

# Dynamic Network Analysis (Spring 2020)

## Course 17-801, 17-685, 19-640

### Instructor

Prof. Kathleen M Carley

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### 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? What are network cascades? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis, link analysis, geo-network analysis, and dynamic network 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 to reason about complex systems as networks.

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, 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-LITE**, available from CASOS -  
<http://www.casos.cs.cmu.edu/projects/ora/>  
**ORA-PRO** --- to be provided by Dr. Carley  
**NetMapper** --- to be provided by Dr. Carley  
**Note** – on all problem sets you must use ORA.

### *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, 2019, ORA User’s Guide 2019, Carnegie Mellon University, School of Computer Science, Institute for Software Research, Pittsburgh, Pennsylvania, Technical Report CMU-ISR-19-100.

## ***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/>

## **Books**

### ***Required Books***

Get a copy of Wasserman and Faust (SNA). Many books are available on-line. Papers are 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](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.

## *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](mailto:kathleen.carley@cs.cmu.edu)

## *Assignments, Grading, and Late Work Policy*

**Homework:** 1-6 are each worth 100 points

- **HW1: Release Jan 13th, Due Jan 26th midnight**
- **HW2: Release Jan 27th, Due Feb 9th midnight**
- **HW3: Release Feb 10th, Due Feb 23rd midnight**
- **HW4: Release Feb 24th, Due Mar 8th midnight**
- **HW5: Release Mar 16th, Due Mar 29th midnight**
- **HW6: Release Mar 30th, Due Apr 12th midnight**

**Paper Presentation: 50 points each**

- Papers to be assigned by instructor.
- You present a published paper. Provide detailed description and critic – apx 15 minutes.
- To be scheduled in second half of term.
- You ask questions of other presenters.
- These will be during the application sections
- You will produce a powerpoint deck

**Course Project:** 750 for PhD 350 for MS

- **P1: Due Jan 31 - Project Short Proposal: 20** Due February; A brief discussion of your proposed research problem, dataset, methods, and expected challenges. No more than 500 words.
- **P2: Due Feb 28 - Project Revised Proposal: 30**
- **P3: Due April 3 - Project Draft 1: 200/70** March; Intro, Background, and Methodology Sections
- **P4: Due between April 24 and April 30 - Project Presentation: 230/100** To be scheduled in late April, 10-15 minute conference talk discussing your project's methods and key findings
- **P5: Due May 1 - Project Write Up: 270/130** Due Last Day of Class; Publication style write up of your project. See examples on CANVAS
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***\*\*No Classes Monday January 20<sup>th</sup>***

***\*\*\*SPRING BREAK March 9<sup>th</sup> – 13<sup>th</sup>***

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. Otherwise late assignment may be docked 15%.

For assistance with the written or oral communication assignments in this class, visit the Global Communication Center (GCC). GCC tutors can provide instruction on a range of communication topics and can help you improve your papers and presentations. The GCC is a free service, open to all students, and located in Hunt library. You can make tutoring appointments directly on the GCC website: <http://www.cmu.edu/gcc>. You may also visit the GCC website to find out 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](mailto:gcc-cmu@andrew.cmu.edu).

## [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 home-works, 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 web 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 I: Introduction – What is Dynamic Network Analysis***

**Carley, K.M.** 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.

### ***Lecture II: Network Elite***

**Carley, K.M.** Chapter 2

**Wasserman & Faust**, Chapter 5

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

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

### ***Lecture III: Groups***

**Carley, K.M.** Chapter 4

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

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

**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.

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

### **Lecture V: Compare and Contrast Networks**

**Carley, K.M.** 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, Missing Data, Sampling**

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

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

**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.

**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.

**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.

**Perozzi, Bryan, Rami Al-Rfou, and Steven Skiena.** "Deepwalk: Online learning of social representations." In *Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining*, pp. 701-710. ACM, 2014.

