ME493: Methods of Data-Driven Control

Spring 2024

Instructor:	Dr. Dirk M. Luchtenburg	**Time:**	TBD
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Credits: 3.0 (3hrs)

Prerequisite: ME351 – Feedback Control Systems

Grading:

- Oral exam
- Final project (conference or journal style paper)

Course Description: This independent study provides an introduction to state-of-the-art methods employed in the field of data-driven engineering. Data-driven Methods such as the proper orthogonal decomposition and dynamic mode decomposition are used in a variety of fields including fluid dynamics, climate analysis, mixing problems, the study of infectious diseases etc. Data-driven methods rely heavily on concepts from linear algebra, calculus, probability and statistics. We will review these essential elements and develop a hands-on understanding of a selection of data-driven methods. The study culminates with an application of some method(s) to a practical problem which is to be carefully detailed in a technical report.

Course Structure: Weekly meetings with the professor will be held to discuss readings, clarify course material, and review progress on the deliverable at a time convenient for all.

References:

[1] G. Strang, *Linear Algebra and Learning from Data*. SIAM, 2019.

[2] R. W. Beard, "Linear operator equations with applications in control and signal processing," *IEEE Control Systems Magazine*, vol. 22, no. 2, pp. 69–79, 2002.

[3] S. L. Brunton and J. N. Kutz, *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*. Cambridge University Press, 2022.

[4] S. Boyd and L. Vandenberghe, *Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares*. Cambridge University Press, 2018.

[5] A. Géron, *Hands-On Machine Learning with scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, Inc., 2022.

[6] R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*. MIT Press, 2018.

Deliverable: A final project will be developed throughout the semester and due no later than the last week.

Topics and Tentative Reading List:

1. Linear Algebra Review and the Singular Value Decomposition
   - Strang §I.6 - I.11,
   - Brunton §1.1 - 1.5
2. Least Squares and Optimizers (Gradient Descent, SGD, Adam, etc.)
   - Boyd §12.1 - 12.4, Strang §VI.1 - VI.5
3. The Fast Fourier Transform and Principles of Sparsity and Compression
   - Brunton §2.1 - 2.2, §3.1 - 3.8
4. Regression, Clustering, and Classification
   - Boyd §2.1 - 2.3, §4.1 - 4.5, Géron Chs. 3 - 4, Brunton §4.1 - 5.9
5. Neural Networks and Deep Learning Fundamentals
   - Strang §VII.1 - VII.4, Brunton §6.1 - 6.8
6. Dynamic Mode Decomposition and SINDy
   - Brunton §7.1 - 7.3
7. Model Reduction and System Identification
   - Brunton §9.1 - 9.3
8. Data-Driven Control (Model Predictive Control, Extremum-Seeking Control)
   - Brunton §10.1 - 10.4
9. Multi-Armed Bandits and Dynamic Programming
   - Sutton §1.1 - 2.10, 4.1 - 4.8