Real-time monitoring of additive manufacturing processes using a variational data assimilation method with model reduction and bias correction

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ABSTRACT

Real-time monitoring of a system may be difficult when associated phenomena are multiphysics and multiscale. Difficulties mainly come from the numerical complexity which requires large computing resources that are hardly compatible with real-time.To overcome this issue, the initial high-fidelity parameterized physical model can be simplified, which leads to additional model bias. Moreover, parameter values can be inaccurate and erroneous. All those errors affect the effectiveness of numerical diagnosis and prognosis, and thus have to be corrected with assimilation techniques on observation data. Therefore, the monitoring of the process is made of two stages: (1) state estimation at the acquisition time, which may be associated with the identification of a set of unknown parameters of the parameterized model and the data-based enrichment of the model; (2) state prediction for future time steps from the updated model.

The present study aims at implementing this framework with an extension, for time-dependent problems, of the Parameterized Background Data-Weak (PBDW) method introduced in [1]. Classical PBDW is a non-intrusive, reduced basis, real-time and in-situ data assimilation method that applies to physical systems modeled by parametrized pdes (initially for steady-state problems). The key idea of the formulation is to seek an approximation to the true state employing projection-by-data, with a first contribution from a background estimate computed from a reduced-order method (ROM) enhanced on-the-fly, and a second contribution from an update state informed by the experimental observations (correction of model bias). It thus constitutes a hybrid twin as defined in [2]. Further research works [3, 4] developed a tailored version of PBDW in order to deal with noisy data and nonlinear problems. Moreover, a priori error analysis was conducted by providing a bound on the state error and identifying separate error contributions.

In the present work, we investigate the use of PBDW for state reconstruction and prediction-in-time purposes. A space/time/parameter decomposition is proposed and the state prediction for future time steps is performed using an evaluation of the updated model and an extrapolation of the time evolution from the tensor-based decomposition (SVD) on prior updates over a window time [5]. We illustrate the performance of the method for the online monitoring of thermal effects in additive manufacturing processes from a surrogate model and high-fidelity and high-frequency camera-based data. Several test cases, at the scale of the melting pool or of the manufactured part, will be shown during the talk.

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