Dynamic Network Analysis (Spring 2024)
Course 17-801, 17-685, 19-640

Instructor

Prof. Kathleen M Carley Phone: x86016

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E-Mail: kathleen.carley@cs.cmu.edu

Office Hours: by appointment; contact Sienna Watkins for scheduling
smwatkin@andrew.cmu.edu

****In-person & remote instruction**

Lectures: Monday and Wednesdays 4:00pm – 5:50pm, Tepper 1403

Recitation: Fridays 9:00-9:50 am, Posner Hall 153

Join Zoom Meeting

S24 Dynamic Network Analysis

https://cmu.zoom.us/j/98227048018?pwd=dndUWmlzY201VytpaHNIVlhWaHFBQT09

Meeting ID: 982 2704 8018

Passcode: 125047

Teaching Assistants

Catherine King; E-mail: cking2@andrew.cmu.edu, Office hour: Wed 1:30-2:30pm (TCS 444)

Charity Jacobs; E-mail: csking@andrew.cmu.edu, Office hour: Mon 1:30-2:30pm (TCS 444)

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 networks constrain and enable behavior? How can a network be compromised or made resilient? What are network cascades? Network Science can address such questions. Network Science, a.k.a. social network analysis, link analysis, geo-network analysis, and dynamic network analysis, is a fast-growing interdisciplinary field to understand simple & high dimensional networks from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, & simulation methodologies help to reason about complex systems as networks

This course provides an interdisciplinary perspective on network science, emphasizing high-dimensional dynamic data. We will examine the fundamentals of network science, methods, theories, metrics & confidence estimation, constraints on data collection & bias, and key research findings & challenges. 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. We explore applications from business, science, art, medicine, forensics, social media & numerous other areas. Key issues addressed: Conceptualization, measurement, comparison & evaluation of networks. Identification of influential nodes and hidden groups. Network emergence, evolution, change & destabilization.

In this course, we examine the fundamentals of network science, the methods, the theories, the constraints on data collection. This graduate seminar offers an overview and evaluation of the theory and research on networks broadly defined. Students are encouraged to bring and use their own data or use one of a 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, assignments, and supplemental readings are available for the course on Canvas. 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-PRO --- to be provided by Dr. Carley

NetMapper --- to be provided by Dr. Carley

Important Background Reading

Kathleen M. Carley, 2017, "ORA: A Toolkit for Dynamic Network Analysis and Visualization." In Reda Alhajj and Jon Rokne (Eds.) Encyclopedia of Social Network Analysis and Mining, Springer. DOI:10.1007/978-1-4614-7163-9_309-1

Neal Altman, Kathleen M. Carley and Jeffrey Reminga, 2022, ORA User's Guide 2022, Carnegie Mellon University, School of Computer Science, Institute for Software Research, Pittsburgh, Pennsylvania, Technical Report CMU-ISR-22-107, http://www.casos.cs.cmu.edu/publications/papers/CMU-ISR-22-107.pdf.

Books

Required Books

Papers referenced under lectures are available on Canvas.

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

Carley, K.M. 2017. 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

Sean Everton, 2012, *Disrupting Dark Networks,* Cambridge University Press

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

David Easley and Jon 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.

Albert-László Barabási and Jennifer Frangos. 2014. *Linked: the new science of networks science of networks*. Basic Books.

Duncan J. Watts, 1999. *Small worlds: the dynamics of networks between order and randomness*. Princeton university press, 1999.

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

Jackson, Sarah J., Moya Bailey, and Brooke Foucault Welles, 2020, #HashtagActivism: Networks of race and gender justice**.** MIT Press

Take care of yourself.

Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support.

Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at https://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922

Re:solve Crisis Network: 888-796-8226

If the situation is life threatening, call the police:

On campus: CMU Police: 412-268-2323 Off campus: 911

If you have questions about this or your coursework, please contact Prof. Kathleen M. Carley kathleen.carley@cs.cmu.edu

Assignments, Grading, and Late Work Policy

Please note that final letter grades may be curved.

