MAT 6932 Special Topics in Math: Applied Koopman Operator Theory 2023

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Class: LIT 223, MWF 1:55–2:45pm (per. 7)
Office Hours: LIT 454, MW 3:00–3:50pm (per. 8), or appointment

Course Description and Objectives: Understanding dynamical systems beyond a local analysis and determining unknown dynamical equations from data are two examples of key issues in modern applied dynamical systems and span multiple domains in the physical sciences. The Koopman operator has gained significant attention in recent years due to its potential in directly addressing these issues. We will discuss algorithms for approximating the Koopman operator and highlight relationships to other methods including dimensionality reduction (in particular dynamic mode decomposition), machine learning, and control theory. As time permits, we will explore use cases in various fields including biology/neuroscience, engineering/robotics, and big data. Fluency in Python is highly recommended.

Course Goals and Objectives: A student who successfully completes this course will be able to:

- Understand the Koopman operator and its properties from a mathematical perspective.
- Understand the relevance of the Koopman operator to modern scientific problems.
- Understand the conditions under which algorithms are relevant
- Apply various algorithms to generate models from data.

Resources: Most of the course will be based on lecture notes. If needed, additional notes will be provided in class and on Canvas. The following are useful resources (more will be added throughout the semester).

- "Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control", Brunton and Kutz (2016)
- "Applied Koopman Operator Theory for Power Systems Technology", Susuki, Mezić, Raak, and Hikihara (2016)
- "Koopman Operators for Estimation and Control of Dynamical Systems", Otto and Rowley (2021)

Programming Prerequisite: We will use Python for all assignments and in-class demos, exercises, and discussions. If you don't know how to program Python, you will need enough proficiency to keep pace, or be comfortable in another language with comparable libraries.

Homework: Homework will be assigned every other week on Fridays and due the in two weeks with occasional breaks. It will be posted as a File in Canvas. The homework will foster mastery over the material covered in class in the previous weeks. It will include hand or computer computations and proofs. The lowest homework score will be dropped.

Honor Code and Collaboration: In this course authorized aid on projects and homework consists of talking to me, other students, reading documentation for your computational platform, and looking at the notes for this course. You may use online resources and students with permission but **cite all sources**. I encourage collaboration and discussion, but you must write and submit your own work.

Weekly Schedule (subject to change):

- Week 1-2: Review of relevant mathematical concepts. Linear algebra, nonlinear dynamical systems, functional analysis.
- Week 3-4: Theory of Koopman operators on steady-state (ergodic) dynamical systems. Theoretical examples.
- Week 5-6: Numerical methods for ergodic systems and applications.
- Week 7-8: Theory of Koopman operators on transient (non-ergodic) dynamical systems.
- Week 9-10: Numerical methods for non-ergodic systems and applications.
- Week 11-12: More numerical methods, control and estimation.
- Week 13+: More applications to different fields.

Grading: Homework problems will be assigned and due every other week. There will be no exams or quizzes. All homework grades will be posted to canvas. Please notify me as soon as possible if you anticipate being unable to submit a homework assignment. Any issues or questions about the grading of homework or exams must be brought to my attention within one week after the exams or homework are returned to the class.
Semester letter grade assignments will be no stricter than the following: 93-100 A, 90-92 A-, 87-89 B+, 83-86 B, 80-82 B-, 77-79 C+, 73-76 C, 70-72 C-, 67-69 D+, 63-66 D, 60-62 D-, 0-59 E. We will adhere to the university grading policies that can be found here: https://catalog.ufl.edu/UGRD/academic-regulations/grades-grading-policies/

Announcements: You are responsible for all announcements made in Canvas and via email which could include changes in exam dates and material covered.

Diversity Statement: I am committed to diversity and inclusion of all students in this course. I acknowledge, respect, and value the diverse nature, background and perspective of students and believe that it furthers academic achievements. It is my intent to present materials and activities that are respectful of diversity: race, color, creed, gender, gender identity, sexual orientation, age, religious status, national origin, ethnicity, disability, socioeconomic status, and any other distinguishing qualities.

Attendance: Attendance is required. We will adhere to the university attendance policies that can be found here: `https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/`.

Student Evaluations: Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at `https://gatorevals.aa.ufl.edu/students/`. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via `https://ufl.bluera.com/ufl/`. Summaries of course evaluation results are available to students at `https://gatorevals.aa.ufl.edu/public-results/`.

Disabilities statement: Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the Disability Resource Center by visiting `https://disability.ufl.edu/`. It is important for students to share their accommodation letter with their instructor and discuss their access needs as early as possible in the semester.

Academic Integrity: UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code." On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Conduct Code specifies a number of behaviors that are in violation of this code and the possible sanctions. See `https://sccr.dso.ufl.edu/process/student-conduct-code/` to read the Conduct Code. If you have any questions or concerns, please consult with the instructor of this class.