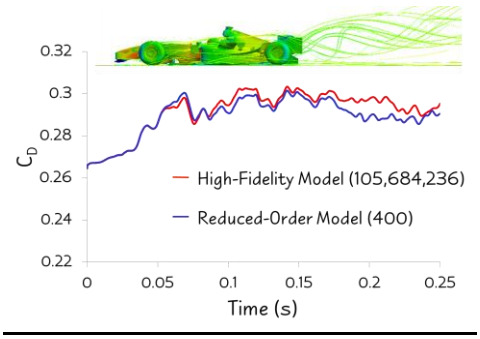
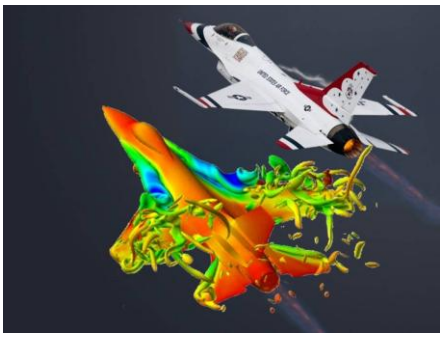
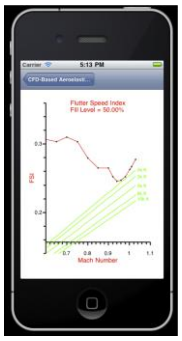
Stanford ENGINEERING
Aeronautics & Astronautics

AA216/CME345: Projection-Based Model Order Reduction

Schedule: Autumn 25, M-W-F (2 of 3) 10:30 am – 11:50 am **Units:** 3
Venue : McCullough 126







Course Description

Projection-based model order reduction (PMOR) is an important pillar of physics-based machine learning. It has rapidly become critical for computational-based design and optimization, statistical analysis, embedded computing, and real-time optimal control; and indispensable for scenarios where real-time, physics-based numerical simulation responses are desired. This course presents the basic mathematical theory for PMOR. It is intended primarily for graduate students interested in computational sciences and engineering. The course material outlined below is complemented by a balanced set of theoretical, algorithmic, and computer programming assignments.

Course Outline

Parametric modeling and simulation - Why model order reduction? – Parameterized differential equations – Linear or affine approximation – Projection-based model order reduction – Error analysis – Proper orthogonal decomposition (POD) and connection with singular value decomposition (SVD) – Linear dynamical systems – Balanced truncation methods – Moment matching methods based on Krylov subspaces – Local parametric database approaches – Hyperreduction – Least-squares Petrov-Galerkin method – Kolmogorov barrier – Nonlinear approximation methods and connection with deep learning.

Instructor

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Office Hours: 4:30 pm – 5:30 pm on each lecture day and/or by appointment, Durand Building, Room 257

Teaching Assistant

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Office Hours: M, W 3:00 PM – 4:30 PM in Durand 270

Prerequisites

- Solid foundations in numerical linear algebra (CME 200 or equivalent)
- Basic numerical methods for ODEs (CME 206 or equivalent)

Textbook

- Approximation of Large Scale Dynamical Systems, A.C. Antoulas, SIAM 2005
- Lecture notes and reading materials provided by instructor

Homeworks

- Assigned in general on a weekly basis
- Subject to the Stanford Honor Code, including a prohibition on the use of AI and on searching for or consulting published solutions. Collaboration with other students is permitted only to discuss the problem statement and approaches to solving it; all other work must be completed individually.

Examination

- 24-Hour Take Home Final Exam: **Released on 12/08/2025 at 10:00 am**
  Due on 12/09/2025 at 10:00 am
- Subject to the Stanford Honor Code, including a prohibition on the use of AI and on searching for or consulting published solutions. Collaboration with other students is strictly forbidden in any form, and students may not pose questions to the professor or teaching assistant.

Course Grade

- Based 60% on the grades for the homework assignments
- Based 40% on the grade for the Take Home Final Exam
- To ensure fairness and facilitate timely posting of solutions and grading, homework assignments must be submitted on time to receive a grade. Additionally, the Take Home Final Exam will only be administered once, with the release and due dates clearly indicated above.

Students with Documented Disabilities

Students who may need an academic accommodation based on the impact of a disability must initiate the request with the Student Disability Resource Center (SDRC) located within the Office of Accessible Education (OAE). SDRC staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare an Accommodation Letter for faculty dated in the current quarter in which the request is

being made. Students should contact the SDRC as soon as possible since timely notice is needed to coordinate accommodations. The OAE is located at 563 Salvatierra Walk (phone: 723-1066).