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Kernel embedding of maps for Bayesian inference: The variational mapping particle filter

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Data assimilation for high-dimensional highly nonlinear systems is becoming crucial for several geosciences applications. In this work, a novel particle filter is introduced which aims to an efficient sampling of the posterior pdf in high-dimensional state spaces considering a limited number of particles. Particles are mapped from the proposal to the posterior density using the principles of optimal transport. The Kullback-Leibler divergence between the posterior density and the proposal divergence is minimised using variational principles, leading to an iterative gradient-descent like algorithm. A key ingredient of the mapping is that the transformations are embedded in a reproducing kernel Hilbert space which constrains the dimensions of the space for the optimal transport to the number of particles. Gradient information of the Kullback-Leibler divergence allows a quick convergence using well known gradient-based optimization algorithms from machine learning, adadelta and adam, which do not require cost function calculations.

Evaluation of the method and comparison with a SIR filter is conducted as a proof-of-concept in the Lorenz-63 system, where the exact solution is known. No resampling is required even for long recursive implementations. The number of effective particles remains close to the total number of particles in all the recursions. Hence, the mapping particle filter does not suffer from sample impoverishment, even in highly nonlinear settings. Finally, results from experiments on a high-dimensional turbulent geophysical system will be presented, and the performance of the new method compared to other existing method will be discussed.