Homework (40% of grade for PhD, 60% of grade for Masters): 6 homeworks are scaled to 100 points each. Homework assignments typically have extra problems for PhD students.

- HW 1: Due 31 January at 11:59 pm
- HW 2: Due 14 Feb at 11:59 pm
- HW 3: Due 13 March at 11:59 pm
- HW 4: Due 27 March at 11:59 pm
- HW 5: Due 10 April at 11:59 pm
- HW 6: Due 24 April at 11:59 pm

Research Paper Review Presentation(s) (5% of grade): Masters students present once, PhD students present twice. Graded out of 50 points per presentation. Scaled to 75 points total for PhD students.

- Research papers will be assigned by the instructor.
- Students will produce a PowerPoint presentation that provides a detailed description and critique of their assigned paper (~15 minutes).
- Students must ask questions of other presenters**.**

Participation (5% of grade): Students are expected to attend class and ask questions. 75 points for PhD students, 50 points for Masters students.

Final Project (50% of grade for PhD/30% of grade for Masters): 750 points for PhD, 300 points for Masters students.

- **Project Short Proposal** (10 points): A brief discussion of your proposed research problem, dataset, methods, and expected challenges (not to exceed 500 words). **DUE FEB 7 at** 11:59 pm**)**
- **Project Update** (10 points): Revisions to the project proposal based on feedback. Includes formal research questions, a more detailed description of data and networks, and a list of 2-3 network papers for your Background section. **DUE FEB 23 at** 11:59 pm
- **Project Final Update** (10 points): Network overviews, methods. Suggested to include Intro, Background, and Methods sections of Final Paper. **DUE MAR 15** at 11:59 pm
- **Project Paper First Draft** (100/30 points): **DUE APR 15 at** 11:59 pm
- **Project Presentation** (200/100 points): Conference talk discussing your project's methods and key findings (not to exceed 15 minutes) **DUE 10 APR - 22 APR**
- **Project Paper** (420/140 points): Publication style write-up of your project **DUE 3 MAY**
- Detailed requirements will be posted to canvas.

No Classes on Monday January 16th

****No Classes during Spring Break March 4th - 8th***

*****No Classes during Spring Carnival Thursday and Friday April 11th and 12th***

Late Work Policy: You are expected to turn in all work on time. However, we understand that exceptional circumstances may arise. If you need an extension, you must reach out to Prof. Carley in advance of the deadline. Please copy the TAs on the email if you receive an extension. Otherwise, a late assignment may be docked 15%.

For assistance with the written or oral communication assignments in this class, visit the Global Communication Center (GCC). The GCC is a free service, open to all students, and located in the Hunt Library. GCC tutors can provide instruction on a range of communication topics and can help you improve your papers and presentations. You can make tutoring appointments directly on the GCC website: http://www.cmu.edu/gcc. You may also visit the GCC website to learn about communication workshops offered throughout the academic year. To find out more about any of the ways the GCC can help you, please email them at gcc-cmu@andrew.cmu.edu

ChatGPT Policy: You may use ChatGPT to assist you in writing your paper or fixing any grammatical errors. However, you **must** abide by the following guidelines:

1. Acknowledge any usage of ChatGPT and estimate the amount of verbiage that came from ChatGPT.
2. Double check all references to ensure they are real and correct.
3. Use best practices, which includes sculpting any text provided to make sure it has the correct tense and that it flows naturally within the paper.

University Policy on Cheating and Plagiarism You are expected to read and attend to the information in - University Policy on Academic Integrity. The full policy is available by clicking the hyperlinked text above. Additional information about the university process for handling violations and links to resources is also available via this comprehensive website:

http://www.cmu.edu/academic-integrity/index.html .

It is extremely important that the homework, assignments, papers, and tests that you turn in during the course reflect your own understanding. To copy answers from another person not only denies you the necessary feedback on whether or not you really understand the material, but it also compromises your integrity. In addition, those who do not succumb to cheating feel that they are "getting the short end of the stick" when they see others getting away with it. For these reasons, we expect everyone to behave with integrity. It is also important that the work represents your work. Thus, any unauthorized assistance in doing the course project or homework is also considered cheating.

