Python quantum programming languages

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September 19, 2018

Overview

- We looked at python based quantum programming libraries.
- Tried writing the common programs (e.g. Grover's, Shor's, etc.)
- Tried compiling a simple program for different hardware platforms (i.e. with gate restrictions, etc.)
- We've written a programming guide – we're currently reviewing it.

```
# Do quantum stuff
qvm = QVMConnection()
qprog = Program()

# do X on q1, q3, q7
# remember HZH is X
qprog.inst(H(1), Z(1),
 ↪  H(1))
qprog.inst(X(3))
qprog.inst(X(7))
# do measurement over
 ↪  all 8 qubits
for i in range(0, 8):
    qprog.measure(i, i)
```

Short comparison

What is there

- Focused on the quantum circuit model.
- You can apply gates to specific qubits.
- Classical control in the same source code.
- Python syntax is beginner friendly.
- Simulators are available.
- Hardware compilers are available.

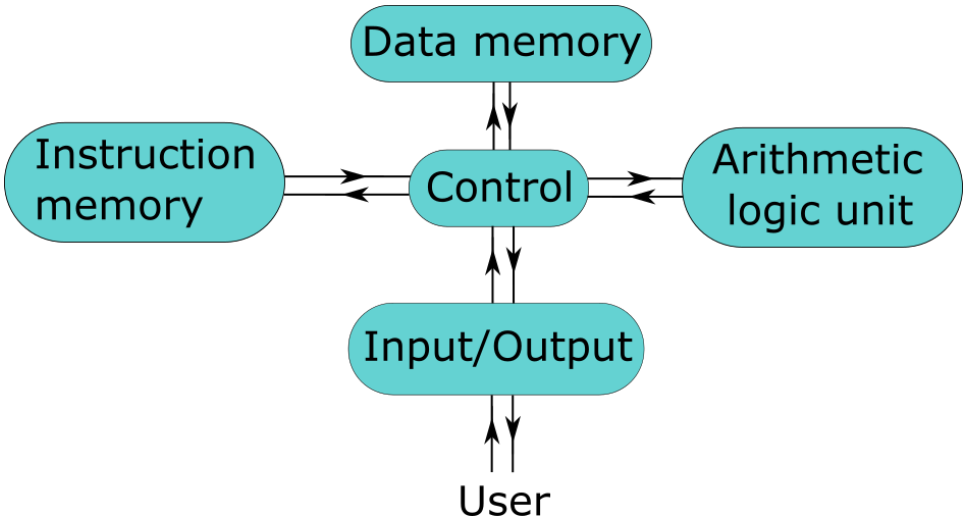
What is lacking

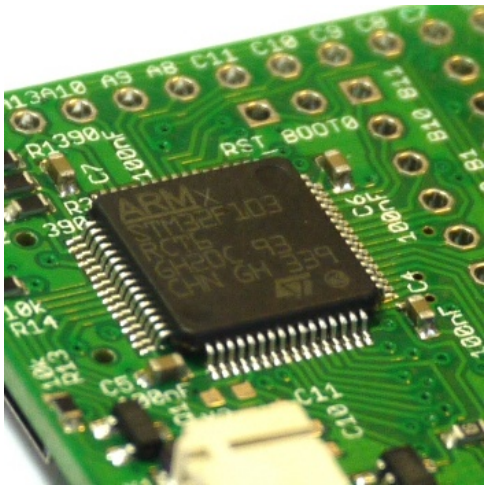
- Some languages target specific hardware.
- Some simulators are cloud based and need accounts.
- Lack of support for custom unitaries.
- Compilers are not highly developed.
- No real quantum programming constructs (e.g. quantum if etc.)

Cloud based quantum computing

- The superconducting qubit developers (IBM [1], Rigetti [2], Google [3], etc.) have made their hardware accessible through the cloud.
- They've released software written in Python for use on their simulators and hardware.
- We found the connection to some cloud services would time out for moderate sized quantum circuits.

Long term: comparison with classical computers

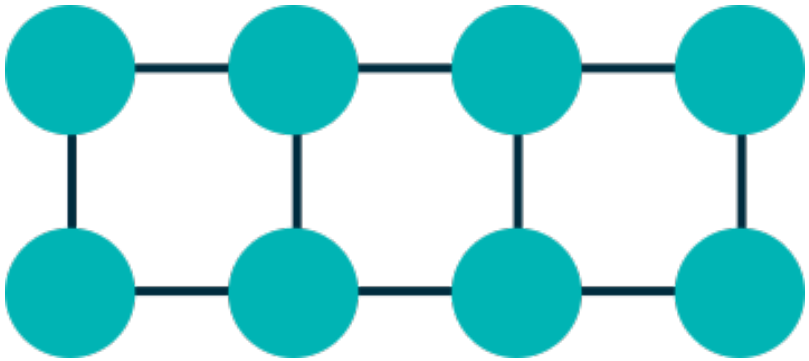


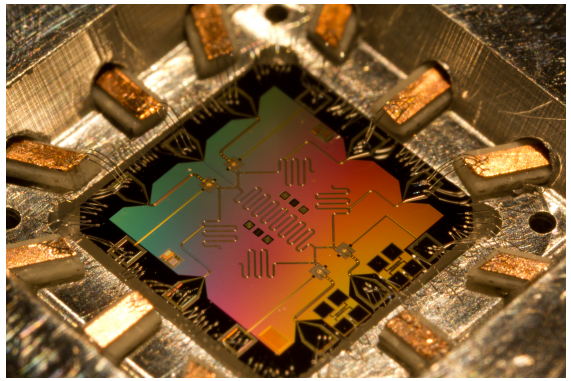


[4]

- Classical computers have a lot of internal structure – they are not just a collection of addressable bits.
- Classical computers are controlled using an instruction set, which has elementary operations for arithmetic, control, moving data around, etc.

Long term: comparison with classical computers





[5]

- Quantum processing units (QPUs) currently comprise a lattice of qubits which can be manipulated and measured.
- The only 'instructions' which can be performed are qubit initialisation, gate operations, and measurement
- Will QPUs eventually involve higher level structures like in the classical case? This will determine the type of languages that will control the devices.

Conclusion: long term programming languages

- The structure of long term languages depends on the structure of long term quantum computers
- We need a quantum instruction set that isn't just listing gates. We want to see **coherent addition**, **multiplication**, **exponentiation**, etc. Possible also **coherent branching**?
- Don't see Python being the long term quantum language – there's no need to wrap assembly language in high level syntax.
- Existing Python libraries not built to be scalable languages. Heavy focus on quantum circuits, not useful for new algorithms.

References

[1] Ibm's qiskit docs. https://github.com/Qiskit/qiskit-terra.

[2] Rigetti's pyquil docs. https://pyquil.readthedocs.io/en/stable/.

[3] Google's cirq docs. https://github.com/quantumlib/Cirq.

[4] Arm chip. http://www.espruino.com/.

[5] Superconducting chip. http://web.physics.ucsb.edu/~martinisgroup/.