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Reduced Order Models for Distributed Adaptive Monitoring of Atmospheric Dispersion Processes

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Atmospheric dispersion of hazardous materials due to chemical leaks can highly affect human health and well-being. For this reason, online state and parameter estimation of these processes is an important step for disaster response to enable the assessment of future impacts. The estimation procedure relies on a combination of the forecasts of a process PDE-model and on measurements obtained by multiple mobile sensor platforms, which are adaptively guided to locations where additional measurements are most useful. The latter challenge can be solved by a cooperative vehicle controller maximizing the quality of the estimates based on the current error covariance matrix [1, 2].

The described approach can be made more flexible and less prone to error if the required calculations (model forecast, estimation procedure, vehicle control) are performed locally on-board of the sensor vehicles instead of using a central supercomputer. While the on-board computing power is limited and results have to be obtained in real-time, complex PDE-models are required to describe the dynamics and to compute accurate forecasts. This highly motivates the use of model order reduction in this context and demonstrates at the same time that the described problem scenario is a paradigmatic application area for reduced order models.

A reduced joint state parameter estimation approach is developed for the advection-diffusion equation. The initial condition as well as possible source functions, shapes and locations are unknown. However, it is assumed that the initial condition can be approximated by several radial basis functions with height and shape parameter to be determined. Furthermore, source effects can be represented by the convolution of the same radial basis functions with their height. In the offline phase, multiple simulations with the different radial basis function as initial conditions are performed and snapshots are taken. With the aid of Proper Orthogonal Decomposition, the reduced order model is constructed out of the snapshot matrix and reduced model forecasts are performed locally to repeatedly and jointly estimate process state and parameters of the radial basis functions with the Kalman Filter.

As a first step, a basic two-dimensional test-case, in which the true state is simulated along with the estimation, is set up and promising results are obtained.

References

[1] J. Euler, T. Ritter, S. Ulbrich, and O. von Stryk. Centralized ensemble-based trajectory planning of cooperating sensors for estimating atmospheric dispersion processes. In *Proceedings of the Dynamic Data-driven Environmental Systems Science Conference (DyDESS)*, November 2014.

[2] T. Ritter, J. Euler, S. Ulbrich, and O. von Stryk. Adaptive observation strategy for dispersion process estimation using cooperating mobile sensors. In *Proceedings of the 19th IFAC World Congress*, pages 5302–5308, August 2014.