In this class, without explicit permission of the instructor, the following do not count as original work and would constitute cheating:

- Turning in the same or largely similar paper to another class or classes. Joint work with another student on a problem set or final project.
- Copying material from the internet without citing it correctly.
- Plagiarism, including – copying images, graphs, and tables from published work. Failure to correctly cite material produced by others regardless of whether it appeared in a blog, news article, web-post, journal publication, book, etc.
- Failure to correctly cite previously published works by yourself.
- Utilizing source code developed by others or drawn from the web for your project without explicit prior permission of the instructor, and appropriate reference.

Note, papers may be assessed using automatic tools for plagiarism detection.

Course Outline

Lecture 1: Introduction – What is Dynamic Network Analysis

Carley, K.M. Chapter 1, 6.1

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.

Stadfeld, C. and Amati, V., 2021, Network mechanisms and network models. In Research Handbook on Analytical Sociology. Edward Elgar Publishing.

Recommended:

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

Lecture 2: Node and Graph Level Measures

Carley, K.M. Chapter 2

Wasserman & Faust, Chapter 5

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

Borgatti, Stephen P., 2005. "Centrality and network flow." Social networks 27(1): 55-71.

Lecture 3: Groups and Community Detection

Carley, K.M. Chapter 4

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

Newman, Mark. 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.

Recommended:

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

Fortunato, Santo. 2010, "Community detection in graphs." *Physics reports* 486.3: 75- 174.

Tiago Peixoto, 2019, "Bayesian stochastic blockmodeling." Chapter 11 in Advances in network clustering and blockmodeling p289-332, Wiley

Lecture 4: Network Topology

Barabási, Albert-László, and Réka Albert. "Emergence of scaling in random networks." *science* 286, no. 5439 (1999): 509-512.

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

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

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

Holme, Petter. "Rare and everywhere: Perspectives on scale-free networks." Nature communications 10, no. 1 (2019): 1-3.

Lecture 5: Compare and Contrast Networks

Carley, K.M. Chapter 6.3

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.

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

Goodreau, S. M., Kitts, J. A., & Morris, M. (2009). Birds of a feather, or friend of a friend?: Using exponential random graph models to investigate adolescent social networks. Demography, 46, 103-125

Recommended:

Wasserman & Faust, Chapter 15

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

Marcum, C. S., Lin, J., & Koehly, L. (2016). Growing-up and coming-out: Are 4-cycles present in adult hetero/gay hook-ups? Network Science, 4(3), 400-405.

Application Papers – Social Media Analytics (February 5th)

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

Dyer, Joel, Blas Kolic, 2020, "Public risk perception and emotion on Twitter during the Covid-19 pandemic." Applied Network Science, 5(99). DOI: 10.1007/s41109-020-00334-7

Boshmaf, Yazan, et al. "The socialbot network: when bots socialize for fame and money." Proceedings of the 27th Annual Computer Security Applications Conference. ACM, 2011.

Wang Dandan, Qian Yuxing, 2021, "Echo Chamber Effect in Rumor Rebuttal Discussions

About COVID-19 in China: Social Media Content and Network Analysis Study."
J Med Internet Res 2021;23(3):e27009

Recommended:

Smith, Marc A., Lee Rainie, Ben Shneiderman, and Itai Himelboim. 2014. "Mapping Twitter topic networks: From polarized crowds to community clusters." Pew Research Center 20. https://www.pewresearch.org/internet/2014/02/20/mapping-twitter-topic-networks-from-polarized-crowds-to-community-clusters/

Hamilton, William, et al., 2017, "Loyalty in online communities." Proceedings of the International AAAI Conference on Web and Social Media. Vol. 11. No. 1

Application Papers – Diffusion (February 5th and 7th)

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

Mbaru, Emmanuel K., and Michele L. Barnes. "Key players in conservation diffusion: using social network analysis to identify critical injection points." *Biological Conservation* 210 (2017): 222-232.

