15.579 Fall 2018
Applied Network Theory and Analysis
Professor Sinan Aral
W: 1-4pm Room: E62-587

Instructor	**Professor Sinan Aral**
Classroom	E62-587
Class times	Wednesday 1-4pm
Office Hours	By Appointment
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Summary and Objectives

This course will examine the foundations of and recent advances in Network Theory, Network Science and Applied Network Analysis from sociological, economic and statistical perspectives. The course is aimed at doctoral students conducting original research in applied network theory and analysis in a diverse set of fields including sociology, economics, statistics, computer science/machine learning, management, computational biology and physics. The course will follow a research seminar format, with deep critical examinations of original research papers from these disciplines, designed to teach networks research through an evaluation of networks research. Topics covered include: network structure, foundations of sociological network theory, weak ties and structural holes, embeddedness, homophily and assortative mixing, information diffusion in networks, small world phenomena, influence maximization in networks, statistical inference in networks, causal inference in networks, networks and coordination, network dynamics, networked experiments, estimating peer effects, networked interventions and more.

Topics Covered: The course will cover, but not be limited to, the following topics:

- Fundamentals of Network Structure
- Random Graphs
- Scale Free Networks
- Small World Phenomena
- The Strength of Weak Ties, Structural Holes, Embeddedness
- The Diversity-Bandwidth Tradeoff
- Homophily and Assortativity
- Information Diffusion and Cascading Behavior
- Contagion on Networks
- Influence Maximization
- Optimal Network Seeding
- Networks, Coordination and Cooperation
- Community Detection and Graph Evolution
- Theoretical Models of Causal Inference in Networks
- Applied Causal Inference in Networks: Peer Effects and Social Influence

- Networked Experiments
- Interference in Networked Experiments
- The Future of Networks Research

Course requirements

There are three main requirements in this course:

1. **Participation in Class Discussion:** Clearly, discussion makes up the bulk of the class. You should consider that your participation in the discussion will be the key to you learning and benefiting from the class. Active, productive and useful participation that contributes to the learning we are accomplishing in the classroom will be rewarded.

2. **Discussion Questions:** Each week, you will be asked to write a short reflection on the reading for that week. The basic idea is to begin an intellectual discussion about the thoughts that the reading inspired in you with regard to research. The conversation could be about whether you think the scientific questions being asked in the work were intellectually important and why, what theoretical or methodological insights you gleaned from reading the papers, where the research should go from here, what the strengths and weaknesses of the theory or methods entailed, what did you learn (or not learn) from the work, what would you have done differently and why, etc. These reflections are intended to be short, meaning up to 1 page in length.

   Please Email Your Answers to Allison McDonough (almcd@mit.edu) by 1pm every Wednesday.

3. **Final Term Paper:** You will write a final term paper that proposes a research study, introduces the puzzle or problem the research addresses, defends the intellectual importance of the work, describes and defends the methodology you would use to address the questions asked, describes and defends the data (if any) you would collect and how you would collect it, describes and defends the methods you would use to conduct analyses, describes the results that you would expect, comments on the contribution of the work to the literature and describes next steps in the line of research it would create or contribute to.

Grading

Discussion Questions: 30%
Final Term Paper: 35%
Participation in Class Discussion: 35%

Class Schedule

	Date	*Session*
S1	9/5	***Introduction to Networks Research***
S2	9/12	***Fundamentals of Network Structure***
S3	9/19	***Small World Phenomena***
S4	9/26	***Weak Ties, Structural Holes and Embeddedness***
S5	10/3	***Homophily and Assortativity***
S6	10/10	***Diversity, Heterogeneity & Knowledge Productivity***
S7	10/17	***Information Diffusion & Cascading Behavior***
	10/24	***SIP – NO CLASS***
S8	10/31	***The Influence Maximization Problem***
S9	11/7	***Networks, Coordination & Cooperation***
S10	11/14	***Theoretical Models of Causal Inference in Networks***
	11/21	***(PRE) THANKSGIVING - NO CLASS***
S11	11/28	***Applied Causal Inference in Observational Networks***
S12	12/5	***Experiments in Networks: Peer Effects and Social Influence***
S13	12/12	***Approaches to Interference in Networked Experiments***
S14	TBD	***The Future of Networks Research***

Reading List

Session 1: *Introduction to Networks Research* (9/5): *No Readings*.

