CS 238 Homework: Implement a quantum circuit simulator

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The code is available at https://github.com/jc65536/quantum-simulator

Design

My design supports up to 64 qubits, since `BitVec` is a `u64`. I made sure my amplitudes were also using `i64`, so that they are long enough to represent amplitudes up to and including $2^{64/2}$. I am using an integer to represent amplitudes because the integer counts multiples of $2^{-n/2}$. This representation scheme exploits the fact that we are operating on a limited instruction set that only supports phase rotations by $\pi/4$. By doing this, I can avoid floating point errors.

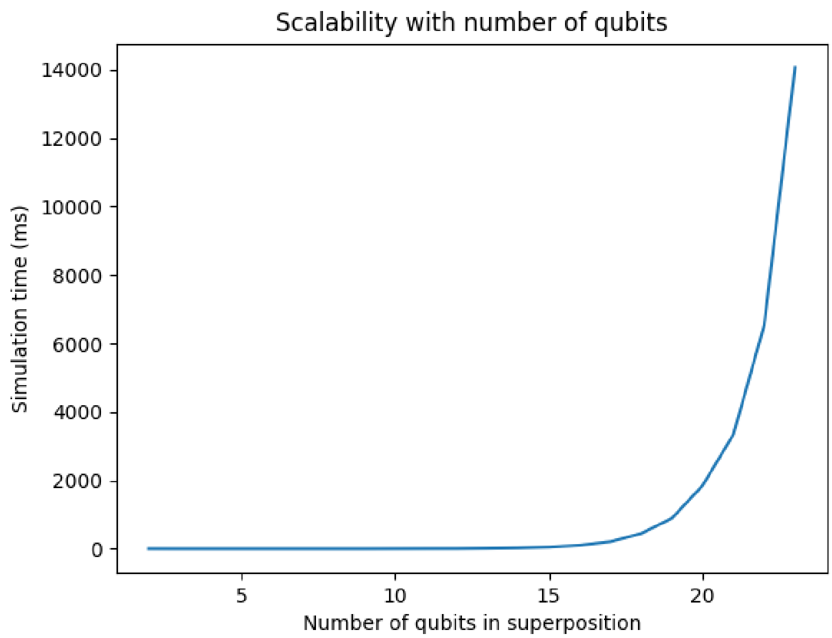
The actual number of qubits n is determined from the program. I realized that cirq doesn't actually care about the `qreg` statement, but counts the number of actual qubits used instead. Similarly, my program counts the number of qubits used across instructions and uses that as n.

Of course, the user can always override the detected number of qubits by setting `n` in `State`.

Evaluation

To test my simulator, I ran it on all the given benchmarks. They all passed correctness checks.

For scalability, I generated programs from 2 to 24 qubits, where a Hadamard gate is applied to each qubit to make them be in superposition. The runtime increases exponentially as the number of qubits in superposition increases.



Instructions

How to provide input

Pass in a string of the quantum program to `csm238.simulate`

How to run the program

First, build the project

```
$ cargo build --release
```

Next, move/copy/link the shared library to the desired working directory. Note the file needs to be renamed to `cs238.so`.

```
$ ln -s ./target/release/libcs238.so ./desired/directory/cs238.so
```

Use `cs238.so` as if it were a Python module.

```python
from cs238 import simulate

simulate("quantum program here")
```

How to understand the output

The output of `cs238.simulate` is compatible with that of `cirq`. This means that qubits are in big-endian order, e.g. $|q_0q_1q_2q_3\rangle = |0101\rangle = |5\rangle$. The output is a list of complex amplitudes. The complex number at index k is the amplitude for state $|q_0 \cdots q_n\rangle = |k\rangle$.