SIMULATION OF QUANTUM CIRCUITS WITH *MATHEMATICA*®

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Quantum computation is a rapidly developing interdisciplinary research field that combines mathematics, physics and computer science. One reason for this is a potential ability of a quantum computer to do certain computational task much more efficiently than it can be done by any classical computer. For example, quantum computation may in some cases polynomially (e.g. Grover's algorithm for searching in an unsorted data base) or even exponentially (Shor's algorithm for integer factoring) speed-up classical computation [1].

Since realistic quantum computers have not yet been built, it is worthwhile to simulate quantum computation on a classical computer. Among two equivalent models of quantum computation – quantum Turing machine and the circuit model – the last one is more convenient both for simulation and application [1].

The problem of simulating a quantum computation consists in constructing some quantum circuit transforming an initial state of quantum memory register into the final state that can be measured. Such transformation must be done by means of unitary operator. Therefore, first of all a simulator program must be able to construct a quantum circuit and to calculate a unitary matrix corresponding to this circuit in general case of n-qubit memory register. Besides, a simulator must be a user-friendly tool which can be easily used to design and test different quantum algorithms.

Here we present the first version of our Mathematica package "QuantumCircuit" that, in our opinion, satisfies both these requirements [2]. In our approach all the information about a structure of the n-qubit circuit is stored in a matrix with n rows whose elements are some symbols corresponding to the standard notations for different quantum gates. The number of columns in the matrix is determined from the condition that each column contains either one multi-qubit gate or several single-qubit gates acting on different qubits. Thus, to define an arbitrary quantum circuit it is sufficient to specify the corresponding symbolic matrix. Then we can easily draw the circuit and calculate the corresponding unitary $2^n \times 2^n$ matrix transforming initial state on the n-qubit memory register to some its final state that can be measured.

Note that in comparison with other Mathematica-based simulators of quantum computation our package is quite universal in a sense that it can be used to simulate any quantum circuit while times of calculation of the circuit matrix have the same order of magnitude. To demonstrate this we have considered two test examples, namely, quantum circuits implementing the algorithm of quantum Fourier transformation and a reversible full-adder algorithm.

References

1. *Nielsen M., Chuang I.* Quantum Computation and Quantum Information. Cambridge University Press, 2000.

2. *Gerdt V.P., Kragler R., Prokopenya A.N.* A Mathematica Package for Construction of Circuit Matrices in Quantum Computation // Computer Algebra and Differential Equations. Acta Academiae Aboensis. Ser. B. 2007. V. 67. No. 2. P. 28–38.