SSIE501/ISE440: Introduction to Systems Science

From Cybernetics to Complex Networks and Systems

FALL 2023

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Teaching Assistant: Vision (Xin) Wang (https://xin-wang-kr.github.io/). Systems Science and Industrial Engineering Department (https://www.binghamton.edu/ssie/), Thomas J. Watson College of Engineering & Applied Science (https://www.binghamton.edu/watson/), Binghamton University (SUNY) (https://www.binghamton.edu)

Class Location and Time: Tuesdays and Thursdays 1:15 - 2:40PM, Engineering Building (https://goo.gl/maps/B3pbGckVunUg4p6o7), Room J01.

Contents

Course Description

Description: The course deals with the foundations of Systems Science, as well as current advances in Complex Networks and Systems which is the modern expression of this interdisciplinary field. A complex system is any system featuring a large number of interacting components (agents, processes, etc.) whose aggregate activity is nonlinear (not derivable from the summations of the activity of individual components) and typically exhibits hierarchical self-

organization under selective pressures. The networks of interactions that comprise such systems can be studied separately from or together with the multivariate dynamics that define them. In the former case, the focus is the graph structure of networks which is typically pursued in Network Science, whereas dynamical systems theory focuses on the latter. Understanding networked complex systems is key to solving some of the most vexing problems confronting humankind, from discovering how thoughts and behaviors arise from dynamic brain connections, to detecting and preventing the spread of epidemics or unhealthy behaviors across a population. But the study of complex systems requires an understanding of both structure and dynamics which often interact in non-separable multiple levels where information, selection, and collective dynamics operate. Indeed, modeling network interactions among variables operating at multiple scales is an essential capability for effective interventions in complex systems---such as the dynamic web of cellular processes and genetic regulation, the intricate wiring of the brain, as well as patterns of human and social behavior involved in disease. Across all these systems, mapping, analyzing, modeling, and visualizing underlying networks are indispensable steps toward understanding how they work. The sciences of complexity are also necessarily based on interdisciplinary research so that teams of scientists can most effectively approach both the general characteristics of all these systems as well as the specific methodologies required to measure and model them.

Aims: This course is designed to introduce and discuss the history, methodology and impact of complex systems science; we cover key literature, recent advances in the field, and introduce useful computational techniques in the field. We will study concepts such as Information, General Systems Theory, Networks, Modeling, Multi-Level Complexity, as well as their impact on science and society. The course will also attempt to define and understand what systems thinking can bring to science and society.

Syllabus

Lecture Outline

- **Cybernetics and the Information Turn**
  - Inventing Computers and Information
  - Information, and Semiotics
  - Organisms as Computers
- **From Cybernetics to Systems Science**
  - Systemhood and General Systems
  - Organized Complexity
  - Modeling Complex Systems
- **Complex Systems Science under Limits**
  - Limits of Computation
  - Dynamics and Tipping Points
  - Self-organizing Systems
- **Interdisciplinarity in a Two-Dimensional Science**
  - Team Science
  - Costs and Needs of Interdisciplinary Science
- **Organization of Complex Systems**
  - Heterarchies and Networks
  - Hierarchies and Multi-Level Complexity
  - Evolutionary Systems and Model Failure
  - Collective Intelligence: Life as intertwined networks
- **Systems Thinking in Science and Society Today**
  - Biomedicine and Health
  - Computational Social Science
  - Artificial Intelligence

Course Evaluation

- **Participation**: 20%.
  - based upon attendance and participation in class discussion. We expect that students will approach the course as they should a professional job and attend every class.
- **Paper Presentation and Discussion** : 20%.
  - Presentation of research paper plus leading of discussion. All **SSIE501** Students are assigned to one paper as lead presenters and discussants, but all students are supposed to read and participate in the discussion of every paper. During class, the presenter prepares a short summary of the paper (10-15 minutes)---no formal presentations or PowerPoint unless figures are indispensable. The summary should: 1) Identify the key goals of the paper (not go in detail over every section); 2) What discussant liked and did not like; 3) What authors achieved and did not; 4) Any other relevant connections to other class readings and beyond. After initial summary, discussion is opened to all, and role of presenter is to lead the discussion to make sure we address the important paper contributions and failures. **ISE440 students** will chose one of the presented papers to participate as lead discussant, whose role is not to present the paper, but to comment on points 2-3) above.
- **Black Box Group Assignments**: 60%
  - **Black Box Assignment 1**: 25%
    - Due: October 6th, 2023
  - **Black Box Assignment 2**: 35%
    - Due: December 1st, 2023

Office Hours

Luis M. Rocha: Tuesdays: 9:00 - 11:30am, EB-S4, EB-C3, or Online (https://binghamton.zoom.us/my/luismrocha).

