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NETS 8941
Network Science
Literature Review Seminar

Summary

This Literature Review Seminar is course designed to introduce Network Science students to a wide range of foundational research in Network Science and Complex Systems, both contemporary and historical. The goal for students is to leave the course with exposure to the ideas, insights, and techniques that were integral in the creation of Network Science as we know it today. It is difficult to commit rigidly to a single syllabus for this course; as such, the schedule is designed to be edited, expanded upon, and reconsidered. The ultimate goal is not about identifying and mastering a small number of important scientific contributions—instead, this class provides a space to learn about the insights behind the ideas we use today, untangling where and how these ideas came about, and what they evolved into.

This course is open to members of the Network Science Institute community. It is modeled after an informal journal club that was hosted by Professor Alessandro Vespignani from 2016-2018, when many NetSI members would sit together on Friday afternoons to discuss a paper. This would attract students, postdocs, and faculty, all sitting together listening to each others' questions and insights as peers. As the instructor, I will aim to guide discussion and bring students' voices and questions into the conversation, while also being willing to explore tangents and balancing our various expertises.

We also will be inviting guest participants to class. These will typically be more senior researchers who select the article(s) to read and participate in the journal club for that week, essentially as a peer—asking questions, bringing up discussion points, adding context, commenting on other students' ideas, etc. The idea is not necessarily for the students to hear a lecture from the guest participant, but rather to feel what it's like to sit around the same table and discuss big ideas. The guest participants are asked to choose the week's reading(s), which can be about their own work, or ideas that are inspiring their current work, or ideas inspired them as a student, research that they think should be required reading for young network scientists, any/all/none of the above, etc.

This syllabus will be updated and can be found here: `https://brennanklein.com/nets8941-spring24`.

Coursework, Class Structure, Grading

This is a weekly discussion-based class. As is the case in typical "journal club" settings, there will naturally be some students who are more interested and invested in the week's readings and will likely participate more. I hope to assign readings that are broad enough that every student has at least one week where the readings are especially salient. At the same time, I challenge every student to come to class prepared to ask questions and share their thoughts about the week's readings, no matter the topic.

From time to time, we may encounter disruptions to in-person class (e.g. snow, pandemic, etc.). If that is the case, we will meet at my Zoom room: https://northeastern.zoom.us/my/brennan. Zoom etiquette: Nobody likes endless, boring zoom meetings. Please do your part to create a space that is welcoming for everyone to contribute, including yourself.

Instructor

Brennan Klein is an associate research scientist at the Network Science Institute, with a joint affiliation at the Institute for Experiential AI. He is the director of the Complexity & Society Lab. His research spans two broad topics: 1) Information, emergence, and inference in complex systems — developing tools and theory for characterizing dynamics, structure, and scale in networks, and 2) Public health and public safety — creating and analyzing large scale datasets that reveal inequalities in the United States, from epidemics to mass incarceration. Dr. Klein received a PhD in Network Science in 2020 from Northeastern University and got his BA in Cognitive Science & Psychology from Swarthmore College in 2014. Website: brennanklein.com.

Schedule

Week 1: January 11, 2024 – Criticality, chaos, and networks (w/ Alessandro Vespignani)

Readings:

- Primary reading: Bak, P., Tang, C., & Wiesenfeld, K. (1987). **Self-organized criticality: An explanation of the 1/f noise**. *Physical Review Letters*, 59(4), 381. doi: 10.1103/PhysRevLett.59.381.

    - Supplementary reading: Bak, P., Tang, C., & Wiesenfeld, K. (1988). Self-organized criticality. *Physical Review A*, 38(1), 364. doi: 10.1103/PhysRevA.38.364.

    - Supplementary reading: Anderson, P.W. (1972). More Is Different: Broken symmetry and the nature of the hierarchical structure of science. *Science*, 177(4047), 393-396. doi: 10.1126/science.177.4047.393.

    - Supplementary reading: Gell-Mann (1995). What is Complexity? Complexity, 1(1). John Wiley and Sons, Inc.

Guest participant:

- Professor Alessandro Vespignani (Northeastern University)

Additional resources:

- SocSim Python package: BTW model. `https://socsim.readthedocs.io/en/latest/BTW.html`

    - Manna Model. toppling two grains of sand, but with stochasticity

- Vespignani, A., & Zapperi, S. (1998). How self-organized criticality works: A unified mean-field picture. *Physical Review E*, 57(6), 6345. doi: 10.1103/PhysRevE.57.6345.

