IEEE CSS Italy Chapter
Seminar Series

Addressing Limits of Operability of Scramjet Engines in Nonlinear Adaptive Flight Controllers for Hypersonic Vehicles

Prof. Andrea Serrani

Department of Electrical and Computer Engineering The Ohio State University

February, 14th 2023 – Politecnico di Torino
Department of Mechanical and Aerospace Engineering
Meeting Room, 3rd Floor
10:30 AM – 11:10 AM

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Abstract:

Air-breathing hypersonic vehicles (HSVs) offer a promising technology for reliable access to space for commercial and military applications. Among many outstanding problems in flight control system design for HSVs, one of the most challenging is to simultaneously account for the inevitable constraints on the control inputs and the stringent limits of vehicle operability at hypersonic speed. In particular, state-dependent constraints on the propulsion system arise as a result of the complex physics of combustion at hypersonic speed and the tight integration between engine and airframe. The envelope of operating conditions for a typical scramjet engine is bounded by thermal and structural limitations, and combustion stability. Lower bounds on the throttle setting arise from the necessity of maintaining a minimal fuel rate for thermal management, whereas trajectory-dependent constraints on angle-of-attack and sideslip angle must also be imposed to avoid the occurrence of inlet unstart at a given Mach number. In addition, thermal chocking occurs from excessive heat addition in the combustor when acceleration commands are too aggressive, hence incompatible with the physical limit of the engine. This talk considers the incorporation of limits of operability of the scramjet engine in a previously developed adaptive guidance and flight control architecture for a 6-DOF model of a generic hypersonic air-breathing vehicle. A dynamic reference management is presented for the adaptive inner-loop module of the flight controller that provides tracking of airspeed reference trajectories. A model-recovery anti-windup strategy is teamed with a reference governor so that feasible input reference trajectories (which depends on parameter estimates) are provided to the adaptive controller, so that convergence to a feasible setpoint for the throttle setting is attained.

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Andrea Serrani received the Laurea (B.Eng.) degree in Electrical Engineering, summa cum laude, from the University of Ancona, Italy, in 1993, and the Ph.D. degree in Artificial Intelligence Systems in 1997. From 1994 to 1999, he was a Fulbright Fellow at Washington University in St. Louis, where he obtained the M.S. and D.Sc. degrees in Systems Science and Mathematics in 1996 and 2000, respectively. Since 2002, he has been with the Department of Electrical and Computer Engineering of The Ohio State University, where he is currently a Professor and Associate Chair. He has held visiting positions at the Universities of Bologna and Padua, Italy, and multiple summer faculty fellowships at AFRL. The research activity of Prof. Serrani lies at the intersection of methodological aspects of nonlinear, adaptive and geometric control theory with applications in aerospace and marine systems, fluidic systems, robotics and automotive engineering. His work has been supported by AFRL, NSF, Ford Motor Co. and NASA, among others. Prof. Serrani has authored or coauthored more than 150 articles in journals, proceedings of international conferences and book chapters, and is the co-author of the book Robust Autonomous Guidance: An Internal Model Approach published by Springer-Verlag. Prof. Serrani was a Distinguished Lecturer of the IEEE CSS. Prof. Serrani is the Editor-in-Chief of the IEEE Trans. on Control Systems Technology and a past Associate Editor for the same journal (2010-2016), Automatica (2008-2014) and the Int. Journal of Robust and Nonlinear Control (2006-2014). He serves on the Conference Editorial Boards of IEEE CSS and IFAC, and served as Program Chair for the 2019 ACC and as General Co-chair for the 2022 CDC.