### **Lecture VII: Ego Networks**

**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

Everett, M. and S.P. Borgatti, 2005, "Ego network betweenness." *Social Networks* 27: 31-38

### **Lecture VIII: Meta-Networks**

**Carley, K.M.** 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

**Kathleen M. Carley, Wei Wei and Kenneth Joseph**, Nov 2015, "High Dimensional Network Analytics: Mapping Topic Networks in Twitter Data During the Arab Spring" In Shuguan Cui, Alfred Hero, Zhi-Quan Luo and Jose Moura (eds) *Big Data Over Networks*, Cambridge University Press.

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

### **Lecture IX: Link Inference & Socio-Cultural Cognitive Mapping**

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

**Geoffrey P Morgan, 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.

### **Lecture X: Triads**

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

**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

**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.

### **Lecture XI: Social Influence**

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

**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.

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

## **Lecture XII: Network Dynamics I**

**Carley, K.M.** Chapter 7.1, 7.2

**Tobias Schröder, 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.

**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

**Jacqueline A. Merrill, 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.” *Applied Clinical Informatics*, 6(3): 548-64.

**Giulio Rossetti, Remy Cazabet,** 2018, “Community Discovery in Dynamic Networks: A Survey.” *ACM Computer Survey*, 51(2): Article 35.

**Charu Aggarwal, Karthik Subbian,** 2014, “Evolutionary Network Analysis: A Survey.” *ACM Computer Survey*, 47(1): Article 10.

## **Lecture XIII: Network Dynamics II**

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

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

**Illustrative Video:** <https://www.youtube.com/watch?v=CxJkVrD2ZIM>

**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>

**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.

**Additional Materials/Software:**

- GitHub page of python package pathpy, <https://github.com/IngoScholtes/pathpy>
- ipython tutorial, <https://ingoscholtes.github.io/pathpy/tutorial.html>

## **Lecture XIV: Geo-Spatial Networks**

## **Lecture XV: Fourier Analysis & Change Detection**

## **Lecture XVI: Network Text Analysis**

**Carley, K.M.** Chapter 8

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

**Kenneth Joseph, Kathleen M. Carley, David Filonuk, Geoffrey P. Morgan, and Jürgen Pfeffer**, 2014. "Arab Spring: From News Data to Forecasting." *Social Network Analysis and Mining*. Online publication, February 2014, 4(1), Springer Vienna.

**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.

**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.

## **Lecture XVII: Social Media Analytics**

### **Lecture XVIII: Big Data Analytics**

**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.

**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, Jure, & 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 XIX: Application: Social Media & BotNets**

**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. DOI: [10.1007/s13278-016-0358-5](https://doi.org/10.1007/s13278-016-0358-5).

**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.

**Ferrara, Emilio**, Onur Varol, Clayton Davis, Filippo Menczer, and Alessandro Flammini. "The rise of social bots." *Communications of the ACM* 59, no. 7 (2016): 96-104.

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

**Benigni, Matthew & Carley, Kathleen**, 2017, The Low Cost of Online Credibility: Socialbot Networks and Their Manipulation of Public Opinion on Twitter, Under Review

### **Lecture XX: Application: Science Networks**

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

**Powel, Walter M, Douglas R. White, Kenneth W. Koput and Jason Owen-Smith**. "Network dynamics and Field Evolution: The Growth of Inter-organizational Collaboration in the Life Sciences" *American Journal of Sociology* 110:1132-1205

**Miray Kas, 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.

**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.

### **Lecture XXI: Application: Diffusion**

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

**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.

**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.

**Newman, Mark EJ**. 2002. "Spread of epidemic disease on networks." *Physical review E* 66(1): 016128.

### **Lecture XXII: 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>
- Barbara B. Brewer, Kathleen M. Carley, Marge Benham-Hutchins, Judith A. Effken, and Jeff Reminga**, 2018-under review, Exploring the Stability of Communication Network Metrics in a Dynamic Nursing Context
- Harriet Keane, Brent J. Ryan, Brendan Jackson, Alan Whitmore, and Richard Wade-Martins**, 2015, "Protein-protein interaction networks identify targets which rescue the MPP+ cellular model of Parkinson's disease," *Scientific Reports*, 5:17004, DOI: 10.1038/srep17004.

### **Lecture XXIII: 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).
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***Lecture XXV: Fake News***

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***Lecture XXIX LAST: The Future of Network Science***

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