- Serafino, M., Cimini, G., Maritan, A., Rinaldo, A., Suweis, S., Banavar, J. R., & Caldarelli, G. (2021). True scale-free networks hidden by finite size effects. *Proceedings of the National Academy of Sciences*, 118(2), e2013825118. doi: 10.1073/pnas.2013825118.

- Watkins, N.W., Pruessner, G., Chapman, S.C. et al. (2016). 25 Years of Self-organized Criticality: Concepts and Controversies. *Space Science Review* 198, 3–44. doi: 10.1007/s11214-015-0155-x.

- Morin, E. (1992), From the concept of system to the paradigm of complexity. *Journal of Social and Evolutionary Systems*, 15(4), 371-385. doi: 10.1016/1061-7361(92)90024-8.

- Petri, A., Paparo, G., Vespignani, A., Alippi, A., & Costantini, M. (1994). Experimental evidence for critical dynamics in microfracturing processes. *Physical Review Letters*, 73(25), 3423. doi: 10.1103/PhysRevLett.73.3423.

Week 2: January 18, 2024 – Complexity, old and new

Readings:

- Primary reading: Wheeler, W.M., (1926). **Emergent Evolution and the Social**. *Science*, 64(1662), pp. 433-440. doi: https://www.jstor.org/stable/1651238.

- Primary reading: Simon, H.A. (1962). **The Architecture of Complexity**. *Proceedings of the American Philosophical Society*, 106(6), 467–482. doi: http://www.jstor.org/stable/985254.

- Primary reading: Holme, P. (2022). **What complexity science is, and why**. arXiv: 2201.03762.

    - Supplementary reading: Weaver, W. (1948). Science and Complexity. *American Scientist*, 36(4), 536–544. doi: http://www.jstor.org/stable/27826254.

    - Supplementary reading: Amaral, L.A.N., Ottino, J.M. (2004). Complex networks. *European Physical Journal B* 38, 147–162. doi: 10.1140/epjb/e2004-00110-5.

    - Supplementary reading: Ashby, W.R. (1962). Principles of the self-organizing system. In *Principles of Self-Organization: Transactions of the University of Illinois Symposium*, H. Von Foerster and G.W. Zopf, Jr. (eds.), Pergamon Press: London, UK, pp. 255-278.

Week 3: January 25, 2024 – Publics, counterpublics, and connective action (w/ Brooke Foucault Welles)

Readings:

- Primary reading: Primary reading: Bennett, W.L., & Segerberg, A. (2012). **The logic of connective action: Digital media and the personalization of contentious politics**. *Information, Communication & Society*, 15(5), 739-768. doi: 10.1080/1369118X.2012.670661.

- Primary reading: Barberá, P., Wang, N., Bonneau, R., Jost, J. T., Nagler, J., Tucker, J., & González-Bailón, S. (2015). **The critical periphery in the growth of social protests**. *PLOS One*, 10(11), e0143611. doi: 10.1371/journal.pone.0143611.

- Primary reading: Jackson, S.J., & Foucault Welles, B. (2015). Hijacking #myNYPD: **Social media dissent and networked counterpublics**. *Journal of Communication*, 65(6), 932-952. doi: 10.1111/jcom.12185.

    - Supplementary reading: Rothschild-Whitt, J. (1979). The Collectivist Organization: An Alternative to Rational-Bureaucratic Models. *American Sociological Review*, 44(4), 509–527. doi: 10.2307/2094585.

    - Supplementary reading: Habermas, J. (1991). The structural transformation of the public sphere: An inquiry into a category of bourgeois society. MIT Press.

    - Supplementary reading: Asen, R., & Brouwer, D.C. (Eds.). (2001). Counterpublics and the State. SUNY Press.

- Supplementary reading: Shirky, C. (2008). Here comes everybody: The power of organizing without organizations. Penguin.
- Supplementary reading: Papacharissi, Z., & de Fatima Oliveira, M. (2012). Affective news and networked publics: The rhythms of news storytelling on #Egypt. *Journal of Communication*, 62(2), 266-282. doi: 10.1111/j.1460-2466.2012.01630.x.
- Supplementary reading: Freelon, D., McIlwain, C., & Clark, M. (2018). Quantifying the power and consequences of social media protest. *New Media & Society*, 20(3), 990-1011. doi: 10.1177/1461444816676646.

Guest participant:

- Professor Brooke Foucault Welles (Northeastern University)

Additional resources:

- Jackson, S.J., Bailey, M., & Welles, B.F. (2020). #HashtagActivism: Networks of race and gender justice. MIT Press.

