BQSKit

An overview

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Unitary Fund

Overview

Robust and Resource-Efficient Quantum Circuit Approximation

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`https://arxiv.org/abs/2108.12714`

Berkeley Quantum Synthesis Toolkit

The Berkeley Quantum Synthesis Toolkit (BQSKit) is a superoptimizing quantum compiler and research vehicle that combines ideas from several projects at LBNL into an easily accessible and quickly extensible software suite.

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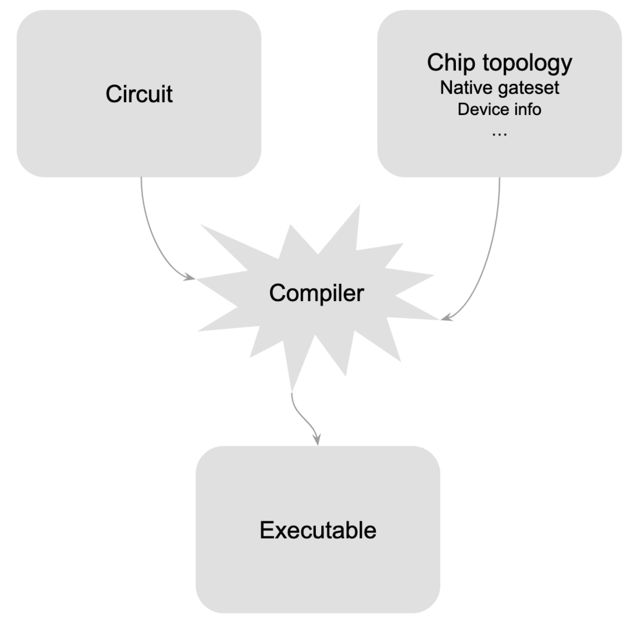
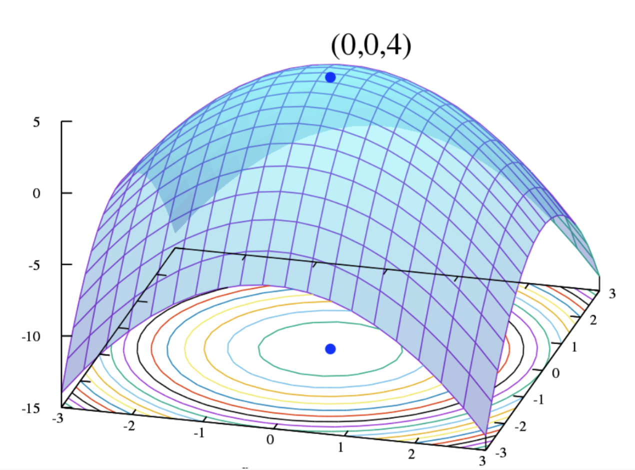
What is a compiler?



What is “superoptimizing”?



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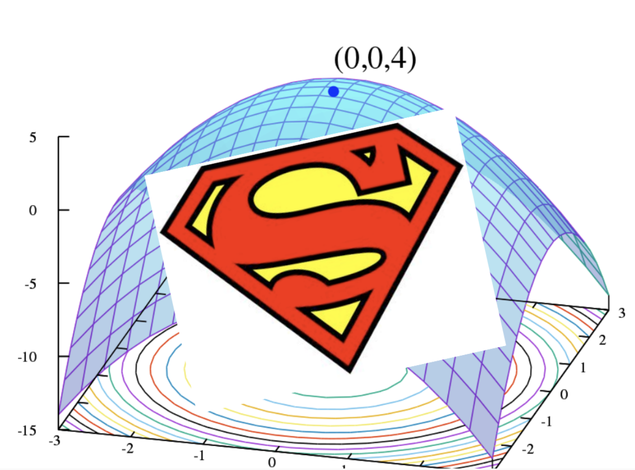
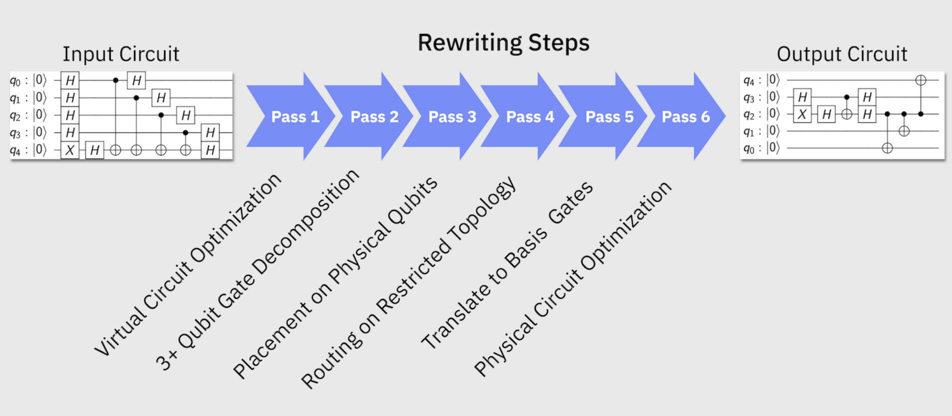


