Informing Missing Physics with Model Form Error and Model Selection

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Despite continuing advances in statistical inversion and modeling, model inadequacy due to model form error remains a concern in all areas of mathematical modeling. The Bayesian paradigm naturally integrates uncertainties from both experimental data and model formulation, including initial or boundary conditions, model form, and parameter and numerical approximation. While model improvement is an enterprise that is continuously enabled by the availability of cost-effective high-performance computing infrastructure, model error is unavoidable in many situations. This problem is attributed to the incomplete understanding of the underlying physics, likely in addition to large and poorly characterized uncertainties in calibration and validation data.

Introducing a model discrepancy term into the Bayesian framework can improve the predictive power of a given model and, arguably, the transferability of physical parameters. Much like physical models, calibrating a discrepancy model requires careful consideration regarding formulation, parameter estimation, and uncertainty quantification, each of which is often problem-specific. At the intersection of model form error quantification and model selection lies a systematic methodology for identifying and characterizing model form error as a means of identifying missing physics or unknown phenomena, which has the potential to inform model development and experimental design. One such methodology is presented, with an application to hypersonic re-entry experimental data.

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