



THE UNIVERSITY OF  
CHICAGO

Computational and Applied Mathematics  
&  
Statistics Student Seminar

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Optimization-Free Diffusion Model - A Perturbation Theory Approach

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ABSTRACT

Diffusion models have emerged as a powerful framework in generative modeling, typically relying on optimizing neural networks to estimate the score function via forward SDE simulations. In this work, we propose an alternative method that is both optimization-free and forward SDE-free. By expanding the score function in a sparse set of eigenbasis of the backward Kolmogorov operator associated with the diffusion process, we reformulate score estimation as the solution to a linear system, avoiding iterative optimization and time-dependent sample generation. We analyze the approximation error using perturbation theory and demonstrate the effectiveness of our method on high-dimensional Boltzmann distributions and real-world datasets.