Session 2: *Fundamentals of Network Structure* (9/12):

1. "*Chapter 2: Graphs*" David Easley and Jon Kleinberg (2010) Networks, Crowds, and Markets: Reasoning about a Highly Connected World, Cambridge University Press.
2. *"Emergence of Scaling in Random Networks"* Laszlo Barabasi and Reka Albert (1999); Science, 286 (5439), 509-512.
3. *"Community Structure in Social and Biological Networks"* M. Girvan and M.E.J. Newman (2002), Proceedings of the National Academy of Sciences (PNAS), 99(12): 7821–7826.
4. *"Subgraph Frequencies: Mapping the Empirical and Extremal Geography of Large Graph Collections"* Johan Ugander, Lars Backstrom, Jon Klienberg (2013); In Proceedings of the International Conference on World Wide Web (WWW), May 13–17, 2013, Rio de Janeiro, Brazil. ACM 978-1-4503-2035-1/13/05.

Optional Reading:

5. *"Random graphs with arbitrary degree distributions and their applications"* MEJ Newman, SH Strogatz, DJ Watts (2001); Physical Review E.

Session 3: *Small World Phenomena* (9/19):

6. *"An experimental study of the small world problem"* J. Travers and S. Milgram (1969); Sociometry 32.
7. *"Collective Dynamics of Small World Networks"* Duncan Watts and Steve Strogatz (1999); Nature, 393: 440-442.
8. *"Networks, Dynamics and the Small World Phenomenon"* Duncan Watts (1999); American Journal of Sociology, 105(2): 493-527.
9. *"Identity and Search in Social Networks"* Duncan Watts, Peter Dodds and Mark Newman (2002); Science, 296(5571): 1302-1305.

Optional Reading:

10. *"Small World Phenomena and the Dynamics of Information"* Jon Kleinberg (2002); Advances in neural information processing systems, 1, 431-438.
11. *"Small World Phenomena: An Algorithmic Perspective"* Jon Kleinberg (2000); In Proceedings of the thirty-second annual ACM symposium on Theory of computing (pp. 163-170). ACM.

Session 4: *Weak Ties, Structural Holes & Embeddedness* (9/26):

12. *"The Strength of Weak Ties"* Mark Granovetter (1973); American Journal of Sociology, 1360-1380.
13. *"Structural Holes: The Social Structure of Competition. Chapter 5: Formalizing the Argument"* Burt, R. S. (2009). Structural Holes: The Social Structure of Competition. Harvard University Press: 50-81.

14. *"Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness"* Uzzi, B. (1997); Administrative Science Quarterly, 35-67.
15. *"The Diversity-Bandwidth Tradeoff"* Sinan Aral and Marshall Van Alstyne (2011); American Journal of Sociology, 117(1): 90-171.
16. *"The Future of Weak Ties"* Sinan Aral (2016); American Journal of Sociology, 121(6): 1931-1939.

Optional Reading:

17. *"Structural Holes and Good Ideas"* Ronald Burt (2004); American Journal of Sociology 110(2): 349-399.

Session 5: *Homophily & Assortativity* (10/3):

18. *"Birds of a Feather: Homophily in Social Networks"* Miller McPherson, Lynn Smith-Lovin, and James M Cook (2001) Annual Review of Sociology, 27: 415-444.
19. *"Origins of Homophily in an Evolving Social Network"* Kossinets and Duncan Watts (1999) American Journal of Sociology, 115(2): 405-450.
20. *"Identifying the roles of race-based choice and chance in high school friendship network formation"* Sergio Currarini, Matthew O. Jackson, and Paolo Pin (2010) Proceedings of the National Academy of Sciences (PNAS); 107(11): 4857–4861.
21. *"Why Social Networks are Different from Other Types of Networks."* Newman, M. E., & Park, J. (2003). Physical Review E, 68(3), 036122.

Session 6: *Diversity, Heterogeneity and Knowledge Productivity* (10/10):

22. *"The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organization Subunits"* Hansen, M. T. (1999); Administrative Science Quarterly, 44(1): 82-111.
23. *"Network Structure and Knowledge Transfer: The Effects of Cohesion and Range"* Reagans, R., & McEvily, B. (2003); Administrative Science Quarterly, 48(2): 240-267.
24. *"Networks, Diversity, and Productivity: The Social Capital of Corporate R&D Teams"* Ray Reagans and Ezra Zuckerman (2001) Organization Science, 12(4): 502-517.
25. *"Information, Technology and Information Worker Productivity"* Sinan Aral, Marshall Van Alstyne, Erik Brynjolfsson (2012), Information Systems Research, 23(3-part-2): 849-867.

Optional Reading:

26. *Knowledge Networks: Explaining Effective Knowledge Sharing in Multiunit Companies.* Hansen, M. T. (2002). Organization Science, 13(3): 232-248.

