Robustness of quantum algorithms against coherent control errors

Julian Berberich[1], Daniel Fink[2], Christian Holm[2]

[1]University of Stuttgart, Institute for Systems Theory and Automatic Control
Pfaffenwaldring 9, 70569 Stuttgart, Germany
julian.berberich@ist.uni-stuttgart.de
[2]University of Stuttgart, Institute for Computational Physics
Allmandring 3, 70569 Stuttgart, Germany
{firstname.lastname}@icp.uni-stuttgart.de

Coherent control errors, for which ideal Hamiltonians are perturbed by unknown multiplicative noise terms, are a major obstacle for reliable quantum computing [1, 2, 3]. In this work, we present a framework for analyzing the robustness of quantum algorithms against coherent control errors using Lipschitz bounds. We derive worst-case fidelity bounds which show that the resilience against coherent control errors is mainly influenced by the norms of the Hamiltonians defining the individual gates. These bounds are explicitly computable even for large circuits, and they can be used to guarantee fault-tolerance via threshold theorems. Moreover, we apply our theoretical framework to derive a novel guideline for robust quantum algorithm design and transpilation, which amounts to reducing the norms of the Hamiltonians. With an application to the 3-qubit Quantum Fourier transform, we demonstrate that this guideline targets robustness more effectively than existing ones based on circuit depth or gate count. Further, we apply our framework to study the effect of parameter regularization in variational quantum algorithms. Finally, we validate our theoretical findings in simulation and on a quantum computer.

References

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