Programmable networks for quantum algorithms

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The implementation of complex N-qubit operations (where $N \geq 3$) and the realization of quantum algorithms are major challenges in the field of quantum computation. The attempts of practical implementation focus on Shor's algorithm [1], Grover's database search [2], and the Deutsch–Jozsa algorithm [3, 4]. A feature common to all existing qubit-based implementations so far [5–11] is that the operation sequences depend on the specific physical system and the number of qubits. More importantly, they depend also on the particular function to implement.

The universality of quantum computation states that arbitrary N-qubit gates can be generated by means of one-qubit and two-qubit operations only [12, 13]. Barenco *et al.*, and later on Cleve *et al.*, have developed tools to design networks for N-qubit controlled operations [14, 15]. However, it is not obvious how to apply these rules for a systematic and efficient implementation of algorithms.

Here we present a method to generate arbitrary controlled phase shifts with a single programmable network. This network can be adapted to various physical implementations of quantum computing and is suitable to realize many computational tasks, in particular both the Deutsch–Jozsa algorithm and Grover's search algorithm.

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