Vision (Xin) Wang (TA): Tuesdays 4-5pm, Wednesdays 12:30-2:30pm, and Thursdays 9:00-11:00am, EB-K1, Online (https://binghamton.zoom.us/j/5483243323), or by appointment.

Course Materials and Readings

LECTURE NOTES AND SLIDES

- **Lecture Slides**
  - Module 1 - Lecture 1 - Introduction and Information From Borges to Shannon (pdfs/ssie501_lecture1_slides.pdf)
  - Module 1 - Lecture 2 - From the Garden of Forking Paths to Information as Surprise (pdfs/ssie501_lecture2_slides.pdf)

READINGS, AVAILABLE ON LINE, LIBRARY RESERVE OR BRIGHTSPACE (HTTPS://BRIGHTSPACE.BINGHAMTON.EDU/D2L/HOME/255004)

1. **Cybernetics and the Information Turn**
   - Borges, Jorge Luis. [1941]. *The Library of Babel* (https://maskofreason.files.wordpress.com/2011/02/the-library-of-babel-by-jorge-luis-borges.pdf).
   - Borges, Jorge Luis. [1941]. *The Garden of Forking Paths* (http://shiraz.fars.pnu.ac.ir/portal/file/?970437/The-Garden-of-Forkling-Paths-Original.pdf).

- Brenner, Sydney. [2012]. "History of Science. The Revolution in the Life Sciences" (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/14vsi1q/cdi_crossref_primary_10_1126_science_1232919). *Science* **338** (6113): 1427-8.
- Brenner, Sydney. [2012]. "Turing centenary: Life's code script (https://www.nature.com/nature/journal/v482/n7386/full/482461a.html). *Nature* **482** (7386) (February 22): 461-461.
- Cobb, Matthew. [2013]. "1953: When Genes Became 'Information'. (https://dx.doi.org/10.1016/j.cell.2013.04.012)" *Cell* **153** (3): 503-506.
- Gleick, J. [2011]. *The Information: A History, a Theory, a Flood* (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/12rb53h/alma990023518060204802). Random House. Chapter 8.
- Kline, Ronald R [2015]. *The cybernetics moment, or, why we call our age the information age* (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/8bi7k1/alma9936567943904802). Johns Hopkins University Press. Chapters 1-2.
- Heims, S.G. [1991]. *The Cybernetics Group* (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/8bi7k1/alma990007498590204802). MIT Press. Chapters: 1 and 2.
- **Optional**
  - Heims, S.G. [1991]. *The Cybernetics Group* (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/8bi7k1/alma990007498590204802). MIT Press. Chapters: 11 and 12.
  - McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity (https://link.springer.com/article/10.1007/BF02478259)". *Bulletin of Mathematical Biophysics* **5**:115-133.
  - Prokopenko, Mikhail, Fabio Boschetti, and Alex J. Ryan. "An information theoretic primer on complexity, self organization, and emergence (https://onlinelibrary.wiley.com/doi/abs/10.1002/cplx.20249)." *Complexity* **15**.1 (2009): 11-28.
  - Searls, David B. [2010]. "The Roots of Bioinformatics" (https://www.ploscompbiol.org/article/info:doi/10.1371/journal.pcbi.1000809). *PLoS Computational Biology* **6**(6): e1000809.

2. **From Cybernetics to Systems Science**
   - Weaver, W. [1948]. "Science and Complexity" (https://www-jstor-org.proxy.binghamton.edu/stable/27826254?sid=primo&seq=1#metadata_info_tab_contents). *American Scientist*, **36**(4): 536-44. (PMID: 18882675 (http://www.ncbi.nlm.nih.gov/pubmed/18882675) and an alternative pdf (http://people.physics.anu.edu.au/~tas110/Teaching/Lectures/L1/Material/WEAVER1947.pdf).) Also available in Klir, G.J. [2001]. *Facets of systems Science* (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/8bi7k1/alma9936841967404802). Springer, pp: 533-540.

CLASS BOOK

Klir, G.J. [2001]. *Facets of systems science* (https://link.springer.com/book/10.1007/978-1-4615-1331-5). Springer. Available in electronic format for SUNY students (https://suny-bin.primo.exlibrisgroup.com/permalink/01SUNY_BIN/8bi7k1/alma9936841967404802)and the Campus Bookstore. (https://binghamton.bncollege.com/)

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