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The power of one qubit in quantum simulation algorithms

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Stellingen

Behorende bij het proefschrift
"The power of one qubit in quantum simulation algorithms"

1. Quantum thermalization can be emulated by coupling a system to a small bath, whose excitations are actively dissipated through measurement and feedback. [Chapter 2]

2. Purity-constraint error mitigation can be implemented by multiplexing state preparation in time, rather than in space, with a technique reminiscent of Loschmidt's echo [Chapter 3]

3. Restricting measurements on a n-qubit quantum state to extracting a single bit of information, rather than the n bits saturating Holevo's bound, reduces the accuracy of expectation value measurements by an amount scaling sub-linearly in the system size. [Chapter 4]

4. Quantum error mitigation has applications beyond the reduction of hardware noise; these include the reduction of algorithmic noise in randomized quantum algorithms and in adiabatic state preparation [Chapter 5; W. J. Huggins *et al.*, *Phys. Rev. X* **11**, 041036 (2021)]

5. The QMA-hardness of the local Hamiltonian ground state problem is a worst-case result, which does not apply to systems that reach their ground state in Nature. These are the systems of interest for ground state quantum simulation

6. The second law of thermodynamics can be stated in a time-symmetric form: the entropies of two temporarily-separated subsystems must change with the same sign. This is indistinguishable from the standard formulation for an internal observer, but it solves Loschmidt's paradox. [E. Schrödinger, *Proc. R. Ir. Acad. A*, **53**, 189-195 (1951)]

7. The scientific study of complex quantum systems will be the first field to benefit from beyond-classical quantum computation.

8. Advanced numerical simulation methods, such as tensor network approaches and quantum Monte Carlo, will be indispensable in the development of useful quantum algorithms in the beyond-classical regime.

9. After the first fault tolerant quantum computers are deployed, a phase of experimentation will be needed to define commercially and societally

relevant applications. Nevertheless, today's quantum algorithm research is necessary to accelerate this process.

10. Today's quantum devices should be regarded as experiments, not as computing machines; although they can generate reproducible results out of reach of classical emulation, these current benchmark tasks are too limited and arbitrary to be categorized as *computation*.

11. At the current stage of developent of quantum computing, all stakeholders share the benefits of anyone's successes. While some rivalry between competitors is natural, aggressive contention on the public stage is detrimental to the whole field.

12. There is no intrinsic difficulty in understanding quantum mechanics as compared to other modern scientific fields. Its conceptual framework is no more difficult to internalize than electromagnetism or relativity, nor more open to interpretation than statistics or thermodynamics.

Stefano Polla
Leiden, 22 Februari 2024