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Rapid Bayesian Inference for Fluid Flow Modeling and Control[1]

ROBERT K. NIVEN, The University of New South Wales, EURIKA KAISER, University of Washington, BERND R. NOACK, LIMSI, CNRS, Paris, France., LOUIS N. CATTAFESTA III, Florida State University, MARKUS W. ABEL, Potsdam University, LAURENT CORDIER, CNRS - Université de Poitiers — We give a new framework for rapid Bayesian inference for flow modeling and control, based on Bayes' rule $p(\vec{\theta}|\vec{x}) = p(\vec{x}|\vec{\theta})p(\vec{\theta})/p(\vec{x})$, where p is a probability density function, $\vec{x}$ are multivariate data and $\vec{\theta}$ is one model drawn from a continuous model space $\Omega_{\vec{\theta}}$. We thus seek the pdf of the model $\vec{\theta}$, given the data $\vec{x}$. Traditionally, Bayesian inference requires marginalization of the integral $p(\vec{x}) = \int d\vec{\theta}\, p(\vec{x}|\vec{\theta})p(\vec{\theta})$, which is highly computationally expensive and may not even be feasible. Instead, we propose initial order reduction of the data, such as by k-means clustering, to generate discretized data c_i on a reduced-order data space C, followed by Bayesian inference to infer the conditional probability $P(\gamma_m|c_k)$ of the discretized model γ_m in a reduced-order model space Γ. If needed, an inversion to infer $p(\vec{\theta}|\gamma_m)$ can be conducted. The method substantially reduces the computational complexity of Bayesian inference, enabling real-time turbulent modeling and control. We report applications to several turbulent flow and dynamical systems.

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Robert K. Niven
The University of New South Wales

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