Week 4: February 1, 2024 – Philosophy in/and/of networks

Readings

- Primary reading: Ross, L.N. (2021). **Distinguishing topological and causal explanation**. *Synthese* 198, 9803–9820. doi: 10.1007/s11229-020-02685-1.

    - Supplementary reading: Bertolero, M. & Bassett., D.S. (2020). On the nature of explanations offered by network science: A perspective from and for practicing neuroscientists. *Topics in Cognitive Science*, 12, 1272–1293. doi: 10.1111/tops.12504.
    - Supplemental reading: Ross, L.N. (2022). Cascade versus mechanism: The diversity of causal structure in science. *The British Journal for the Philosophy of Science*, 1. doi: 10.1086/723623.
    - Supplemental reading: Ross, L.N. (2021). Causal Concepts in Biology: How Pathways Differ from Mechanisms and Why It Matters. *The British Journal for the Philosophy of Science*, 72(1), 131-158. doi: 10.1093/bjps/axy078.
    - Supplementary reading: Chang, H. (2004). Inventing temperature: Measurement and scientific progress: Chapter 5. Oxford University Press.
    - Supplementary reading: Andersen, H. (2014). A field guide to mechanisms: Part I. *Philosophy Compass*, 9(4), 274-283. doi: 10.1111/phc3.12119.
    - Supplementary reading: Andersen, H. (2014). A field guide to mechanisms: Part II. *Philosophy Compass*, 9(4), 284-293. doi: 10.1111/phc3.12118.
    - Supplementary reading: Rosenblueth, A. & Wiener, N. (1945). The role of models in science. *Philosophy of Science*, 12(4), 316-321. doi: 10.1086/286874.

Additional resources:

- Ross, L.N. & Bassett, D.S. (2024). Causation in neuroscience: keeping mechanism meaningful. *Nature Reviews Neuroscience*. doi: 10.1038/s41583-023-00778-7.

Week 5: February 8, 2024 – Meaning and measurement in computational social science

- Primary reading: Healy, K. (2017). **The performativity of networks**. European Journal of Sociology, 56(2), 175-205. doi: 10.1017/S0003975615000107.

- Primary reading: Lazer, D., Hargittai, E., Freelon, D., González-Bailón, S., Munger, K., Ognyanova, K. & Radford, J. (2021). **Meaningful measures of human society in the twenty-first century**. *Nature* 595, 189-196. doi: 10.1038/s41586-021-03660-7.

    - Supplementary reading: Lazer, D., Pentland, A., Watts, D.J., Aral, S., Athey, S., Contractor, N., Freelon, D., Gonzalez-Bailon, S., King, G., Margetts, H., Nelson, A., Salganik, M.J., Strohmaier, M., Vespignani, A. & Wagner, C. (2020). Computational social science: Obstacles and opportunities. *Science*, 369(6507), 1060-1062. doi: 10.1126/science.aaz8170.

    - Supplementary reading: Chang, H. (2004). Inventing temperature: Measurement and scientific progress: Chapter 5. Oxford University Press.

    - Supplementary reading: Dodds, P.S., Alshaabi, T., Fudolig, M.I., Zimmerman, J.W., Lovato, J., Beaulieu, S., Minot, J.R., Arnold, M.V., Reagan A.J. & Danforth, C.M. (2021). Ousiometrics and telegnomics: the essence of meaning conforms to a two-dimensional powerful-weak and dangerous-safe framework with diverse corpora presenting a safety bias. arXiv: 2110.06847.

Week 6: February 15, 2024 – First principles, scaling, boundaries

Readings:

- Primary reading: Krakauer, D., Bertschinger, N., Olbrich, E., Flack, J. & Ay, N. (2020). **The information theory of individuality**. *Theory in Biosciences*, 139, 209–223. doi: 10.1007/s12064-020-00313-7.

- Primary reading: Alon, U. (2003). **Biological networks: the tinkerer as an engineer**. *Science*, 301(5641), 1866-1867. doi: 10.1126/science.1089072.

- Primary reading: West, G.B., Brown, J.H., & Enquist, B.J. (1999). **The fourth dimension of life: Fractal geometry and allometric scaling of organisms**. *Science*, 284(5420), 1677-1679. doi: 10.1126/science.284.5420.1677.

    - Supplementary reading: West, G.B., Brown, J.H., & Enquist, B.J. (1997). A general model for the origin of allometric scaling laws in biology. *Science*, 276(5309), 122-126. doi: 10.1126/science.276.5309.122.

