Topics in Control and Model Reduction

- **Title**: Nonlinear Model Reduction for Unsteady Discontinuous Flows
  Speaker: *Nail Yamaleev* (nkyamale@ncat.edu), North Carolina A&T State University
  Coauthors: *Kedar Pathak* (kedarapathak@gmail.com), Ganpat University

  Abstract: We develop a new nonlinear reduced-order model (ROM) based on proper orthogonal decomposition (POD), which can be used for quantitative simulation of both smooth and discontinuous flows. The POD basis functions in the new model are constructed for each component of the vector of the conservative variables, rather than only for the velocity and pressure fields as it is traditionally done in conventional POD reduced-order models for incompressible flows. The new POD ROM is derived using the Galerkin projection of fully conservative discretized Euler equations onto the POD basis, thus leading to a system of ODEs which closely resembles the nonlinear and conservation properties of the original full-order model. This approach can be interpreted as a variant of the spectral method with a truncated set of basis functions. The most distinctive feature of the new POD ROM equations is that they are locally stable in the L_2 sense if the discrete full-order model equations are stable in the energy norm. As a consequence of this, no artificial dissipation terms are introduced into the new ROM unlike the conventional approaches that require additional stabilization to suppress numerical instabilities inherent in POD-based reduced-order models. The performance of the new POD ROM is demonstrated for 2-D compressible unsteady inviscid flows over a wide range of Mach numbers including trans- and supersonic flows with strong shock waves.

- **Title**: Optimal Control Applied in Coupled Within-host and Between-host Models
  Speaker: *Eric Numfor* (numfor@math.utk.edu), University of Tennessee
  Coauthors: *Kedar Pathak* (kedarapathak@gmail.com), Ganpat University

  Abstract: An immuno-epidemiological model is formulated and analyzed for a "within-host" system of ODEs coupled with a "between-host" system of PDEs and ODEs. Using the method of characteristics and a fixed point argument, we prove the existence and uniqueness of solution to our system. An optimal control problem for the coupled model is considered, and existence, characterization and uniqueness results established. This work is in collaboration with Drs. Suzanne Lenhart, Maia Martcheva and Souvik Bhattacharya.

- **Title**: Gaussian Process Regression in Neuro-Adaptive Control
  Speaker: *Patricio A. Vela* (pvela@gatech.edu), Georgia Tech
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  Abstract: To handle unmodeled, nonlinear uncertainty model reference adaptive control (MRAC) strategies often utilize neural-network function approximators within the adaptive framework. While effective, neuro-adaptive structures require a more complex, persistently exciting signal to ensure parameter convergence. Furthermore, in the case of disturbances or measurement uncertainty, neuro-adaptive strategies require stabilizing elements to guarantee stable behavior. This talk will discuss an alternative approach that couples Gaussian process regression (GRP) with MRAC for adaptive control of uncertain feedback-linearizable, nonlinear systems. The approach does not alter the conditions for parameter convergence beyond the linear case and provides an iterative optimization based technique for handling nonlinear uncertainty and measurement noise.

- **Title**: Wavelet-based Adaptive Mesh Refinement (WAMR) algorithm for numerical simulation of atmospheric chemical transport

  Speaker: *Yevgenii Rastigejev* (ye_rast@ncat.edu), North Carolina A&T State University
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  Abstract: Application of non-adaptive numerical techniques for computational modeling of multi-scale atmospheric chemical transport often results in significant numerical errors due to poor spatial and temporal resolution. Here we present an adaptive multi-scale Wavelet-based Adaptive Mesh Refinement method applied to numerical simulation of transpacific pollution plume transport. It is shown that multilevel numerical grid efficiently adapts to the numerical solution development and the algorithm accurately reproduces the plume dynamics at a reasonable computational cost unlike conventional non-adaptive numerical methods.