Qudit-based transpilation of quantum circuits

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Recent progress in the development of quantum processors based on d-level quantum systems, qudits [1,2], makes it essential to study subtle aspects of quantum algorithms implementation on them. Since qudits provide more computational space compared to qubits, the number of possible implementations of the given circuit increases significantly. This is due to the fact that depending on a particular mapping between qubits' and qudits' computational spaces, the resulting qudit-based circuits that realise the same qubit-based circuit can be very different, e.g. in terms of the number of two-qudit operations required for algorithm's implementation. As a result, developing a method for efficient quantum circuit transpilation is crucial.

Basically, there are two main approaches to use qudits [3]. First of them is to embed several qubits in the d-dimensional space of one qudit. This technique is relevant when the number of qubits n is such that $d \geq 2^n$. It allows us to reduce the number of information carriers (e.g. atoms or ions). The second method is to substitute ancillary qubits by higher levels of qudits [4,5]. The use of qudits' upper levels as ancillas dramatically reduces the the number of two-particle gates in multiqubit gate decomposition, therefore it is especially useful for implementation of quantum circuits with multiqubit gates.

We develop a qudit-based circuit transpiler that supports a combination of two basic approaches to use qudits, while the works proposed earlier consider only one of them. Our transpiler takes as input a qubit-based quantum circuit with the concrete qubit-to-qudit mapping and creates a qudit circuit, which can be implemented on a qudit-based quantum processor as a sequence of single- and two-qudit gates. We expect our approach to provide a valuable contribution to the realisation of quantum algorithms on qudit-based quantum processors.

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References

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