Improved Gate Level Simulation of Quantum Circuits

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Quantum computers are a paradigm shift in computing. However, intermediate to large-scale quantum devices are not yet available. This has introduced a need for the fast, accurate simulation of quantum computers. There are novel and fast algorithms suitable for the simulation of quantum circuits. Still, these approaches are not always usable by researchers. There is also no clear way to decide on the best simulation method for a given circuit. This research addresses these issues. My software implements four methods of simulation. I developed a novel method for state vector simulation. Unlike current tools, this enables the use of both hardware acceleration and distributed systems. Near-Clifford, tensor network, and path integral simulation methods are also implemented. This allows simulation of circuits with a reasonably large number of qubits. To optimally choose the simulation method, a quantum circuit analysis procedure was developed. The analysis is based on computational complexity and heuristics. The use of this analysis procedure in conjunction with the simulation methods allows for the exploitation of the individual algebraic and topological properties of a quantum circuit. A statistical benchmark displayed a significant speedup over leading alternatives (p = .0017643). Simulating a 25 qubit quantum Fourier transform showed a 120x increase in speed. Experimental verification of the analysis method was also completed. The software I developed improves upon alternatives in terms of performance, methods, and utility. This allows researchers to perform simulations that would otherwise be intractable.

Awards Won:

Intel ISEF Best of Category Award of $5,000

First Award of $3,000

Dudley R. Herschbach SIYSS Award

National Security Agency Research Directorate : Honorable Mention "Science of Security"