What does Qiskit do?



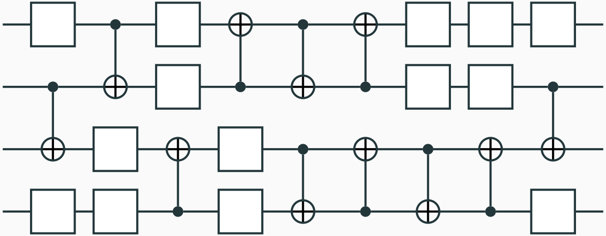
Unitary Synthesis

Problem Statement

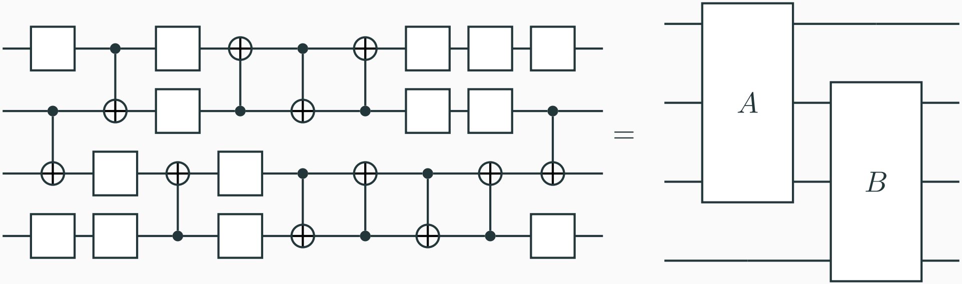
Let G be a gate set (i.e. a finite collection of unitary operators), and $U \in \mathrm{U}(2^n)$ be the **target unitary**. Find a sequence of gates $g_i \in G$ such that the target unitary U can be written as $U = g_n \cdot g_{n-1} \cdots g_2 \cdot g_1$.

- Need ways to "compare" the similarities of unitaries
- Hilbert-Schmidt inner product: $\langle U, V \rangle \overset{\text{def}}{=} \operatorname{tr}\left(UV^\dagger\right)$
- Can turn this into a normalized distance function as $d_{\text{HS}}(U, V) \overset{\text{def}}{=} \sqrt{1 - \frac{|\langle U,V \rangle|}{2^{2n}}}$
- Total Variation Distance of probability distributions: $\frac{1}{2} \sum_{k=1} 2^n |p_1(k) - p_2(k)|$
    - $p_1(k)$ is probability of state k after target unitary
    - $p_2(k)$ is probability of state k after synthesized unitary
- d_{HS} scales poorly due to unitaries growing exponential with number of qubits

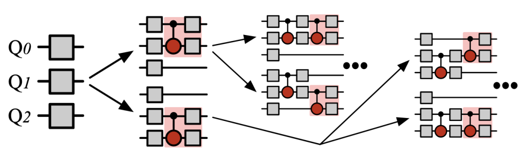
Partitioning



Partitioning



Approximate block synthesis



- Bottom up approach to synthesis
- Each layer consists of one CNOT, and two single-qubit rotations
- Tree is pruned every few layers for branch with best approximations to target unitary

Block stitching

- Synthesizing many, low-CNOT count circuits is easier than a single, but much more accurate one
- Averaging over multiple approximations can give an accurate representation of target unitary
- Dual annealing optimization: $\min f = (\text{CNOT count} + \text{dissamilarity})/2$
- $d_{\mathsf{HS}}(U, V) \leq \sum_{k=1}^{K} \varepsilon_k$ for V being a partioned version of U with K blocks

Summary

- BQSKit/QEST is a compiler primarily focused on reducing circuit depth via CNOT gate count reduction
- 30–80% CNOT gate count reduction on ideal systems