SSIE-523:
COLLECTIVE DYNAMICS OF COMPLEX SYSTEMS

Fall 2016 Monday/Wednesday 1:10-2:35pm @ EB-J23

Overview:

In the last several decades, a plethora of nontrivial collective phenomena have been discovered in real-world complex systems, i.e., systems made of a massive amount of lower-level components interacting with each other in a nonlinear way. Such phenomena include: self-organization and pattern formation, emergence of long-tail distribution, coexistence of robustness and sensitivity, collective decision making without leaders, and phase transition, or “tipping points”. While originally investigated in statistical physics and applied mathematics, they are now recognized as fundamental concepts and applied in many other disciplines beyond physical sciences, ranging from philosophy and social sciences to biology and engineering. There are increasing societal demands for personnel that have a solid understanding of, and technical capabilities to simulate and analyze, such collective dynamics of complex systems.

Complex systems science provides powerful conceptual/technical frameworks to formulate and explore the behavior of such systems. Instead of taking traditional reductionistic approaches, complex systems scientists take more synthetic approaches, such as agent-based modeling and complex network modeling. They are now employed in a variety of disciplines, ranging from biology and medicine to engineering and social sciences.

This course will introduce students to the study of collective dynamics of complex systems. Several computational modeling frameworks will be discussed, including spatial models (cellular automata, partial differential equations), network models (random networks, small-world and scale-free networks, dynamical networks, adaptive networks), and agent-based models (particle models, game-theoretic models, ecological and evolutionary models). Mathematical concepts and tools to analyze and understand their behavior will also be discussed, e.g., linear stability analysis, bifurcation, chaos, pattern formation, mean-field approximation, scaling, renormalization, and phase transition.

Python will be used as a primary computer programming language for modeling and simulation. Prior computer programming experience is helpful, but not strictly required.

Prerequisites:

Graduate standing and basic knowledge of calculus, linear algebra and probability theory, or consent of the instructor.

Faculty:

Dr. Hiroki Sayama
Director, Center for Collective Dynamics of Complex Systems
Associate Professor, Department of Systems Science and Industrial Engineering
Visiting Research Associate Professor, Northeastern University
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Teaching Assistant

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Course Structure:

Each class meeting of this course will consist of a lecture and in-class activities. The lectures will provide basic concepts and techniques of each modeling framework and mathematical or computational analysis, with hands-on programming/modeling/analysis exercises. The in-class activities will be used for more problem-oriented modeling practices, where the entire class will work together to implement a computational model of a scientific or engineering problem that could be addressed by complex systems modeling approaches.

Students are required to read the assigned textbook chapter(s) of each class meeting and post their reflections to the Blackboard before coming to the class. There will also be take-home midterm and final exams, and a final research project by interdisciplinary student teams, culminating with an oral presentation and a final paper submission.

Course Schedule:

8/29 Course introduction / initial discussion on course materials and goals / fundamentals of modeling / software installation (Chapters 1 & 2)
8/31 Introduction to Python programming
(9/5 no class – Labor Day)
9/7 Introduction to Python programming (cont'd)
9/12 Discrete-time models: Modeling (Chapters 3 & 4)

9/14	Discrete-time models: Analysis (Chapter 5)	
9/19	Python programming exercise (1) by Farnaz (optional)	
9/21	Python programming exercise (2) by Farnaz (optional)	
9/26	Continuous-time models: Modeling (Chapter 6)	
9/28	Continuous-time models: Analysis (Chapter 7)	
(10/3	*no class – Rosh Hashanah)*	
10/5	Bifurcations (Chapter 8)	
10/10	Bifurcations (cont'd) / Chaos (Chapter 9)	**[midterm exam assigned]**
(10/12	*no class – Yom Kippur)*	
10/17	Chaos (cont'd)	
10/19	Interactive simulation of complex... (Chapter 10; optional)	**[midterm exam due]**
10/24	Cellular automata: Modeling (Chapter 11)	
10/26	Cellular automata: Modeling (cont'd)	
10/31	Cellular automata: Analysis (Chapter 12) / Agent-based models (Chapter 19)	
11/2	Agent-based models (cont'd)	
11/7	Agent-based models (cont'd)	
11/9	Continuous field models: Modeling (Chapter 13)	
11/14	Continuous field models: Modeling (cont'd)	
11/16	Basics of networks (Chapter 15)	
11/21	Dynamical networks: Modeling (Chapter 16)	**[final project assigned]**
(11/23	*no class – Thanksgiving)*	
11/28	Dynamical networks: Topological analysis (Chapter 17)	
11/30	Projects (1)	
12/5	Projects (2)	
12/7	Projects (3)	
12/8	Student presentations *(* this day is on Monday schedule *)*	**[final project paper due]**
TBA	[**Final exam (take-home)]**	

Required Textbook, Software and Computer Access:

1. **Introduction to the Modeling and Analysis of Complex Systems** -- Hiroki Sayama, Open SUNY Textbooks, 2015. Available for free download at http://bingweb.binghamton.edu/~sayama/textbook/.
2. **Python 2.7 (e.g., Anaconda) and PyCX**
   Python is a freely available programming language. You can install Anaconda, a pre-packaged Python distribution, which is freely available from http://continuum.io/downloads. PyCX is an online sample code repository we will use in class, which is also freely available

from http://pycx.sf.net/. Download and installation instructions will be given in the first class.

3. **Access to the class Blackboard site:** http://blackboard.binghamton.edu/
4. **It is STRONGLY RECOMMENDED, though not strictly required, to arrange and bring to classes your own laptop computer with wireless networking capability installed.** In every class we will work on many hands-on modeling exercises, so having your own computational environment in class will be crucial for your learning.

Grading System:

Class attendance	10
Reading reflections	20
Midterm exam	15
Final project presentation	20
Final project paper	20
Final exam	15

Total	100

Grade Categories (Percentage):

A	>= 90
A-	>= 85
B+	>= 80
B	>= 75
B-	>= 70
C+	>= 65
C	>= 60
C-	>= 55
F	otherwise

Other Important Points:

- This course is a 3-credit course, which means that students are expected to do at least 9 - 9.5 hours of course-related work or activity each week during the semester. This includes scheduled class lecture/discussion meeting times as well as time spent completing assigned readings, studying for tests and examinations, preparing written assignments, working on projects, and other course-related tasks.
- **Incidents of academic dishonesty will be fully investigated and processed in accordance with university regulations.** As teamwork is strongly encouraged in this course, however, what the academic honesty means is that you must always give full credit where you are helped by any external resources (classmates, webpages, etc.).
- **Accommodations:** If you are a student with a disability and wish to request accommodations, please notify me by the second week of class. You are also encouraged to contact the Office of Services for Students with Disabilities (SSD) at 777-2686. The SSD office makes formal recommendations regarding necessary and appropriate accommodations based on your specifically diagnosed disability. Information regarding your disability will be treated in a confidential manner.
- If you are experiencing undue personal or academic stress at any time during the semester

or need to talk with someone about a personal problem or situation, you are encouraged to seek support as soon as possible. The instructor is available to talk with you about stresses related to your work in class. Additionally, you can reach out to any one of a wide range of campus resources, including:

1. Dean of Students Office: 607-777-2804
2. Decker Student Health Services Center: 607-777-2221
3. University Police: On campus emergency, 911
4. University Counseling Center: 607-777-2772
5. Interpersonal Violence Prevention: 607-777-3062
6. Watson Advising: 607-777- 6203
7. Office of International Student & Scholar Services:607-777-2510