PoCS
Principles of
Complex Systems
@pocsvox
What's the Story?

Principles of Complex Systems, Vols. 1 & 2

@pocsvox
CSYS/MATH 300 and 303; Deliverator: Prof. Peter Sheridan Dodds

https://pdodds.w3.uvm.edu//teaching/courses/2021-2022principles-of-complex-systems/

Basic stuff:

Regional Deliverator (RD): Prof. Peter Sheridan Dodds
Office: Innovation, fourth floor
Office hours: TBD
Teams site: Set up internally
Twitter handle: @pocsvox
Source material: Journal papers and book excerpts
Assistant to the Regional Deliverator (ARD): TBD
Contact: Message the RD and the ARD through Teams (not email)
Suggested text: No official textbook

Volume 1, Fall, 2021:

Lecture room: Perkins 003
Meeting times: 10:05 am to 11:20 am

Volume 2, Spring, 2022:

Lecture room: Lafayette 411
Meeting times: 10:05 am to 11:20 am

If instructor's permission is required: Students are asked to please send a short message on Teams describing their interests (and their netid and/or 950 student number).

Synopsis:

Volume 1:

Many of the problems we face in the modern world revolve around comprehending, controlling, and designing multi-scale, interconnected systems. Networked systems, for example, facilitate the diffusion and creation of ideas, the physical transportation of people and goods, and the distribution and redistribution of energy. Complex systems such as the human body and ecological systems are typically highly balanced, flexible, and robust, but are also susceptible to systemic collapse. These complex problems almost always have economic, social, and technological aspects.

So what do we know about complex systems? The basic aim in these postdisciplinary courses is to impart knowledge of a suite of theories and ideas and tools that have been evolved over the last century in the pursuit of understanding complex systems.

We'll touch on everything from physics to sociology, from randomness to the fabric of meaning.

Throughout the course, we'll maintain a focus on (1) real small-scale mechanisms that give rise to observed macro phenomena, (2) scaling phenomena, (3) complex networks, and (4) biological and social contagion, allowing us to explore how seemingly disparate systems correspond—the phenomenon of universality—and, just as importantly, where tempting analogies break down.

In the section on contagion, and based on work done pre-COVID-19, we will show how pandemics are deeply unpredictable. Towards the end of the course, we will explore the social construction of reality, understand the mechanics of fame, and show that fate does not exist.

Volume 2:

The second PoCS course explores special topics potentially including (but not limited to) language, stories, emotion, happiness, meaning, social and biological contagion, and complex networks.

A few major areas:

Telegnomics: The distant measurement of knowledge.

Hedonometrics: The distant measurement of happiness and sadness.

Ousiometrics: The measurement of essential meaning.

We will consider stories through measurements of narratives, plots, characters, language use, interaction networks, and more.

A note on complex networks:

Some complex systems can be viewed as complex networks. Networks crucially underpin much of the real and synthetic world. Networks distribute and redistribute information, water, food, and energy. Networks can be constituted by physical pipes, embodied in relationships carried in people's minds, or manifested by economic interdependencies.

Starting in the late 1990s and building on work in a wide range of disciplines, many (but certainly not all) advances have been made in understanding all manner of complex networks such as the World Wide Web, social and organizational networks, biochemical networks, and transportation networks.

Notes:

Each Volume of Principles of Complex Systems is a 3 credit course.

Both courses are designed for graduates and advanced undergraduates.

Potential topics:

(Note: this list is undoubtedly incomplete, in no particular order, and subject to change; more detailed treatments of many of the topics that follow will appear in the advanced courses.)

