Compilation of Qubit Circuits on Qudit-Based Quantum Processors

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The remarkable advancement of experimental prototypes of qudit-based quantum processors [1-3] makes it reasonable to investigate how best to execute common qubit circuits on them. Due to the larger dimension of the quantum information carriers, their space can be used in several possible ways. The space of one qudit can be considered as the space of several qubits or as the space of one qubit with additional levels that can be used as ancillary states in the decompositions of multiqubit gates [4]. As a result, each translation of the initial qubit gate sequence to the set of implementable single- and two-qudit gates is not unique. The exact final sequence of qudit gates is determined by the mapping between the space of qubits from the initial qubit circuit and the space of qudits of the processor. Such 'qubit-to-qudit' mapping specifies how the space of each qudit is used.

In this work, we propose a compilation method of qubit circuits to the set of single- and two-qudit gates, which is obtained according to the given qubit circuit and 'qubit-to-qudit' mapping [5]. For this compilation method, we chose a special case of 'qubit-to-qudit' mapping, in which the space of a qubit is entirely embedded in the space of a particular qudit. This assumption allows us to consider the space of qudit not only as a composition of qubits or as one qubit with ancillary levels but also as a composition of several qubits with at least one ancillary level. To our knowledge, this combination of two approaches to using qudits in the compilation of qubit circuits is implemented for the first time. As it allows us to estimate the exact number of single- and two-qudit gates in the realization of a qubit circuit on a qudit processor, the proposed compilation method can be useful for further research of the algorithm for finding the sub-optimal 'qubit-to-qudit' mapping.

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References

[1] M Ringbauer, M Meth, L Postler, R Stricker, R Blatt, P Schindler and T Monz, arXiv:2109.06903 (2022)

[2] Y Chi, J Huang, Z Zhang, *et al.*, Nat. Commun. **13**, 1166 (2022)

[3] A D Hill, M J Hodson, N Didier and M J Reagor, arXiv:2108.01652 (2021)

[4] A S Nikolaeva, E O Kiktenko and A K Fedorov, Phys. Rev. A **105**, 032621 (2022)

[5] A S Nikolaeva, E O Kiktenko and A K Fedorov, arXiv:2111.04384 (2021)