Fusing Computational Models and Data for Calibration, Monitoring, and Evaluation

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When considering some existing system, both data from sensors, measurements, or observations, and mathematical / computational models are forms of knowledge about the system. Their fusion can allow one to exploit this information to increase or sharpen the knowledge about the system. This is particularly true for complex systems, where often the quantities of interest are not directly observable. Here the computational model can act like an extension or additional measurement instrument. This has many different potential areas of application, such as monitoring, state tracking and identification, quantification and inverse identification of parameters and quantities of interest, assessments after accidents or damage, etc.

One way to achieve this is the Bayesian approach to inverse problems, the basic ideas of which will be presented. Traditionally often deemed too computationally demanding for complex mathematical models, relatively recent numerical techniques for uncertainty quantification -- the forward problem -- offer a realistic possibility for this task, considerably increasing its range of practical applicability, and also benefit the inverse problem. As these recent numerical techniques accelerate the forward problem, they also have direct bearing -- independent of the inverse problem -- on the efficient uncertainty quantification (UQ) of system states and other quantities dependent on it due to uncertainties in system properties and / or system loading / excitations. This can then be used in traditional UQ tasks like determining the probability of occurrence of certain system states, as it is used for example in quantitative risk assessment.