis Preprint. Pittsburgh, PA: Carnegie Mellon University.