Park, Patrick S., Joshua E. Blumenstock, and Michael W. Macy, 2018, "The strength of long-range ties in population-scale social networks." Science 362, no. 6421

Romero, D.M., Meeder, B., and Kleinberg, J. , 2011. "Differences in the mechanics of information diffusion across topics: idioms, political hashtags, and complex contagion on twitter," in *Proceedings of the 20th International Conference on World Wide Web*, pp. 695–704.

Recommended:

Kempe, David, Jon Kleinberg, and Éva Tardos. 2003. "Maximizing the spread of influence through a social network." In *Proceedings of the ninth ACM SIGKDD international conference on Knowledge discovery and data mining*, pp. 137-146. ACM.

Application Papers – Organizations (February 7th and 12th)

Tsai, Wenpin, and Sumantra Ghoshal. 1998. "Social capital and value creation: The role of intrafirm networks." Academy of management Journal 41(4): 464-476.

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

Cross, Rob, Stephen P. Borgatti, and Andrew Parker. 2002. "Making invisible work visible: Using social network analysis to support strategic collaboration." California management review 44: 25-46.

Levin, Daniel Z., and Rob Cross. 2004. "The strength of weak ties you can trust: The

mediating role of trust in effective knowledge transfer." Management science 50.1: 1477-1490.

Recommended:

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. 0

Application Papers – Hate, Extremism, and Counter-Terrorism (February 12th and 14th)

Benigni, Matthew, Kenneth Joseph and Kathleen M. Carley, 2017, "Online Extremism and the Communities that Sustain It: Detecting the ISIS Supporting Community on Twitter," PLOS ONE

Burcher, Morgan, Whelan, Chad. 2015. "Social network analysis and small group 'dark' networks: an analysis of the London bombers and the problem of 'fuzzy' boundaries." *Global Crime*, DOI: 10.1080/17440572.2015.1005363.

Bovet, Alexandre, Peter Grindrod, 2022, "Organization and evolution of the UK far-right network on Telegram." Applied Network Science, 7(76). DOI: 10.1007/s41109-022-00513-8
Caiani, Manuela, Claudius Wagemann, 2009, "Online networks of the Italian and German extreme right." Information, Communication & Society, 12(1): 66-109.

Recommended:

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

Tien, Joseph H., Marisa C. Eisenberg, Sarah T. Cherng, Mason A. Porter, 2020, "Online reactions to the 2017 'Unite the right' rally in Charlottesville: measuring polarization in Twitter networks using media followership." Applied Network Science, 10. DOI: 10.1007/s41109-019-0223-3

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

Application Papers – Fake News (February 12th)

Shu, Kai, H. Russell Bernard, and Huan Liu, 2019, "Studying fake news via network analysis: detection and mitigation." Emerging research challenges and opportunities in computational social network analysis and mining.

Azzimonti, Marina, Fernandes, Marcos, 2022, "Social media networks, fake news, and polarization." European Journal of Political Economy, 102256.

Massey, Philip M., et al. "Dimensions of misinformation about the HPV vaccine on Instagram: Content and network analysis of social media characteristics." *Journal of Medical Internet Research* 22.12 (2020): e21451.

Zhou, Xinyi and Zafarani, Reza, 2019. "Network-based Fake News Detection: A Pattern-Driven Approach". ACM SIGKDD Explorations Newsletter, Vol. 21 Issue 2, pp 48-60. DOI: 10.1145/3373464.3373473

Lecture 6: Network Dynamics I

Carley, K.M. Chapter 7.1, 7.2

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

Rivera, M. T., S. B. Soderstrom and B. Uzzi. 2010. "Dynamics of Dyads in Social Networks: Assortative, Relational, and Proximity Mechanisms." Annual Review of Sociology 36: 91-115

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.

