Q700
Modeling Evolutionary and Adaptive Systems

Seminar Time and Place

Tuesdays and Thursdays from 11:15 am to 12.30 pm.
Conference Room in Geology Building 6th floor.

Instructor Information

Instructor: Eduardo J. Izquierdo
Office: Geology 3044
Office Hours: By appointment.
Office Telephone: (812) 856-3371
Email Address: edizquie@indiana.edu

Course Overview

This will be a graduate seminar devoted to reading, discussing, replicating, and extending work that involves computational modeling of evolutionary and adaptive systems, including the neural basis of behavior. We will implement and analyze different agent-based models and different neural network models, including firing-rate neural networks, spiking neural networks, echo state networks. We will consider different learning techniques, at both the evolutionary and lifetime scale. We will also consider models of synaptic plasticity. We will consider empirical architectures from the connectomes of model organisms as well as arbitrary topologies. We will consider a variety of different analysis techniques to better understand the operation of these complex systems, including graph-theoretic analysis, neural lesions and manipulations, and information-theoretic analysis. We will also discuss conceptual issues on the usefulness of computational models in science. The seminar will involve some lectures, and some invited guests talks, but most time will be spent in student-led discussions and developing small programming projects every two weeks and one larger final mini-research project. An intermediate level of programming is required.

Topics

- Role of simulation models in science
- Neural models
- Neuromodulation and synaptic plasticity
- Lifetime learning and evolutionary methods
- Dynamical and informational analysis
- Functional neural systems
- Behavioral brain-body-environment systems

Link to course materials on Github.

Schedule

Week 1: Introductions and discussion on the role of models in science. We will discuss the teaching style, how the seminar is structured, we will provide a clear roadmap for what we aim to cover, and how to help you accomplish the goals of the seminar during the semester. We will also have our first conversation about modeling in science. Why model? What is a model? We will discuss some basics of programming.

Week 2: Module 1: Neural Dynamics: Neural network models. Learn how to implement and run a dynamical neural model, including firing-rate neural networks, spiking neural networks, echo state networks, or any other dynamical neural model of your choice. We will build and share Python libraries for all to use.

Week 3: Module 1: Neural Dynamics: Toy project #1. Select a neural model. Determine a parameter to vary (e.g., the proportion of excitatory/inhibitory connections). Determine a simple measure of the neural dynamics (e.g., amount of activity, presence of limit cycles or chaos in the dynamics). Systematically study how the chosen measure varies as a function of the parameter. Present your results to the group (5min presentation: 2 slides, one for the methods and one for the results).

Week 4: Module 2: Lifetime learning and Evolutionary Dynamics: Evolutionary algorithms**.** Learn how to implement a parameter search technique, including a hill-climbing algorithm, an evolutionary algorithm, and all the many different possible variations. We will also build and share Python libraries for all to use.

Week 5: Module 2: Lifetime learning and Evolutionary Dynamics: Toy project #2**.** Select a toy (non-neural) problem to evolve. Select one parameter or configuration to study. For example, what is the effect that recombination has on finding solutions? What is the effect of the size of mutations? How do two different search strategies perform against each other? What is the effect that placing the population in a network or space has on performance? What is most efficient, individual lifetime learning or evolutionary learning, or a hybrid of the two? Present your results to the group (5min presentation: 2 slides, one for the methods and one for the results).

Week 6: Module 3: Tools of analysis. Lesions, manipulations, network neuroscience, and basic information theory. Learn how to implement and use a series of different tools of analysis at different levels that help you to understand the operation of any dynamic complex system. Develop one Python library of analysis to share.

Week 7: Module 3: Evolving neural circuits to maximize some aspect of its dynamics: Toy project #3**.** Select again a neural model and a now more sophisticated measure of interest on neural dynamics, and use that measure to train the neural circuit to maximize/minimize it, using an evolutionary algorithm or similar. Ideally, you can obtain not just one successful solution, but many. If possible, find out what is common about the structure of those circuits that succeeded.

Week 8: Module 4: Functional and Behavioral Systems. Learn to give input signals to your neural circuit and train it to solve a simple functional problem. Learn to embed your neural circuit in a body and train it to produce a simple behavior.

Week 9: Module 4: Functional and Behavioral Systems: Toy project #4. Learn to give input signals to your neural circuit and train it to solve a simple functional problem. Learn to embed your neural circuit in a body and train it to produce a simple behavior.

Week 10: Module 5: Advanced topics (student-led): Synaptic plasticity and neuromodulation. Learn how to extend a basic neural model to include other dynamic components.

Week 11: Module 5: Advanced topics (student-led): Reinforcement learning for dynamical neural networks.

Week 12: Module 5: Advanced topics (student-led): Network neuroethology and partial information decomposition.

Week 13: Module 5: Advanced topics (student-led): Multifunctional circuits, degeneracy and individual variability.

Week 14: Work on final projects (no classes).

Week 15: Final project presentations.

Week 16: Turn in final projects.

Readings

Readings will be assigned on Canvas weekly. It is essential that you complete all readings before class so that you can participate in our discussions.

Reading reactions. You are expected to write a brief reaction on the week's readings (200-300 words). After you have stated the author's main ideas and main supportive evidence, you should state your own response to those ideas. Your reflection should contain a critical and thoughtful reaction to the reading. Submit your writing as a reply to the Discussion on Canvas. Once you post your reflection, you will be able to see other's reactions as well.