    - Supplementary reading: Corominas-Murtra, B., Hanel, R., & Thurner, S. (2015). Understanding scaling through history-dependent processes with collapsing sample space. *Proceedings of the National Academy of Sciences*, 112(17), 5348-5353. doi: 10.1073/pnas.1420946112.

    - Supplementary reading: Song, C., Havlin, S. & Makse, H. (2005). Self-similarity of complex networks. *Nature*, 433, 392–395. doi: 10.1038/nature03248.

    - Supplementary reading: Supplementary reading: Milo, R., Shen-Orr, S., Itzkovitz, S., Kashtan, N., Chklovskii, D., & Alon, U. (2002). Network motifs: simple building blocks of complex networks. *Science*, 298(5594), 824-827. doi: 10.1126/science.298.5594.824.

    - Supplementary reading: Bettencourt, L.M., Lobo, J., Helbing, D., Kühnert, C., & West, G.B. (2007). Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences*, 104(17), 7301-7306. doi: 10.1073/pnas.0610172104.

    – Supplementary reading: Thurner, S., Hanel, R. & Klimek, P. (2018). Introduction to the Theory of Complex Systems: Chapter 1: Introduction. Oxford University Press.

    – Supplementary reading: Thurner, S., Hanel, R. & Klimek, P. (2018). Introduction to the Theory of Complex Systems: Chapter 3: Scaling. Oxford University Press.

Week 7: February 22, 2024 – Higher-order, multi-scale, and simple networks

Readings:

- Primary reading: Battiston, F., Amico, E., Barrat, A., Bianconi, G., de Arruda, G.F., Franceschiello, B., Iacopini, I., Kéfi, S., Latora, V., Moreno, Y., Murray, M., Peixoto, T.P., Vaccarino, F. & Petri, G. (2021). **The physics of higher-order interactions in complex systems**. *Nature Physics*, 17, 1093–1098. doi: 10.1038/s41567-021-01371-4.

    – Supplementary reading: Battiston, F., Cencetti, G., Iacopini, I., Latora, V., Lucas, M., Patania, A., Young, J.G. & Petri, G. (2020). Networks beyond pairwise interactions: Structure and dynamics. *Physics Reports*, 874, 1-92. doi: 10.1016/j.physrep.2020.05.004.

    – Supplementary reading: Orsini, C., Dankulov, M., Colomer-de-Simón, P., Jamakovic, A., Mahadevan, P., Vahdat, A., Bassler, K., Toroczkai, Z., Boguñá, M., Caldarelli, G., Fortunato, S. & Krioukov, D. (2015). Quantifying randomness in real networks. *Nature Communications*, 6, 8627. doi: 10.1038/ncomms9627.

    – Supplementary reading: Klein, B., & Hoel, E. (2020). The emergence of informative higher scales in complex networks. *Complexity*, 2020, 1-12. doi: 10.1155/2020/8932526.

    – Supplementary reading: Palla, G., Derényi, I., Farkas, I. & Vicsek, T. (2005). Uncovering the overlapping community structure of complex networks in nature and society. *Nature*, 435, 814–818. doi: 10.1038/nature03607.

    – Supplementary reading: Peel, L., Larremore, D. & Clauset, A. (2017). The ground truth about metadata and community detection in networks. *Science Advances*, 3(5), e1602548. doi: 10.1126/sciadv.1602548.

Week 8: February 29, 2024 – Topic TBD (w/ Vittoria Colizza)

Readings:

- Primary reading: _____

    – Supplementary reading: _____

Guest participant:

- Professor Vittoria Colizza (Inserm & Sorbonne Universite)

Week 9: March 7, 2024 – Spring Break – No class

Week 10: March 14, 2024 – Adaptation, dynamics, & evolution (w/ C. Brandon Ogbunugafor)

Readings:

- Primary reading: Maynard Smith, J. (1970). **Natural selection and the concept of a protein space**. *Nature*, 225(5232), 563-564. doi: 10.1038/225563a0.

- Primary reading: Ogbunugafor, C.B. (2020). **A Reflection on 50 Years of John Maynard Smith's "Protein Space"**. *Genetics*, 214(4), 749-754. doi: 10.1534/genetics.119.302764.

  - Supplementary reading: Leventhal, G., Hill, A., Nowak, M.A. & Bonhoeffer, S. (2015). Evolution and emergence of infectious diseases in theoretical and real-world networks. *Nature Communications*, 6, 6101. doi: 10.1038/ncomms7101.

  - Supplementary reading: Rayfield, B., Fortin, M.J., & Fall, A. (2011). Connectivity for conservation: A framework to classify network measures. *Ecology*, 92(4), 847-858. doi: 10.1890/09-2190.1.

