

# Design of beneficial wave dynamics for engine life and operability enhancement

Dr. Gregory Hagen

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3:30-4:30 pm

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4-178 EECS Bldg.

**ABSTRACT:** Analysis of the role of jet engine design symmetry in the dynamics of detrimental rotating waves such as thermoacoustic instabilities and blade flutter leads to an explanation of the origin of the waves and practical means of their passive control. Previous stability results of this system under wave-speed mistuning are extended to the infinite-dimensional and nonlinear systems with non-trivial coupling patterns. For a string of (possibly arbitrarily many) coupled stable subsystems that are equipped with negative imaginary frequency response, we characterize stability of the string by a DC gain condition that can be expressed as a continued fraction with verifiable convergence properties. Through analysis of the convergence of the continued fraction, we establish both stability and robustness for the string with various coupling gains and patterns. We discuss how the theory is modified to handle systems coupled in a ring. The derived results are demonstrated on a problem of decentralized control of large vehicle platoons, possibly with heterogeneous neighboring coupling. Extensions to infinite-dimensional nonlinear systems that have a linear part with a banded infinite-dimensional matrix representation, which represent infinite chains of coupled sub-systems, are discussed. Sufficient conditions for absolute stability of the infinite-dimensional system are established by the feasibility of two finite-dimensional linear matrix inequalities (LMI). Numerical results of a thermoacoustics PDE model are presented for an example problem. The second part of the talk focuses on empirical dynamic modeling from high-dimensional data.

**BIOGRAPHY:** Dr. Gregory Hagen is a Staff Research Engineer in the Systems Department of United Technologies Research Center, where he is currently principle investigator of compressed sensing video and AFOSR-sponsored Design of Beneficial Wave Dynamics projects. Previously, he has held the position of Program Manager of Navair-sponsored Life Extending Controls. His recent technical work has focused on video-based empirical modeling of fluid and combustion dynamic systems and system-level modeling of thermo-acoustic instabilities in jet engines. He holds a Ph.D. degree in Mechanical and Environmental Engineering from the University of California at Santa Barbara, where his work focused on control of parabolic partial differential equations and dynamic modeling of compressor stall. Before joining UTRC in 2001 he was a post-doctorate researcher at University of California at San Diego, where his focus of research was in adjoint-based methods of flow control and optimization. He is author of 7 peer-reviewed journal papers, 18 conference papers, and one patent.

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