Recommended:

Rosetti, Giulio and Remy Cazabet, 2018, "Community Discovery in Dynamic Networks: A Survey." ACM Computer Survey, 51(2): Article 35. Rivera, M. T., S. B. Soderstrom and B. Uzzi. 2010. "Dynamics of Dyads in Social Networks: Assortative, Relational, and Proximity Mechanisms." Annual Review of Sociology 36: 91-115

Schröder,Tobias, Jesse Hoey, and Kimberly B. Rogers. 2016. Modeling Dynamic Identities and Uncertainty in Social Interactions: Bayesian Affect Control Theory. *American Sociological Review Vol. 81(4) 828–855.* DOI:10.1177/0003122416650963.

Newman, Mark, 2010, "Percolation & Network Resilience." In *Networks: An Introduction* by Mark Newman. Oxford Press. DOI: 10.1093/acprof:oso/9780199206650.001.0001.

Schaefer, David R. and Christopher S. Marcum. Modeling Social Networks. Chapter in the Oxford Handbook of Social Network Analysis. Edited by James Moody and Ryan Light. Forthcoming. https://osf.io/preprints/socarxiv/6rm9q

Lecture 7: Network Dynamics II

Carley, K.M. Chapter 6.2,6.4,6.5

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

Masuda, Naoki, and Petter Holme, 2019, "Detecting sequences of system states in temporal networks." Scientific reports 9, no. 1

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.

Illustrative Video: https://www.youtube.com/watch?v=CxJkVrD2ZlM

Reference: - Ingo Scholtes, *When is a Network a Network? Multi-Order Graphical Model Selection in Pathways and Temporal Networks,* to appear in KDD'17 - Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, Halifax, Nova Scotia, Canada, August 13-17, 2017.

**Adobe Software used to create video can be found at, http://www.adobe.com/products/character-animator.html

Recommended:

Wasserman & Faust, Chapter 17(17.2)

Peixoto, Tiago P., and Martin Rosvall, 2019, "Modeling Temporal Networks with Markov Chains, Community Structures and Change Points." In Temporal Network Theory, pp. 65-81. Springer, Cham.

Mahyari, A.G. and Aviyente, S., 2014, Fourier transform for signals on dynamic graphs. In 2014 48th Asilomar Conference on Signals, Systems and Computers (pp. 2001-2004). IEEE. Trails (Merrill)

Butts, C. T. (2008). A relational event framework for social action. Sociological Methodology, 38, 155-200.

Modeling Complex Interactions in a Disrupted Environment: Relational Events in the WTC Response **Scott Leo Renshaw, Selena M. Livas, Miruna G. Petrescu-Prahova, Carter T. Butts,** ArXiv, 2022 https://arxiv.org/pdf/2204.07890.pdf

Tranmer, M., Marcum, C. S., Morton, F. B., Croft, D. P., & de Kort, S. R. (2015). Using the relational event model (REM) to investigate the temporal dynamics of animal social networks. Animal Behaviour, 101, 99-105. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4502436/

Lecture 8: Ego Networks and Sphere of Influence

Dunbar, Robin I.M. 1993. "Co-Evolution of Neocortex Size, Group Size, and Language in Humans." *Behavioral and Brain Sciences* 16:681-735.

McPherson, J. M., L. Smith-Lovin, and M. Brashears. 2006. Social isolation in America. American Sociological Review 71 (3): 363-375.

Wellman, Barry. 2007. "Challenges in Collecting Personal Network Data: The Nature of Personal Network Analysis." Field Methods. 19:111

Lecture 9: Text as Networks

Carley, K.M. Chapter 8

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

Mintz, Mike, et al., 2009, "Distant supervision for relation extraction without labeled data." Proceedings of the Joint Conference of the 47th Annual Meeting of the ACL and the 4th

International Joint Conference on Natural Language Processing of the AFNLP

Gerlach, Martin, Tiago P. Peixoto, and Eduardo G. Altmann, 2018, "A network approach to topic models." Science advances 4, no. 7

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

Lecture 10: Meta-Networks

Carley, K.M. Chapter 3

Tang, L., H. Liu, J. Zhang, and 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

Aleta, Alberto, and Yamir Moreno, 2019, "Multilayer networks in a nutshell." Annual Review of Condensed Matter Physics 10 Pages: 45-62

Recommended:

Carley, K.M., 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.

