Qublitz 2024 - Software Prompt

Princeton Students in Quantum (PSQ)

11/2/2024 - 11/3/2024

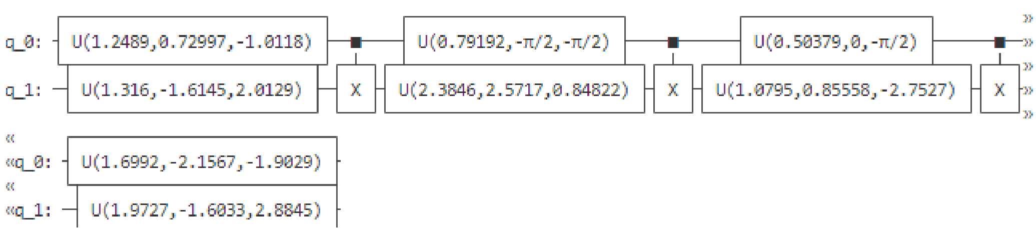
Introduction

Quantum algorithms have a lot of potential to impact the world, including in areas of simulation, optimization, and notably cryptography. These algorithms contain a plethora of many different gates at the highest level. However, in order for these quantum algorithms to run on actual quantum computers, they need to be decomposed into simpler, but equivalent versions of circuits that the quantum computers can actually handle. Superconducting quantum computers, in particular, can usually only handle one and two-qubit gates (as of now), so larger circuits may be compiled into combinations of one and two-qubit gates. Moreover, different superconducting quantum computers can only handle specific types of gates (like X rotations and CZ gates). Two-qubit gates in particular are pretty time-consuming/difficult on these computers, so as programmers, we would like to minimize the number of two qubit gates as much as possible. You will see in the following section how this is possible.

Example

The CNOT (CX) gate is typically the target of two-qubit decompositions because this type of gate can be physically executed on a quantum computer. Any two-qubit unitary can be decomposed using 3 CNOT gates. Qiskit's TwoQubitBasisDecomposer is capable of targeting a CNOT basis, as well as other equivalent basis such as CZ. In the picture below, it is shown how a random two qubit unitary can be decomposed into a combination of 3 CX gates and several 1-qubit gates.

```
from qiskit.circuit.library import CXGate
from qiskit.synthesis import TwoQubitBasisDecomposer
ru = qiskit.quantum_info.random_unitary(4)
decomposer = TwoQubitBasisDecomposer(CXGate())
circ = decomposer(ru)
print(circ)
```



Prompt

For this project, read the B-gate decomposition paper (linked below) which describes a new basis gate that has more power than a CNOT in terms of more efficient construction of two-qubit unitaries. Implement the B-gate two-qubit decomposition method described in this paper, and demonstrate the equivalence of your B-gate decomposition of a random 2-qubit unitary to the unitary you decomposed. Hint: You will need to learn about the Weyl Chamber.

Bonus

Hardware Bonus: Investigate and write about the specifics of the hardware implementation of a B-Gate on superconducting quantum computing.

Final Submission

Please submit your work as a link to a **public GitHub repository** containing the following:

1. A Jupyter notebook with the Python code and anything you wrote in regards to the Bonus Prompt.
2. A `README.txt` file containing information about your team members (names, emails, majors, and academic years).

Resources

The following resources may be helpful:

- B-Gate Decomposition Paper
- Quantum Gates Overview ← Discusses B-Gates and the Weyl Chamber.