TEXAS TECH UNIVERSITY
Department *of* Computer Science

Efficient Evaluation of Exponential and Gaussian Functions on a Quantum Computer, with Application to Quantum Computational Chemistry and Quantum Finance

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BIOLOGY LH100 or Zoom
https://sites.google.com/view/tsalman/teaching/cs5120_sp23

Abstract: The exponential and Gaussian functions are among the most fundamental and important operations, appearing ubiquitously throughout all areas of science, engineering, and mathematics. Whereas formally, it is well-known that any function may in principle be realized on a quantum computer, in practice present-day algorithms tend to be very expensive. In this talk, we present new quantum algorithms that are highly efficient—requiring a (generally) small number of multiplications, which represent the overall computational bottleneck [1]. The new algorithms are then evaluated in the context of two disparate application areas, whose importance to quantum computing is well recognized. For each application, exponential/Gaussian evaluation is the computational bottleneck, and the new approach is found to offer substantial improvement over the current state of the art. The first application is in quantum computational chemistry [2], for which the Gaussian Toffoli count is reduced from 15,690 down to 912, when compared against a state-of-the art competing method by Häner and coworkers [3]. The second application is in quantum finance—specifically, derivative pricing beyond Black-Scholes [4]. Here, the exponential Toffoli count is reduced from 728 down to 50, when compared with the recently-published state-of-the-art "re-parametrization method" [5]. Space requirements are also quite modest, to the extent that both applications above can be implemented with as few as 20–70 logical qubits.

[1] B. Poirier, Efficient Evaluation of Exponential and Gaussian Functions on a Quantum Computer, with Application to Quantum Computational Chemistry and Quantum Finance, Phys. Rev. X Quantum, (submitted; second revision).

[2] B. Poirier and J. Jerke, Full-Dimensional Schrödinger Wavefunction Calculations using Tensors and Quantum Computers: the Cartesian component-separated approach, part of themed collections on "Quantum Computing and Quantum Information Storage" and "Quantum Computing and Quantum Information Storage: Celebrating the 2022 Nobel Prize in Physics," Phys. Chem. Chem. Phys. 24, 4437-4454 (2022). doi: 10.1039/D1CP02036F.

[3] T. Häner, M. Roetteler, and K. M. Svore, Optimizing quantum circuits for arithmetic, arXiv preprint arXiv:1805.12445v1 [quant-ph] (2018).

[4] F. Black and M. Scholes, The pricing of options and corporate liabilities, J. Poli. Econ. 81, 637 (1973).

[5] S. Chakrabarti, R. Krishnakumar, G. Mazzola, N. Stamatopoulos, S. Woerner, and W. J. Zeng, A threshold for quantum advantage in derivative pricing, Quantum 5, 463 (2021).

Bio: Bill Poirier is Chancellor's Council Distinguished Research Professor and also Barnie E. Rushing Jr. Distinguished Faculty Member at Texas Tech University, in the Department of Chemistry and Biochemistry and also the Department of Physics. He received his Ph.D. in theoretical physics from the University of California, Berkeley, followed by a chemistry research associateship at the University of Chicago. His research interest is in understanding and solving the Schrödinger equation, from both foundational and practical perspectives. He has given well over 100 oral presentations on quantum mechanics, to both scientific and general audiences, and published over 100 papers in this field. He is also the creator of the continuous "many interacting worlds" interpretation of quantum mechanics.