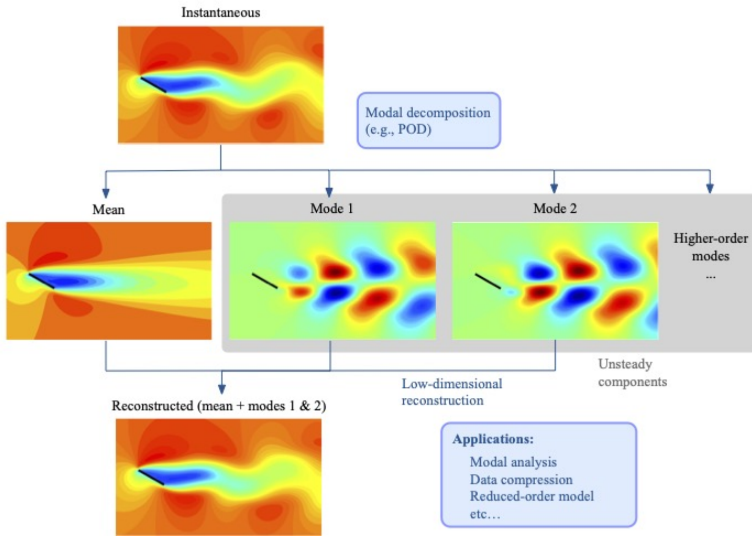
Mechanical and Aerospace Engineering 252E, Spring 2022

Data Science for Fluid Dynamics



OBJECTIVE

Students will learn analysis and modeling techniques from data science and their applications to problems in fluid dynamics. In this course, students will undertake a project to gain a hands-on experience on applying data-driven techniques to solve fluid mechanics problems of their choice. Through class lectures and project presentations, students will become comfortable in utilizing the latest toolsets from data science to assist their endeavors in fluid mechanics.

CLASS TIME AND LOCATION

Lectures: TBA

INSTRUCTOR

Prof. Kunihiko Taira
(office: Engineering IV, 46-147A, `ktaira@seas.ucla.edu`)
Office Hour: TBA

COURSE WEBSITE

Check with `http://ccle.ucla.edu`.

TEXTBOOKS

There are no required textbooks for this class. The following books are great references that can help you. A number of journal articles will be shared on CCLE.

- Trefethen and Nau, *Numerical Linear Algebra*, SIAM, 1997
- Boyd and Vandenberghe, *Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares*, Cambridge 2018.
- Kutz, Brunton, Brunton, and Proctor, *Dynamic Mode Decomposition: Data-Driven Modeling of Complex Systems*, SIAM 2016.
- Brunton and Kutz, *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*, Cambridge 2019.
- Kutz, *Data-Driven Modeling & Scientific Computation: Methods for Complex Systems & Big Data*, Oxford 2013.
- Goodfellow, Bengio, and Courville, *Deep Learning*, MIT Press, 2016.
- Bishop, *Pattern Recognition and Machine Learning*, Springer 2011.
- Abu-Mustafa, Magdon-Ismail, and Lin, *Learning from Data*, AML Book 2012.
- Panton, *Incompressible Flows*, Wiley 2013.
- Kundu, Cohen, and Dowling, *Fluid Mechanics*, Academic Press 2015.

PREREQUISITES

This is an advanced graduate-level course and is *not* an introductory course in fluid dynamics or data science. It is assumed that you have already taken:

- MAE 150A: Intermediate Fluid Mechanics (hard prerequisite)

along with having good understanding of

- Linear Algebra
- Ordinary and Partial Differential Equations
- Computer Programming (you can code in any language you choose)

Access to simulation and/or experimental fluid flow data sets is necessary to complete your assignments (project). Some data can be made available to you through the instructor.

QUESTIONS AND OFFICE HOURS

If you have questions, you should always feel free to ask during class. You can always take advantage of the office hour. If you need help outside of those hours, please email the instructor to schedule an alternative meeting time.

PROJECT

This class is a project-based class.

Each and every student in the class will undertake a quarter-long project. The project will involve data-driven analysis and modeling of a fluid flow of student's choice. The fluid flow data sets to be studied can be from a reliable database, student's research, numerical simulation and/or experiments. Every project must be approved by the instructor.

Students are required to *submit a progress report every two weeks* in a typed LaTeX document, following the AIP/APS Journal Paper format (see https://journals.aps.org/revtex). This biweekly progress report should develop into a document equivalent to an *extended abstract* by Week 3 (proposal presentation) and a *conference paper* by the Week 10 (final presentation). Grading metrics will be based on whether such document will be at a standard of being accepted by a professional fluid mechanics society.

Due to the nature of the course material, students will be required to develop computer programs on their own. While theoretical aspects of the problems and specific coding issues can be solved with the help of the instructor, it is the responsibility of the students to write, debug, and verify their codes. The instructor cannot debug the codes for the students.

Communications with other students and the instructor are highly encouraged to complete the project. The codes, algorithms, and reports needed for the course project must be completed by each individual student. Copying other student's code or simple submission of graduate research work will not be accepted.

GRADING

The final grade for this class will be comprised of the following components:

- Biweekly progress reports: 50%
- Midterm Presentation/Writeup: 20%
- Final Presentation/Writeup: 30%

The grading rubrics for the progress report and presentations/writeups will be provided prior to the due date of the assignments. The extra objective of this course is for this course to prepare students to write a conference paper (and may be even a journal paper) that will be presentable to the research community.

For the final presentation/write-up, we follow to the following guidelines:

- A+: May win a best paper award
- A: Accept without modifications
- B+: Accept with minor modifications
- B: Accept with major modifications
- C and below: Reject

MAKE-UP ASSIGNMENTS

In case of emergency, situation beyond one's control, or for other valid reasons, students will be given an opportunity for making up the missed assignments.Valid excuses include documented illness (including illness of a dependant child), death of an immediate family member, military service obligation, observance of religious holy days, and official university activities. You must notify the instructor in advance when the excused absence is a planned event such as the observance of a religious holy day or an official university activity. Contact the instructor as soon as possible. Proof of valid reason may be required.

COURSE MATERIALS

Note that all course materials (course notes, syllabus, recording of lectures, etc) are the intellectual property of the instructor and/or of UCLA. That means that students and others are NOT legally entitled to post this material on public or other websites or to otherwise disseminate these materials. The course materials are for the use of enrolled students in this quarter's class ONLY.

TENTATIVE COURSE SCHEDULE (from Spring 2020)

Week	Date	Topics
Week 1	3/30 (M)	Introduction to data science
	4/1 (W)	Linear algebra I
Week 2	4/6 (M)	Linear algebra II
	4/8 (W)	Behavior of fluid flows
Week 3	4/13 (M)	Proposal presentations
	4/15 (W)	Dynamical systems I
Week 4	4/20 (M)	Dynamical systems II
	4/22 (W)	Stability and resolvent analysis
Week 5	4/27 (M)	Data-based modal analysis (POD and DMD)
	4/29 (W)	Reduced-order modeling
Week 6	5/4 (M)	Active flow control
	5/6 (W)	Networks I
Week 7	5/11 (M)	Networks II
	5/13 (W)	Clustering
Week 8	5/18 (M)	Machine learning I
	5/20 (W)	Machine learning II
Week 9	5/25 (M)	No class (Memorial Day)
	5/27 (W)	TBA
Week 10	6/1 (M)	Project presentations
	6/3 (W)	Project presentations
Finals		

Table 1: Previous from MAE259a (Spring 2020)