Practical Difficulty and Techniques in Matrix-Product-State Simulation of Quantum Computing in Hilbert Space and Liouville Space

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There have been many studies on matrix-product-state (MPS) simulation of quantum computing for more than a decade [1, 2, 3, 4, 5, 6]. Although it is widely believed to be unlikely, it is still an open problem if a practical simulation of a powerful quantum algorithm like Shor's factoring algorithm is possible. This situation is owing to the fact that not only theoretical analyses but numerical investigations on MPS are quite cumbersome.

In practice, coding an MPS simulation program is highly technical. A quantum circuit should be carefully decomposed as its structure affects the Schmidt ranks of MPS during simulation. In addition, numerical error may accumulate rapidly if we use only double-precision floating-point arithmetics because almost always we need to diagonalize highly degenerate reduced density matrices during simulation. Furthermore, sometimes quantum states initially having very small population play an important role in an algorithm. Thus, multiple-precision computing is often requisite to obtain a reasonable simulation result [5, 6].

In this contribution, I summarize the above-mentioned issues with explicit examples, and how I have been coding my open source C++ library, ZKCM_QC [5, 6]. I also discuss the simulability of spin-Liouville-space quantum computations on the basis of some simulation results.

References

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