

Optimising Trotter-Suzuki Simulations of Markovian Open Quantum Systems via Classical Search

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Developing robust quantum machine learning (QML) algorithms for near-term hardware requires a deep understanding of how environmental noise, such as dissipation and decoherence, impacts algorithmic performance [1, 2, 3]. Investigating these effects necessitates the accurate simulation of open quantum systems, a task typically accomplished on digital quantum computers using Trotter-Suzuki (TS) Product Formulas (PF) to approximate the systems' time evolution. Minimising the computational overhead of these methods relies on obtaining precise estimates of the required number of Trotter steps, as the resulting gate count is strictly tied to this step-count. In this work [4], we build upon established theoretical guarantees to derive analytic bounds for First- and Second-Order Deterministic [5, 6] and Randomised [7] TS-PF, directly mapping the required Trotter steps to model parameters, evolution time and target precision. We also introduce a computationally efficient classical algorithm that leverages diamond norm estimates of individual Liouvillian terms alongside a binary search strategy to significantly decrease the required Trotter steps for a given target precision. We numerically evaluate our methods on two prototypical open quantum system models. Our results demonstrate that while analytical bounds are often overly conservative, our empirical optimisation strategy dramatically reduces the required step count. Notably, the Second-Order Randomised TS-PF consistently demands the lowest computational resources, a benefit that becomes increasingly pronounced for larger system sizes. Ultimately, these findings highlight the vital role of empirical bounding strategies in achieving resource-efficient simulations of Markovian open quantum systems, paving the way for more practical noise-resilience testing in QML.

References

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