Dimensionality Reduction via Markovian Projection in Filtering for Stochastic Reaction Networks: Bridging Accuracy and Efficiency

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Stochastic reaction networks (SRNs) model stochastic effects for various applications, including intracellular chemical/biological processes, and epidemiology. A typical challenge arising in practical problems modeled by SRNs is that only a few state variables can be dynamically observed. Given measurement trajectories, one can estimate the conditional probability distribution of unobserved (hidden) state-variables by solving a stochastic filtering problem. In this setting, the conditional distribution evolves in time according to a large or potentially infinite-dimensional system of coupled ordinary differential equations with jumps, known as the filtering equation. Current numerical filtering techniques, such as the Filtered Finite State Projection [2], are hindered by the curse of dimensionality, significantly impacting their computational performance. To address these limitations, we propose a novel finite-dimensional filter that integrates a dimensionality reduction technique for the SRN system, specifically the Markovian projection [1] initially proposed for forward problems, with the Finite State Projection approach [3]. Our analysis and empirical results highlight the superior computational efficiency of our method compared to the existing Filtered Finite State Projection filter in the high dimensional setting.

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[2] D'Ambrosio, E., Fang, Z., Gupta, A. and Khammash, M., 2022. Filtered finite state projection method for the analysis and estimation of stochastic biochemical reaction networks. bioRxiv, pp.2022-10.

[3] Munsky, B. and Khammash, M., 2006. The finite state projection algorithm for the solution of the chemical master equation. The Journal of chemical physics, 124(4).