Session 7: *Information Diffusion & Cascading Behavior* (10/17):

27. *"Sorting and Mixing"* Thomas Shelling (1978); Micromotives and Macrobehavior; Chapter 4, Norton.
28. *"Threshold Models of Collective Behavior"* Mark Granovetter (1978) American Journal of Sociology, 1420-1443.

29. *"A Simple Model of Global Cascades in Random Networks"* Watts, D. J. (2002). Proceedings of the National Academy of Sciences (PNAS), 99(9): 5766-5771.
30. *"Complex Contagions and the Weakness of Long Ties"* Centola, D., & Macy, M. (2007) American Journal of Sociology, 113(3), 702-734.

Optional Reading:

31. *"Diffusion of Behavior and Equilibrium Properties in Network Games"* Matthew Jackson and Leeat Yariv (2007) American Economic Review: 97(2).
32. *"Innovation Diffusion in Heterogeneous Populations: Contagion, Social Influence, and Social Learning"* Young, H. P. (2009) The American Economic Review, 1899-1924.

Session 8: *The Influence Maximization Problem* (10/31):

33. *"Mining the Network Value of Customers"* Domingos, P., & Richardson, M. (2001); In Proceedings of the seventh ACM SIGKDD international conference on Knowledge discovery and data mining, pp. 57-66.
34. *"Maximizing the Spread of Influence through a Social Network"* Kempe, D., Kleinberg, J., & Tardos, É. (2003); In Proceedings of the ninth ACM SIGKDD international conference on Knowledge discovery and data mining, pp. 137-146.
35. *"Engineering Social Contagions: Optimal Network Seeding in the Presence of Homophily."* Aral, S., Muchnik, L., & Sundararajan, A. (2013). Network Science, 1(02): 125-153.
36. *"Everyone's an Influencer: Quantifying Influence on Twitter"* Bakshy, E., Hofman, J. M., Mason, W. A., & Watts, D. J. (2011). In Proceedings of the Fourth ACM International Conference on Web Search and Data Mining, pp. 65-74.

Optional Reading:

37. *"Personal Influence, The part played by people in the flow of mass communications."* Katz, E., & Lazarsfeld, P. F. (1970) Transaction Publishers.
38. *"Influence Maximization Revisited"* Aral, S. & Dhillon, P. MIT Working Paper.

Session 9: *Networks, Coordination and Cooperation* (11/7):

39. *"An Experimental Study of the Coloring Problem on Human Subject Experiments"* Kearns, M., Suri, S., & Montfort, N. (2006) Science, 313(5788), 824-827.
40. *"Cooperation and Contagion in Web-Based, Networked Public Goods Experiments"* Suri, S., & Watts, D. J. (2011). PLoS One, 6(3), e16836.
41. *"Dynamic Social Networks Promote Cooperation in Experiments with Humans"* David G Rand, Samuel Arbesman and Nicholas A Christakis (2011) Proceedings of the National Academy of Sciences (PNAS); 108(48): 19193-19198.
42. *"The Network Structure of Exploration and Exploitation"* Lazer, D., & Friedman, A. (2007); Administrative Science Quarterly, 52(4), 667-694.

Optional Reading:

43. *"Communication patterns in task-oriented groups"* Bavelas, A. (1950) J. Acoustical Soc. America 22: 725-730.

44. *"Cooperation in evolving social networks"* Hanaki, N., Peterhansl, A., Dodds, P. S., & Watts, D. J. (2007) Management Science, 53(7): 1036-1050.
45. *"Cooperation and Assortativity with Dynamic Partner Updating"* Wang, J., Suri, S., & Watts, D. J. (2012) Proceedings of the National Academy of Sciences (PNAS), 109(36): 14363-14368.
46. *"Facts and Figuring: An Experimental Investigation of Network Structure and Performance in Information and Solution Spaces"* Jesse Shore, Ethan Bernstein, David Lazer (2014) Harvard Business School Working Paper: http://www.hbs.edu/faculty/Publication%20Files/14-075_9b1b2a06-60b7-46d5-957b-c23a18aa6dcd.pdf

Session 10: *Theoretical Models of Causal Inference in Networks* (11/14):

47. *"Identifying Social Influence: A Comment on Opinion Leadership and Social Contagion in New Product Diffusion."* Sinan Aral (2011) Marketing Science*, 30(2); March/April: 217-223.*
48. *"Identification of Endogenous Social Effects: The Reflection Problem"* Charles Manski (1993) Review of Economic Studies,
49. *"Policy Interventions, Low Level Equilibria and Social Interactions"* Robert Moffitt (2001) Social Dynamics
50. *"Identification of Peer Effects through Social Networks"* Yann Bramoullé, Habiba Djebbari and Bernard Fortin (2009) Journal of Econometrics 150(1): 41–55.
51. *"Dynamic Networks and Behavior: Separating Selection from Influence"* Steglich, C., Snijders, T. A., & Pearson, M. (2010). Sociological Methodology, 40(1), 329-393.