1. Fundamentals
    (a) Manifesto
    (b) Emergence
    (c) Statistical mechanics and universality
    (d) Path dependence
2. Measures of complexity
    (a) The poles of randomness and order
    (b) Basic notions of entropy and information theory
3. Scaling phenomena
    (a) Zipf's law
    (b) Non-Gaussian statistics and power law size distributions
    (c) Sample mechanisms for power law size distributions
    (d) Scaling for organisms and organizations
    (e) Scaling of social phenomena: crime, creativity, and consumption.
    (f) Renormalization techniques
4. Multiscale complex systems
    (a) Hierarchies and scaling
    (b) Modularity
    (c) Form and context in design
5. Complexity in abstract models
    (a) The game of life
    (b) Cellular automata
    (c) Chaos and order—creation and maintenance
6. Integrity of complex systems
    (a) Generic failure mechanisms
    (b) Highly optimized tolerance: Robustness and fragility
    (c) Network robustness
7. Complex networks

(a) Random networks
(b) Small-world networks
(c) Scale-free networks
(d) Optimal distribution networks

8. Collective behavior and contagion in social and sociotechnical systems
   (a) Percolation and phase transitions
   (b) Disease spreading models
   (c) Schelling's model of segregation
   (d) Granovetter's model of imitation
   (e) Contagion on networks
   (f) Herding phenomena
   (g) Cooperation
   (h) Wars and conflicts
9. Large-scale Social patterns
   (a) Movement of individuals
10. Collective decision making
   (a) Theories of social choice
   (b) The role of randomness and chance
   (c) Systems of voting
   (d) Juries
   (e) Success inequality: superstardom
11. Information
   (a) Search in networked systems (e.g., the internet, social systems)
   (b) Search on scale-free networks
   (c) Knowledge trees, metadata and tagging
12. More on complex networks:
   (a) Structure and form of complex networks including physical branching networks (river networks and cardiovascular networks), neural networks, social networks, the Internet, the world wide web, transportation networks, and organizations;
   (b) distribution versus redistribution networks;
   (c) properties of networks including degree distributions, clustering, motifs, various measures of betweenness, modularity, the role of randomness, network dynamics, and multiscale structures;
   (d) multilayer networks;
   (e) HOT networks;
   (f) temporal networks;
   (g) community detection algorithms;
   (h) bipartite networks;
   (i) weighted networks;
   (j) partly random networks as models of real world networks;
   (k) generating function techniques;
   (l) universal models including scale-free networks, p-star networks, and generative models;
   (m) small-world networks;

(n) impedance and flow in networks;
(o) connections between delivery networks and energy usage in organisms;
(p) search in networks as facilitated by network structure and search methods;
(q) generalized notions of contagion in networks;
(r) network epidemiology and fad spreading;
(s) computation considerations for analysing networks.

13. Stories
    (a) Contagious stories
    (b) Adjacent narratives
    (c) Conspiracy theories
    (d) Power of stories
    (e) How stories are everything
    (f) The Big Story

Prerequisites: Familiarity with the following would be good but not completely necessary: standard calculus, differential equations, difference equations, linear algebra, and statistical methods.

Computing: Proficiency in coding (e.g., Julia, python, R, Matlab) will be necessary for some assignments and projects.

In general, students are exhorted to develop their unix skills across the board in our Complex Systems and Data Science programs. Good places: Apple's OSX is a Unix system and The VACC runs on Linux. Installing Linux on a Windows machine is the option there.

Textbooks: There is no specific textbook for the class. The course will draw on material from a wide range of sources and will provide students with journal papers as appropriate to supplement lecture notes.

Grading breakdown for both volumes of PoCS:

1. **Assignments (75%)**—All assignments will be of equal weight and there will be ten of them. Aside from correctness, clarity in thinking, writing, and presentation will be taken into account in grading.

   In general, questions are worth 3 points according to the following scale:

   - 3 = correct or very nearly so.
   - 2 = acceptable but needs some revisions.
   - 1 = needs major revisions.
   - 0 = way off.

   Assignments will be submitted via Blackboard.

2. **Projects/talks (24%)**—Students will work on semester-long projects. Students will develop a proposal in the first few weeks of the course which will be discussed with the instructor for approval. Projects may take the form of novel research, investigation of an established area of complex systems, or both. Graduate students already pursuing appropriate research topics are welcome to use the class as a venue to present their work.