Typically 2 people will lead the discussions on the readings each week (one for each of the papers assigned). You are encouraged to prepare a 5-minute summary of the reading. You should aim to: summarize, analyze, criticize, and suggest improvements/extensions (when applicable). I expect that everyone will present two-three papers throughout the semester. Leading discussions will contribute to your reading and participation grades.

Health & Safety

IU is following recommended public health guidance in response to the pandemic. In recognition of all IU community members owe to each other, we expect every member of the IU community will adhere to all current policies and practices. For current information on that guidance see https://covid.iu.edu. Deviations from that practice can often be resolved informally by the instructor, but if they cannot, usual procedures outlined in the Student Code of Conduct apply for further action. Indiana University currently requires all students, faculty, and staff to wear a mask that fully covers the wearer's nose and mouth. Everyone who participates in Q700 is expected to follow the University policies on face masks.

Attendance

If you have a positive COVID-19 test, have COVID-like symptoms, or have been instructed to quarantine you should not attend class. To ensure that you can do this, attendance in this class will be taken but will be prorated and will not lower a student's grade when that student was absent due to compliance with campus isolation expectations. For those students, alternative assignments or make-ups will be offered on a case-by-case basis. Please work with Prof. Izquierdo to determine a path to continue your progress in the class during these absences.

Assignments

Throughout the semester, you will work on small modeling projects on the different topics above. There will be somewhere between 4 (every three weeks) or 6 (every two weeks) such assignments throughout the semester. Assignments will be posted on Canvas and will be submitted through Canvas. Work received late will be deducted by 10% per day from the original due date. You will be welcome to collaborate on assignments with your peers. It is your responsibility to double-check all your grades – both that the assignments themselves were correctly graded and that the scores posted on Canvas match your actual grades. You have two weeks from the time that a lab score is posted to address any grading issues with me. After that, the grades posted on Canvas will be considered final.

Final Project

The final 3-4 weeks of the semester will be dedicated to working on your final programming project of a simulation model of a relevant topic to the course of your interest and relevance to graduate research.

Proposal (5 pts): 500-word abstract proposing what you will focus on for your final project.

Oral presentation (10 pts): 15-20 minute presentation to share your final project with the class and to get feedback from your peers.

Written report (10 pts): You will be asked to write a short paper (1000 words) reporting on the motivation for your project, the methods, a justification of the model, the results, and a discussion. The report should include figures and references.

Code (5 pts): Together with the report, you will be asked to make your programming code publicly available on Github.

Grading

Your final grade is computed as follows:

Participation:	10%
Reading reactions:	20%
Leading discussions:	10%
Assignments:	40%
Final project:	20%
Total:	100%

Grading Scale

A+: 97.0%-100%	A: 93.0%-96.99%	A-: 90.0%-92.99%
B+: 87.0%-89.99%	B: 83.0%-86.99%	B-: 80.0%-82.99%
C+: 77.0%-79.99%	C: 73.0%-76.99%	C-: 70.0%-72.99%

D+: 67.0%-69.99%	D: 63.0%-66.99%	D-: 60.0%-62.99%
F: Below 60%		

Canvas notifications

I expect you to check Canvas notifications once a day. I will send messages to the class with announcements, clarifications, instructions, and/or updates. You are responsible for the content of these messages exactly as if the material had been presented in class. It is worth taking some time at the beginning of the semester to review your notification settings on Canvas (go to Account, then to Notifications). All class-wide Canvas announcements and all e-mail messages are archived and available for reference throughout the course.

Respect

In order for the seminar to work well, there must be a high level of respect between you and me and between you and your fellow classmates. If you have to arrive late or leave early, please let me know in advance. Also, please turn off your cell phones.

Bias-Based Incident Reporting

Bias-based incident reports can be made by students, faculty and staff. Any act of discrimination or harassment based on race, ethnicity, religious affiliation, gender, gender identity, sexual orientation or disability can be reported through any of the options: 1) email biasincident@indiana.edu or incident@indiana.edu; 2) call the Dean of Students Office at (812) 855-8188; or 3) use the IU mobile App (m.iu.edu). Reports can be made anonymously.

Feedback

Do not wait until the end of the semester course evaluations to let me know that I could be doing something better. Tell me as soon as possible so that I can make the class valuable and relevant as we go along. If you have any feedback, good or bad, about the course or how it's being taught, please feel free to let me in person or via email.

Academic Integrity

As a student at IU, you are expected to adhere to the standards and policies detailed in the *Code of Student Rights, Responsibilities, and Conduct* (*Code*). When you submit an assignment with your name on it, you are signifying that the work contained therein is yours, unless otherwise cited or referenced. Any ideas or materials taken from another source for either written or oral use must be fully acknowledged. All suspected violations of the *Code* will be reported to the Dean of Students and handled according to University policies. Sanctions for academic misconduct may include a failing grade on the assignment, reduction in your final course grade, and a failing grade in the course, among other possibilities. If you are unsure about the expectations for completing an assignment or taking a test or exam, be sure to seek clarification beforehand.

Statement for Students with Disabilities

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact IU Disability Services for Students.

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Disclaimer

This syllabus is an outline of the course and its policies, which may be changed for reasonable purposes during the semester at the instructor's discretion. You will be notified in class and/or via email if any changes are made to this syllabus, and an updated syllabus will be provided on Canvas.