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Set-theoretic Reachability-informed Model Predictive Control for Mechanical and Aerospace Systems

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ABSTRACT:

Modern mechanical and aerospace systems, encompassing domains from robotics and autonomous vehicles to spacecraft and aircraft, are defined by their complexity and the critical need for safety and reliability. As these systems operate more autonomously in uncertain environments, traditional control methods that rely on single-point trajectories and nominal models often fail to ensure necessary guarantees against constraint violations and failures. Set-based methods offer a robust alternative for analyzing system behavior under uncertainty and developing controllers with guaranteed performance by directly handling sets of potential system states, uncertainties, and limitations. Instead of asking “What is the state?”, the question becomes “What is the set of all states the system could be in?”. This shift enables the development of methods that can provide formal guarantees for properties like safety and constraint satisfaction, even when faced with unknown but bounded errors or disturbances. This presentation will highlight the set-theoretic framework, employing set-based reachability analysis to characterize possible system trajectories under uncertainties accurately. The outcomes from reachability analysis, particularly the bounds of reachable states, are systematically integrated into advanced control methodologies such as Model Predictive Control (MPC). This integration enables MPC to make optimal decisions that inherently enforce safety and operational constraints, enhancing system robustness and reliability.

BIOGRAPHY:

Dr. Kamesh Subbarao is Jenkins Garrett Professor and director of the Aerospace Systems Laboratory (ASL) in the Mechanical and Aerospace Engineering Department at The University of Texas at Arlington (UTA). He received his BS from Indian Institute of Technology, Kanpur (1993), MS from Indian Institute of Science, Bangalore (1995), and PhD from the department of Aerospace Engineering at Texas A & M University, College Station in 2001. From 1995-1998 he was a Scientist at the Aeronautical Development Agency, working on Verification & Validation of the Flight Control Laws for the Light Combat Aircraft leading to Certification. After his PhD he worked as an Applications Developer at The MathWorks Inc. (2001-2003) in the Controls and Systems Identification and Estimation Toolboxes group. His research interests span flight mechanics, simulation and control, nonlinear and adaptive control, linear and nonlinear filtering/ estimation approaches, control of unmanned vehicles subject to measurement uncertainties and distributed time delays. Dr. Subbarao’s research has been funded by DARPA, NSF, AFRL, ONR, NASA, and local industry. He received the President’s Award for Excellence in Teaching in 2021, and the Lockheed Martin Aeronautics Company Excellence in Teaching Award in 2016. Previously he received the AIAA Foundation Award for “Model Reference Adaptive Control” in 200. He has authored/co-authored more than 200 journal and peer reviewed conference publications. He is a Fellow of the Royal Aeronautical Society (FRAeS), and the American Astronautical Society. He is also an Associate Fellow of AIAA, and Senior Member of IEEE, and ASME.