Lecture 11: Missing Data, Inferring Edges, & Socio-Cultural Cognitive Maps

Lizardo, Omar. "Culture and Networks" (pp. 188-201). Sage.

Morgan, Geoffrey P., Joel Levine and Kathleen M. Carley, 2017, "Socio-Cultural Cognitive Mapping." In Proceedings of the International Conference SBP-BRiMS 2017, Dongwon Lee, YuRu Lin, Robert Thompson and Nathaniel Osgood (Eds.) July 5-8, 2017 Washington DC, Springer.

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

Rossi, Andrea, et al. (2021) "Knowledge graph embedding for link prediction: A comparative analysis." ACM Transactions on Knowledge Discovery from Data (TKDD)

15.2 (2021): 1-49.

Lecture 12: Cohesion, Social Influence, Triads, and Diamonds

Leskovec, J., Huttenlocher, D., & Kleinberg, J. (2010, April). Predicting positive and negative links in online social networks. In Proceedings of the 19th international conference on World wide web (pp. 641-650). ACM.

Aleta, Alberto, Marta Tuninetti, Daniela Paolotti, Yamir Moreno, and Michele Starnini. 2020. "Link prediction in multiplex networks via triadic closure." Physical Review Research 2,

no. 4.

Krackhardt, David. 1999. "Ties That Torture: Simmelian Tie Analysis in Organizations." Research in the Sociology of Organizations 16:183-210.

Friedkin, N. E. and E. C. Johnsen. 1990. "Social Influence and Opinions." Journal of Mathematical Sociology 15(193-205).

Carley, K.M., Michael K. Martin and Brian Hirshman, 2009, "The Etiology of Social Change," Topics in Cognitive Science, 1.4:621-650.

de Arruda, Guilherme Ferraz, Giovanni Petri, and Yamir Moreno, 2020, "Social contagion models on hypergraphs." Physical Review Research 2, no. 2

Fujimoto, K., Snijders, T. A., & Valente, T. W. (2017). Popularity breeds contempt: The evolution of reputational dislike relations and friendships in high school. Social Networks, 48, 100-109.

Recommended:

Labianca, Giuseppe, Daniel J. Brass, and Barbara Gray. 1998. "Social Networks and Perceptions of Intergroup Conflict: The Role of Negative Relationships and Third Parties." Academy of Management Journal 41:55-67

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 Erlbuam Associates.

Lecture 13: Issues of Analysis and Inference

Wei Wei, Kenneth Joseph, Huan Liu and Kathleen M. Carley, 2016, "Exploring Characteristics of Suspended Users and Network Stability on Twitter." Social network analysis and mining, 6:51.

Bernard, H. R., Killworth, P., Kronenfeld, D., & Sailer, L. 1984. The problem of informant accuracy: The validity of retrospective data. Annual review of anthropology, 13(1), 495-517.

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

Recommended:

Peixoto, Tiago P. (2018) "Reconstructing networks with unknown and heterogeneous errors." Physical Review X 8, no. 4

Application Papers – Science Networks (April 1st)

Moody, James "The Structure of a Social Science Collaboration Network: Disciplinary Cohesion from 1963 to 1999." American Sociological Review. 69:213-238

Morgan, Allison C., Dimitrios J. Economou, Samuel F. Way, and Aaron Clauset, 2018, "Prestige drives epistemic inequality in the diffusion of scientific ideas." EPJ Data Science 7, no.

Yoon, Byungun, and Yongtae Park, 2004, "A text-mining-based patent network: Analytical tool for high-technology trend." The Journal of High Technology Management Research 15.1

Meyer, M., Zaggl, M. A., & Carley, K. M. 2011. Measuring CMOT's intellectual structure and its development. Computational & Mathematical Organization Theory, 17(1), 1-34.

Application Papers – Health (April 3rd)

Rustamaji, H. C., Yustina S. Suharini, Angga A. Permana, Wisnu A. Kusuma, Sri Nudriati, Irmanida Batubara, Taufik Djatna, 2022, "A network analysis to identify lung cancer comorbid diseases." Applied Network Science, 7(30).