  - Supplementary reading: Guerrero, R.F., Scarpino, S.V., Rodrigues, J.V., Hartl, D.L. & Ogbunugafor, C.B. (2019). Proteostasis environment shapes higher-order epistasis operating on antibiotic resistance. *Genetics*, 212(2), 565-575. doi: 10.1534/genetics.119.302138.

  - Supplementary reading: Ogbunugafor, C.B. & Edge, M.D. (2022). Gattaca as a lens on contemporary genetics: marking 25 years into the film's "not-too-distant" future. *Genetics*, 222(4), iyac142. doi: 10.1093/genetics/iyac142.

Guest participant:

- Professor C. Brandon Ogbunugafor (Yale University)

Week 11: March 21, 2024 – Complexity, technology, and the economy

Readings:

- Primary reading: Arthur, W.B. (2021). **Foundations of complexity economics**. *Nature Reviews Physics*, 3(2), 136-145. doi: 10.1038/s42254-020-00273-3.

  - Supplementary reading: Arthur, W.B. (2023). Economics in nouns and verbs. *Journal of Economic Behavior & Organization*, 205, 638-647. doi: 10.1016/j.jebo.2022.10.036.

  - Supplementary reading: Arthur, W.B. (2009). The Nature of Technology: What It Is and How It Evolves: Chapter 2 - Combination & Structure. Free Press.

  - Supplementary reading: Hong, I., Frank, M.R., Rahwan, I., Jung, W.S., & Youn, H. (2020). The universal pathway to innovative urban economies. *Science Advances*, 6(34), eaba4934. doi: 10.1126/sciadv.aba4934.

  - Supplementary reading: Bettencourt, L.M., Lobo, J., Helbing, D., Kühnert, C., & West, G.B. (2007). Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences*, 104(17), 7301-7306. doi: 10.1073/pnas.0610172104.

Week 12: March 28, 2024 – Topic TBD (w/ Sandra González-Bailón)

Readings:

- Primary reading: _____
    - Supplementary reading: _____

Guest participant:

- Professor Sandra González-Bailón (University of Pennsylvania)

Week 13: April 4, 2024 – Topic TBD (w/ Keletso Makofane)

Readings:

- Primary reading: _____
    - Supplementary reading: _____

Guest participant:

- Dr. Keletso Makofane (University of Pennsylvania)

Week 14: April 11, 2024 – Statistics, description, and inference in complex networks (w/ Tiago P. Peixoto)

Readings:

- Primary reading: Peel, L., Peixoto, T.P. & De Domenico, M. (2022). **Statistical inference links data and theory in network science**. *Nature Communications* 13, 6794. doi: 10.1038/s41467-022-34267-9.

- Primary reading: Peixoto T.P. (2023). ***Descriptive vs. Inferential Community Detection in Networks: Pitfalls, Myths and Half-Truths***. Cambridge University Press. doi: 10.1017/9781009118897.

    - Supplementary reading: Peixoto, T.P. (2023 ed.). Bayesian stochastic blockmodeling. arXiv: 1705.10225v9. [also published under Peixoto, T.P. (2019). Bayesian Stochastic Blockmodeling. In *Advances in Network Clustering and Blockmodeling* (eds P. Doreian, V. Batagelj and A. Ferligoj). doi: 10.1002/9781119483298.ch11.]
    - Supplementary reading: Peixoto, T.P. (2019). Network reconstruction and community detection from dynamics. *Physical Review Letters*, 123(12), 128301. doi: 10.1103/PhysRevLett.123.128301.
    - Supplementary reading: Peixoto, T.P. (2024). Scalable network reconstruction in subquadratic time. arXiv: 2401.01404.

Guest participant:

- Professor Tiago Peixoto (Central European University)

Additional resources:

- `graph-tool` documentation: `https://graph-tool.skewed.de/static/doc/demos/inference/inference.html`.

- Rosenblueth, A. & Wiener, N. (1945). The role of models in science. *Philosophy of Science*, 12(4), 316-321. doi: 10.1086/286874.

Week 15: April 18, 2024 – Topic TBD (w/ Kiran Garimella)

Readings:

- Primary reading: _____
    - Supplementary reading: _____

Guest participant:

- Professor Kiran Garimella (Rutgers University)

Week 16: April 25, 2024 – Topic TBD (w/ Clara Stegehuis)

Readings:

- Primary reading: _____
    - Supplementary reading: _____

Guest participant:

- Professor Clara Stegehuis (Twente Universty)