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Quantum computation with applications in seismic problems

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Summary

Quantum computers potentially can solve the certain class of problems in science much faster than any existing classical computers. In the beginning of 1980s R.P Feynman, a physics Nobel prize winner proposed that if we would be able to run a computer that executes the algorithms quantum mechanically, the running speed up in the simulation of quantum physics would be exponentially faster than classical computers [1]. The first attempt to establish the mathematical framework for quantum computation is proposed by Deutsch [2]. He introduced the concept of the quantum Turing machine called universal quantum computer and also proposed a model for scientific computation based on the quantum physics laws. The first successful algorithm that demonstrated the quantum computation supremacy was introduced by Shor [3]. Given an integer number, Shor algorithm find its prime factors by running in a polynomial time proportional to cubed N. Quantum parallelism exploited for the first time in the Grover search algorithm [4]. This algorithm demonstrates a quadratic speedup for unstructured search on a quantum computer.

Quantum algorithms can be used also to solve the algebraic problems in mathematics and engineering, among them the solution of linear system of the equations which is applicable in many areas in applied science. Given an N-dimensional problem the best classical algorithm offers a computational time proportional to N. However, a quantum computer can solve the linear system of equation in running time log N, a logarithmic speedup compared to the classical computer [5]. This novel algorithm, is particularly useful for machine learning [6,7] and data fitting [8]. As the finite difference modeling results in a linear system of the equation, this algorithm can be implemented to solve the wave propagation modeling either by finite difference [9] or finite element methods [10]. Generalization of these algorithms to solve seismic wave is an ongoing research and this research is the initial attempt to expand the idea to design and construct the algorithms for seismic problems including modeling, inversion, and imaging. Our attempt in this study is to present an introduction to quantum computing, quantum algorithms and their applications in seismic problems for geophysicists.

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