Merrill, Jacqueline A., Barbara Sheehan, Kathleen M. Carley, P.D. Stetson, 2015, "Transition Networks in a Cohort of Patients with Congestive Heart Failure. A novel application of informatics methods to inform care coordination." A*pplied Clinical Informatics*, *6(3)*: 548-64.

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.

Brewer, Barbara B., Kathleen M. Carley, Marge Benham-Hutchins, Judith A. Effken, and Jeffrey Reminga, 2020, "Exploring the stability of communication network metrics in a dynamic nursing context." Social networks 61

Recommended:

Pascual-Ferrá, Paola, Neil Alperstein, and Daniel J. Barnett. "Social network analysis of COVID-19 public discourse on Twitter: implications for risk communication." Disaster medicine and public health preparedness 16.2 (2022): 561-569.

Lecture 14: Big Data Analytics

Perozzi, Bryan, Rami Al-Rfou, and Steven Skiena, 2014, "Deepwalk: Online learning of social representations." Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining.

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.

Almquist, Z. W., & Butts, C. T. (2014). Logistic network regression for scalable analysis of networks with joint edge/vertex dynamics. Sociological Methodology, 44(1), 273-321.

Recommended:

Lorenzo De Stefani, Alessandro Epasto, Matteo Riondato, and Eli Upfal. 2016. TRIÈST: Counting Local and Global Triangles in Fully-Dynamic Streams with Fixed Memory Size. In *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (KDD '16). ACM, New York, NY, USA, 825- 834.

Application Papers – Geo-Spatial Networks

Yi, Huso, Shu Tian Ng, Aysha Farwin, Amanda Pei Ting Low, Cheng Mun Chang, and Jeremy Lim, 2021, "Health equity considerations in COVID-19: geospatial network analysis of the COVID-19 outbreak in the migrant population in Singapore." Journal of Travel Medicine 28, no. 2.

Kas, Miray, Kathleen M. Carley and L. Richard Carley, 2012, "Who was Where, When? Spatiotemporal Analysis of Researcher Mobility in Nuclear Science," In proceedings of the International Workshop on Spatio Temporal data Integration and Retrieval (STIR 2012), held in conjunction with ICDE 2012, April 1, 2012, Washington D.C.

Moen, E.L., Kapadia, N.S., O'Malley, A.J. and Onega, T., 2019. Evaluating breast cancer care coordination at a rural National Cancer Institute Comprehensive Cancer Center using network analysis and geospatial methods. *Cancer Epidemiology, Biomarkers & Prevention*, *28*(3), pp.455-461.

Guo, Diansheng, et al. 2012. "Discovering spatial patterns in origin-destination mobility data." *Transactions in GIS* 16.3: 411-429.

Recommended:

Merrill, Jacqueline A., Kathleen M. Carley, Mark G. Orr, Christie Y. Jeon and Jonathon Storrick, 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.

Schöttler, S., Yang, Y., Pfister, H. and Bach, B., 2021, September. Visualizing and interacting with geospatial networks: A survey and design space. In Computer Graphics Forum (Vol. 40, No. 6, pp. 5-33).

April 10th, 15th, 17th, and 22nd: Final Presentations

Lecture 15: The Future of Network Science

Carley, K.M. Chapter 9

Battiston, Federico, et al., 2020, "Networks beyond pairwise interactions: structure and dynamics." Physics Reports 874.

Porter, Mason A., 2020, "Nonlinearity + networks: A 2020 vision." Emerging frontiers in nonlinear science.

Sakr, Sherif, et al., 2021, “The future is big graphs: a community view on graph processing systems.” Communications of the ACM 64.9

Bender-deMoll, Skye & Daniel A. McFarland. 2006. “The Art and Science of Dynamic Network Visualization.” Journal of Social Structure 7(2).

Moody, James, Daniel A. McFarland, and Skye Bender-DeMoll. 2005. “Dynamic network visualization.” American Journal of Sociology 110(4):1206-41.