

Highly accurate tau-leaping methods with random corrections

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Abstract: We aim to construct higher order tau-leaping methods for numerically simulating stochastic chemical kinetic systems in this paper. By adding a random correction to the primitive tau-leaping scheme in each time step, we greatly improve the accuracy of the tau-leaping approximations. This gain in accuracy actually comes from the reduction in the local truncation error of the scheme in the order of τ , the marching time step size. While the local truncation error of the primitive tau-leaping method is $O(\tau^2)$ for all moments, our Poisson random correction tau-leaping method, in which the correction term is a Poisson random variable, can reduce the local truncation error for the mean to $O(\tau^3)$, and both Gaussian random correction tau-leaping methods, in which the correction term is a Gaussian random variable, can reduce the local truncation error for both the mean and covariance to $O(\tau^3)$. Numerical results demonstrate that these novel methods more accurately capture crucial properties such as the mean and variance than existing methods for simulating chemical reaction systems. This work constitutes a first step to construct high order numerical methods for simulating jump processes. With further refinement and appropriately modified step-size selection procedures, the random correction methods should provide a viable way of simulating chemical reaction systems accurately and efficiently.