Normalizing Flows for Classical Simulation of Quantum Circuits in Phase Space

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Abstract

We present a novel framework to learn a representation of quantum circuits based on the phase space formulation of many-qubit systems [3]. Given that N-qubit states can be represented as quasi-probability distributions on a 2N-dimensional manifold, we show how unitary gates can be parameterized as normalizing flows between these distributions, opening a new avenue for AI-assisted quantum circuit simulation. We evaluate our method on two common families of quantum circuits, and show that it scales well to large numbers of qubits.

References

[1] Juan Carrasquilla et al. Physical Review A, 115 104(3):032610, 2021.
[2] Juan Carrasquilla et al. Nature Machine Intelligence, 1(3):155–161, 2019.
[3] Timothy Heightman et al. arXiv preprint, 2025.

Figures

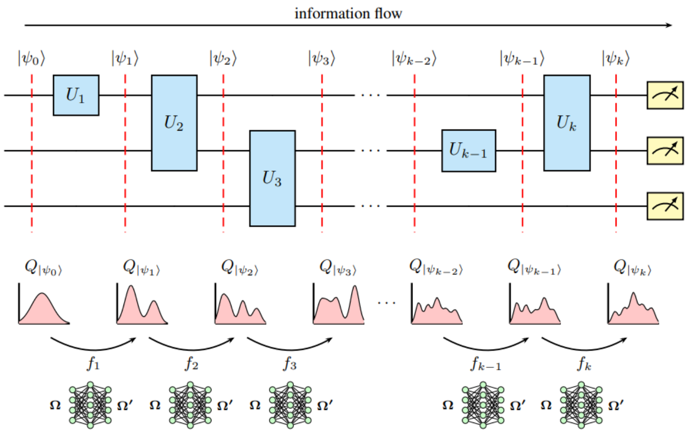

Figure 1: Our proposed framework for learning the output state of a quantum circuit. In the unitary picture (top half), the state of a quantum circuit is represented by state vectors, and maps from one state to the next are given by unitary operators. In the phase space picture (bottom half), the state of a quantum circuit is represented by a probability distribution, and maps from one state to the next are given by normalizing flows parametrized by neural networks.