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Simulating Hamiltonian Dynamics with a Truncated Taylor Series

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One of the main motivations for quantum computers is their ability to efficiently simulate the dynamics of quantum systems. Since the mid-1990s, many algorithms have been developed to simulate Hamiltonian dynamics on a quantum computer, with applications to problems such as simulating spin models and quantum chemistry. While it is now well known that quantum computers can efficiently simulate Hamiltonian dynamics, ongoing work has improved the performance and expanded the scope of such simulations. In this talk, I will describe a very simple and efficient algorithm for simulating Hamiltonian dynamics on a quantum computer by approximating the truncated Taylor series of the evolution operator. This algorithm can simulate the time evolution of a wide variety of physical systems. The cost of this algorithm depends only logarithmically on the inverse of the desired precision, and can be shown to be optimal. Such a cost also represents an exponential improvement over known methods for Hamiltonian simulation based on, e.g., Trotter-Suzuki approximations. Roughly speaking, doubling the number of digits of accuracy of the simulation only doubles the complexity. The new algorithm and its analysis are highly simplified due to a technique for implementing linear combinations of unitary operations to directly apply the truncated Taylor series.

This is joint work with Dominic Berry, Andrew Childs, Richard Cleve, and Robin Kothari.