Improving Quantum Gates with Optimal Quantum Control

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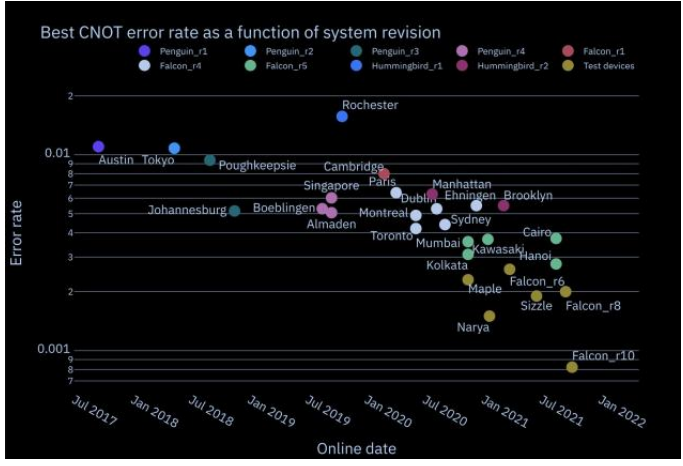
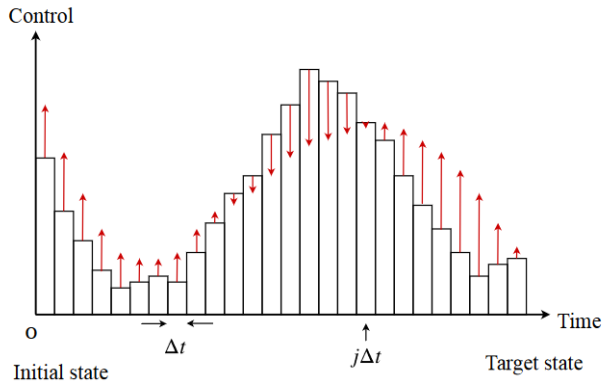
It is necessary to improve the fidelity of quantum gates to achieve computational advantage with quantum computers.



https://twitter.com/jaygambetta/status/1445115380616335373

An alternative is to use optimal quantum control.

$\rightarrow$ Gradient Ascent Pulse Engineering (GRAPE) Pulses.



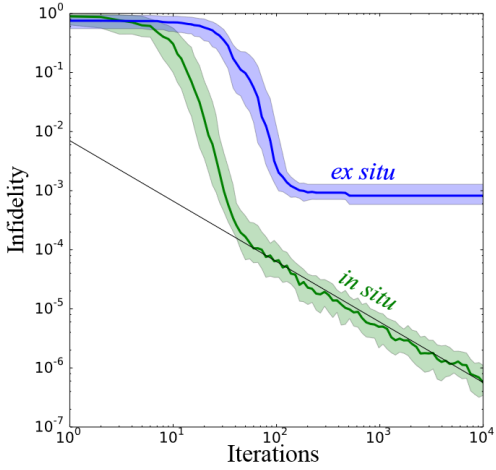
Y. Shi *et al.*, "Optimized Compilation of Aggregated Instructions for Realistic Quantum Computers".

We optimize the GRAPE pulse maximizing the Fidelity.

$$f(\vec{w}) = \frac{1}{d^2} |\, Tr(V^\dagger U(\vec{w}))|^2.$$

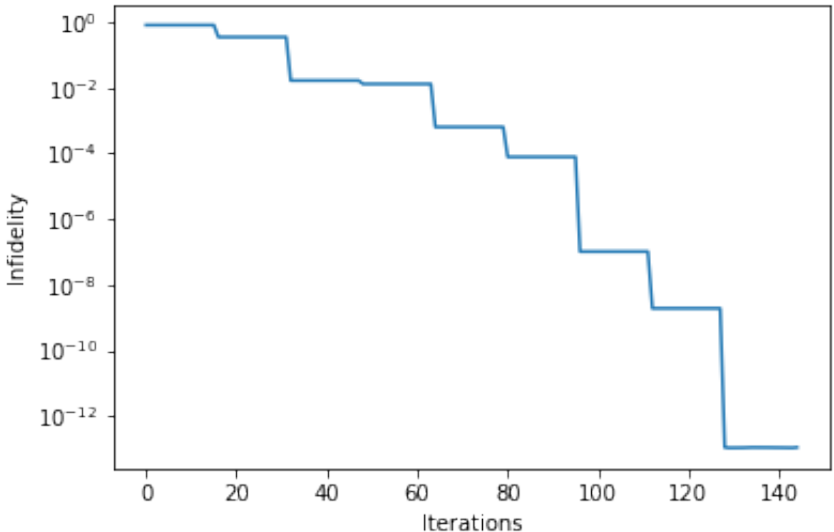
This can be evaluated:

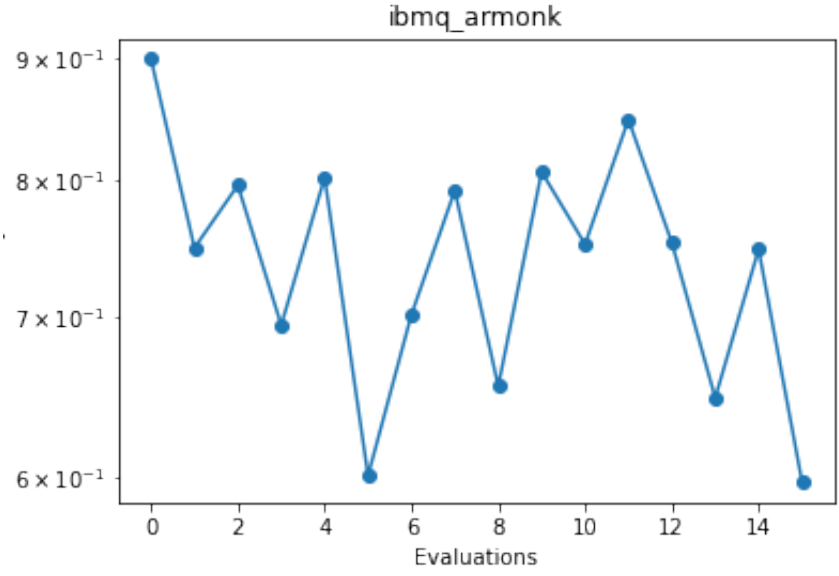
- Numerically, proposing a model for the system.
- Experimentally. S. T. Flammia and Y.-K. Liu, "Direct Fidelity Estimation from Few Pauli Measurements".



C. Ferrie and O. Moussa, "Robust and efficient in situ quantum control".

- We build a Qiskit library to perform the ex-situ and in-situ quantum control with GRAPE.
- We implement GRAPE pulses with Qiskit Pulse.
- We implement Direct Fidelity Estimation for unitary gates.
- We propose a mixed protocol, where first the ex-situ quantum control is carried out, to then refine the result with in-situ quantum control.
- We implement the not-gate with ex-situ and in-situ quantum control.


Infidelity
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
0
20
40
60
80
100
120
140
Iterations


ibmq_armonk
9×10^{-1}
8×10^{-1}
7×10^{-1}
6×10^{-1}
0
2
4
6
8
10
12
14
Evaluations

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Improving Quantum Gates With Optimal Quantum Control

Abstract

It is necessary to improve the fidelity of quantum gates to archive computational advantage with quantum computers [1]. An alternative to do that is to use optimal quantum control [2]. This is based on optimizing the parameters of a Hamiltonian to maximize the fidelity with a target quantum gate. The evaluation of the fidelity can be carried out numerically (ex-situ) or experimentally (in-situ) [3]. In this project, we propose implementing a Qiskit library to perform optimal quantum control.

Our objective is to build a Qiskit library to perform ex-situ and in-situ optimal quantum control. Our control parameters will be the amplitudes of a GRAPE (Gradient Ascent Pulse Engineering) pulse, which will be implemented using Qiskit Pulse. The experimental evaluation of the fidelity will be performed by Direct Fidelity Estimation [4]. We also propose a mixed protocol, where first the ex-situ quantum control is carried out, to then refine the result with in-situ quantum control. We expect to implement some relevant gate with our routines, such as NOT-gate or Hadamard.

[1] https://twitter.com/jaygambetta/status/1445115380616335373

[2] Y. Shi et al., "Optimized Compilation of Aggregated Instructions for Realistic Quantum Computers".

[3] C. Ferrie and O. Moussa, "Robust and efficient in situ quantum control".

[4] S. T. Flammia and Y.-K. Liu, "Direct Fidelity Estimation from Few Pauli Measurements".

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Languages

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- Python 12.1%
- TeX 5.0%