   A list of possible projects will be provided though individuals are encouraged and free to choose their own. Project content may range from novel research to a review of research relevant to the course. The hope here is for some work to percolate up to the level of journal publications. Students will give two brief presentations in the middle of the semester and a longer one at the end (length of talks will depend on class size). Students will also be required to hand in a report on their investigations.

   The grade breakdown will be 8% for the first talk, 8% for the final talk, and 8% for the written project.

3. **General attendance/Class participation (1%)**—it is highly desirable that students attend class and office hours. If the course is online, then the equivalent will be taking in videos/slides and attending online office hours through Microsoft Teams. Class presence/involvement will be taken into account if a grade is borderline.

Schedule for Volume 1:

Week #	Tuesday	Thursday
1	Overview; Fundamentals: The Complexity Manifesto	Scaling
2	Power-law size distributions	Zipf's law; Fundamentals:
3	Allotaxonometry	Power-law mechanisms: Randomness
4	Power-law mechanisms: Variable Transformation	Power-law mechanisms: The Rich-Get-Richer
5	Power-law mechanisms: Optimization	Fundamentals: Statistical Mechanics;
6	Robustness and Fragility	Optimal distribution networks
7	Fundamentals: Data, Emergence, Limits to Understanding;	First project presentations
8	Complex networks: Introduction Basics and Examples	Complex networks: Key Properties Generalized random networks
9	Complex networks: Small-world networks	Complex networks: Small-world networks
10	Complex networks: Scale-free networks	Contagion: Introduction
11	The Unpredictability of Pandemics	COVID-19
12	Social contagion	Social Contagion
13	Thanksgiving	Thanksgiving
14	Social Contagion	Voting, Success, Fame
15	Stories	The Big Story: Complexification

Schedule for Volume 2:

Flexible.

Final projects:

Final project presentations will likely be given in the final exam period which takes place on Monday, December 13, 10:30 am to 1:15 pm, Perkins 003. .

Times may be adjusted based on class size.

Important dates for Volume 1, Fall, 2021:

1. Classes run from Tuesday, August 31 to Thursday, December 9.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 13.
3. Last day to withdraw—Monday, November 1 (Sadness!).
4. Reading and Exam period—Saturday, December 11 to Friday, December 17.

Important dates for Volume 2, Spring, 2022:

1. Classes run from Tuesday, January 18 to Thursday, May 5.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, January 31.
3. No class on Tuesday, March 1 (Town Meeting Day Recess).
4. Spring recess, March 7 to 11.
5. Last day to ~~escape~~ withdraw—Monday, April 4.
6. Reading and Exam period—Saturday, May 7 to Friday, May 13.

Do check the course Twitter account, @pocsvox, for updates regarding the course.

Academic assistance: Anyone who requires assistance in any way (as per the ACCESS program or due to athletic endeavors), please see or contact me as soon as possible.

Being good people: In class there will be no unnecessary electronic gadgetry, no cell phones, no beeping, no text messaging, etc. You really just need your brain, some paper, and a writing implement. I encourage you to use the course's Teams site to ask questions, share ideas, comments, etc., about the class and assignments but request that you please do so in a respectful fashion. Moreover, all interactions with classmates during lectures and office hours or in any way related to being part of PoCS should be respectful. As in all UVM classes, **Academic honesty** will be expected and departures will be dealt with appropriately. We will follow UVM's community standards and guidelines: See https://www.uvm.edu/cses/https://www.uvm.edu/cses/.

Late policy: Unless in the case of an emergency (a real one) or if an absence has been predeclared and a make-up version sorted out, assignments that are not turned in on time or tests that are not attended will be given 0%.

Grades:

A+	97–100	B+	87–89	C+	77–79	D+	67–69
A	93–96	B	83–86	C	73–76	D	63–66
A-	90–92	B-	80–82	C-	70–72	D-	60–62