Constructing an algorithmic quantum search machine by a nuclear magnetic resonance quantum computer

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Nuclear Magnetic Resonance (NMR), which is the technique coherently manipulating an ensemble of spin system, has been applied to the experimental realization of a quantum computer to give successful results. Among those experiments, the implementations of Grover's search algorithm have raised great interest because this algorithm has practical importance in the sense that many of hard problems in practice reduce to search problems. This quantum search algorithm assumes the existence of an "oracle" that answers whether a given item is what we want to find or not. In experimental demonstrations of the algorithm, the oracle was replaced by an operator which gives a pre-defined answer, that is, the operator was designed to give a fixed result to mimic the oracle.

In this work, we presented the whole quantum network for a practical algorithmic quantum search machine and realized it experimentally using a three-bit NMR quantum computer. The practical search machine means that the oracle is explicitly implemented which can search the answer by itself, so that we can choose a "target" we want to find as an input, contrary to the previous demonstrations where the target is included in the network as a part.

For this purpose, the practical database form of the index-content joint state was adopted instead of the index only state and an appropriate quantum circuit was designed since the execution of the original search algorithm on this joint state fails to enhance the probability amplitude of the state to find. The content of an index is not retrieved from some pre-calculated tables, but evaluated by the machine itself, by which an algorithmic search means. We have employed the Chi and Kim's single-query version of the quantum search algorithm to search one out of two.

We used three ^{13}C nuclear spins of 99% carbon-13 labeled alanine in D_2O solvent as qubits. All the experiments were conducted on a Bruker DRX300 spectrometer. An effective pure state was used as the initial state of qubits, and the system was handled in the "triply-rotating" frame in which each qubit experiences no chemical shift. Spin-selective pulses were used to implement the required gates and no hard pulses or multiply selective pulses were used to avoid several undesired effects. The experimental result clearly shows that this practical quantum search machine works perfectly as theory predicts.