Optional Reading:

52. *"Identification of Peer Effects in Networked Panel Data"* Aral, S., Rock, D., Taylor, S. In Proceedings of the 37th International Conference on Information Systems, Dublin, Ireland.

Session 11: *Applied Causal Inference in Observational Networks* (11/28):

53. *"Identifying Formal and Informal Influence in Technology Adoption with Network Externalities"* Catherine Tucker (2008) Management Science, 54(12): 2024-2038.
54. *"Distinguishing Influence Based Contagion from Homophily Driven Diffusion in Dynamic Networks,"* Sinan Aral, Lev Muchnik and Arun Sundararajan (2009) Proceedings of the National Academy of Sciences (PNAS), Dec. 22, 106(51): 21544-21549.
55. *"Homophily and Contagion are Generically Confounded in Observational Social Network Studies"* CR Shalizi, AC Thomas (2011) Sociological Methods & Research 40 (2): 211-239.
56. *"Bias and High-Dimensional Adjustment in Observational Studies of Social Contagion"* Dean Eckles and Eytan Bakshy (2014), Working Paper, Facebook Data Science.

Optional Reading:

57. *"Is Exercise Contagious? Peer Effects in a Global Health Behavior"* Aral, S. & Nicolaides, C. MIT Working Paper.

Sessions 12: *Experiments in Networks: Peer Effects and Social Influence* (12/5)

58. *"Peer Effects with Random Assignment: Results for Dartmouth Roommates"* Sacerdote, B. I. (2001). Quarterly Journal of Economics, 116(2), 681-704.
59. "*Creating Social Contagion through Viral Product Design: A Randomized Trial of Peer Influence in Networks*" Sinan Aral and Dylan Walker (2011) Management Science, 57(9); September: 1623-1639.
60. *"Identifying Influential and Susceptible Members of Social Networks"* Sinan Aral and Dylan Walker (2012) Science, July 20: 337-341.
61. "*The Role of Social Networks in Information Diffusion"* Bakshy, E., Rosenn, I., Marlow, C., & Adamic, L. (2012). In Proceedings of the 21st international conference on World Wide Web (pp. 519-528). ACM.

Optional Reading:

62. *"Social Influence in Social Advertising: Evidence from Field Experiments"* Bakshy, E., Eckles, D., Yan, R., & Rosenn, I. (2012) In Proceedings of the 13th ACM Conference on Electronic Commerce: pp. 146-161.
63. *"Do Your Online Friends Make You Pay? A Randomized Field Experiment in an Online Music Social Network,"* Bapna, R., Umyarov. A. (2014) Management Science, 61(8): 1902-1920.

Sessions 13: *Approaches to Interference in Networked Experiments* (12/12)

64. *"Estimating Average Causal Effects Under Interference Between Units"* Aronow, P. M., & Samii, C. (2013). http://arxiv.org/pdf/1305.6156.pdf
65. *"Graph Cluster Randomization: Network Exposure to Multiple Universes"* Ugander, J., Karrer, B., Backstrom, L., & Kleinberg, J. (2013) In Proceedings of the 19th ACM SIGKDD international conference on Knowledge discovery and data mining (pp. 329-337). ACM. http://arxiv.org/pdf/1305.6979.pdf
66. *"Design and Analysis of Experiments in Networks: Reducing Bias from Interference"* Dean Eckles, Brian Karrer, Johan Ugander (2014); Working Paper, Facebook Data Science: http://arxiv.org/abs/1404.7530
67. *"Networked Experiments"* Aral, S. (2016) in The Oxford Handbook of the Economics of Networks (Yann Bramoullé, Andrea Galeotti, and Brian Rogers eds.)

Sessions 14: *The Future of Networks Research* (TDB – Likely Evening of 12/12)

68. *"Network Interventions"* Valente, T. W. (2012); Science, 337(6090), 49-53.
69. *"Information in Digital, Economic and Social Networks."* Sundararajan, A., Provost, F., Oestreicher-Singer, G., & Aral, S. (2013). Information Systems Research, 24(4): 883-905.
70. *"Computational Social Science"* Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabasi, A.L., Brewer, D., Christakis, N., Contractor, N., Fowler, J., Gutmann, M., Jebara, A., King, G., Macy, M., Roy, D., Van Alstyne, M. (2009) Science, February 6: 721-722.