AAE SPECIAL SEMINAR

Can We Control Flow Without Models?

The Role of Modeling in Learning-Based Control of Air-Breathing Engines

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Abstract

High-fidelity modeling plays a central role in understanding and designing air-breathing propulsion systems, capturing the complex coupling between inlet dynamics, combustion, and flow. These models provide critical physical insight and form the foundation for analysis and validation. However, such models are often computationally expensive and impractical for control synthesis, and may still fail to fully capture off-design and uncertain operating conditions. This raises a fundamental question: how much modeling is actually required for effective control?

This talk presents a data-driven, model-free, learning-based control framework for regulating flow-driven systems, with applications to ramjets, drones, and flexible structures. Controllers are synthesized directly from measured data, without relying on an accurate plant model. Instead, simplified low-fidelity models are used as fast, inexpensive environments for large-scale numerical experiments, enabling rapid controller initialization and training. The resulting controllers are then deployed on higher-fidelity, dynamically coupled simulations, where they adapt online to modeling errors and changing conditions.

Through examples in propulsion, flight, and vibration suppression, we demonstrate that while high-fidelity models remain essential for analysis and validation, low-fidelity models are often sufficient and highly effective for control synthesis when combined with data-driven adaptation. This perspective highlights a complementary relationship between modeling and learning, where computationally efficient models enable scalable controller training through fast numerical experiments, while online learning adapts the controller to high-fidelity dynamics and real physical behavior.

Biography

Dr. Ankit Goel is an Assistant Professor of Mechanical Engineering at the University of Maryland, Baltimore County (UMBC), where he directs the Control, Estimation, and Learning Laboratory. He received his B.E. in Mechanical Engineering from Delhi College of Engineering in 2009, and his M.S. and Ph.D. in Aerospace Engineering from the University of Michigan, Ann Arbor, in 2014 and 2019, respectively. Dr. Goel's research focuses on the development of control systems for complex dynamical environments, spanning both model-based methods and data-driven, learning-based approaches. His work emphasizes learning-based control for systems with uncertainty, nonlinear dynamics, and multi-physics interactions, with a focus on state-constrained control and safety-critical systems.

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