CRUNCH Seminars at Brown, Division of Applied Mathematics

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Physics-Constrained Reservoir-Computing for Turbulence and Chaotic Learning

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The ability of fluid mechanics modelling to predict the evolution of a flow is enabled by physical principles and empirical approaches. Physical principles, for example conservation laws, are extrapolative (until the assumptions upon which they hinge break down): they provide predictions on phenomena that have not been observed. Human beings are excellent at extrapolating knowledge because we are excellent at finding physical principles. Empirical modelling provides correlation functions within data. Artificial intelligence and machine learning are excellent at empirical modelling.

In this talk, the complementary capabilities of both approaches will be exploited to achieve adaptive modelling and optimization of nonlinear, unsteady and uncertain flows. The focus of the talk is on computational methodologies for learning hidden variables, noise filtering, optimal design and turbulence learning. Three physics-constrained architectures: physics-informed echo state networks (PI-ESN), automatic-differentiated physics-informed echo state networks (API-ESN), and auto-encoder echo state networks (AE-ESN). The physics is embedded as soft and hard constraints. The flows under investigation are relevant to aerospace propulsion, with a focus on thermoacoustics, and turbulence, with a focus on the Kolmogorov flow.