Quantum Programming Demo

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Programming workflow in Atos QLM

Gate-based quantum computing

Very general workflow in gate-based computing

- Encode the problem input into the qubit register
- Encode the algorithm into a set of quantum gates
- Perform the calculation
- Readout the results for further processing

Standard workflow in Atos QLM

- Use `qat.lang.AQASM` to build a `Program` object including quantum/classical registers and gates
- Use `Program`'s `to_circ()` method to build a `Circuit` object including the final gate implementation
- Use `Circuit`'s `to_job()` method to build a Job object including the execution parameters
- Build a `QPU` object using Atos' quantum emulators, third-party QPUs, or plugins
- Build the `Result` object with the QPU's `submit(job)` method
- Iterate on the `Result` object to extract the needed parameters for further operation

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Example of code

A basic Bell pair

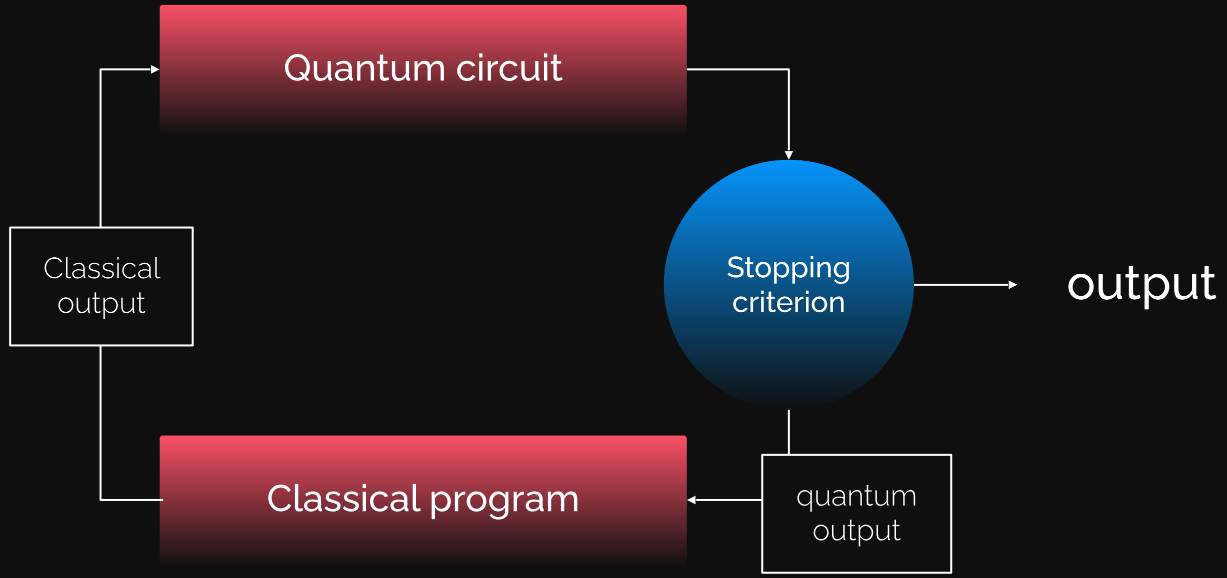
Code

```python
from qat.lang.AQASM import Program, H, CNOT
from qat.qpus import get_default_qpu

# Create a circuit
qprog = Program()
qbits = qprog.qalloc(2)
H(qbits[0])
CNOT(qbits[0], qbits[1])
circuit = qprog.to_circ()

# Create a job
job = circuit.to_job(nbshots=100)

# Execute
result = get_default_qpu().submit(job)
for sample in result:
    print("State %s: probability %s +/- %s" % (sample.state, sample.probability, sample.err))
```

Output

```
State |00>: probability 0.53 +/- 0.050161355804659184
State |11>: probability 0.47 +/- 0.050161355804659184
```

Quantum Approximate Optimisation Algorithm



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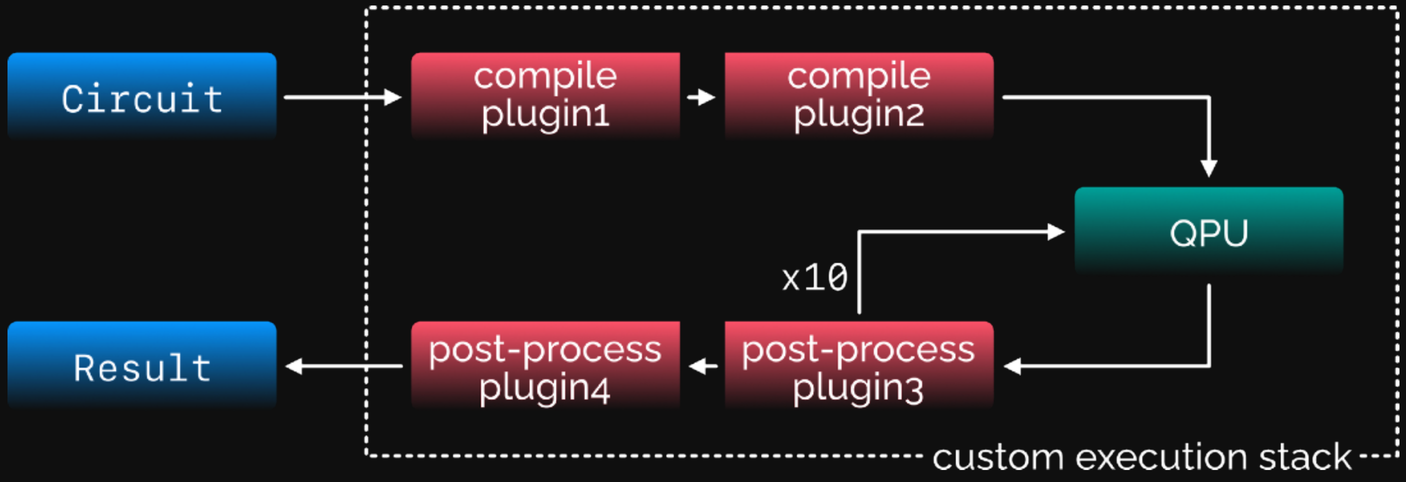
Custom execution stacks

Extend the capabilities of any computing backend



Extension of any QPU object to a stack

```
my_stack = plugin1 | plugin2 | plugin3 | plugin4 | my_qpu
```

How to model very large problems with good fidelity

Atos quantum emulators

Linear Algebra emulator (LinAlg)

- Encode the state of the QPU into a state vector
- Since each qubit can interact with any other, you must consider all the possible combinations
- N qubits → 2^N combinations, each one with a certain amplitude
- Encode each gate as a matrix that modifies the state vector
- The result is the vector that comes out of the various gates
- Huge RAM consumption

Matrix Product State emulator (MPS)

- Encode the state of the QPU into a sequence of single qubit states multiplied by a matrix that encodes the interactions with the others
- Weak qubit interactions → small matrices → simple calculations
- Very good when qubits either do not interact each other, or they only interact with their neighbours

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How to model very large problems with good fidelity

Atos quantum emulators

QPEG emulator

- Developed as a joint effort between Atos and CEA
- Group up qubits into a network of “tiny" QPUs
- Treat each QPU using LinAlg
- Treat the interaction between groups using MPS
- Apply gates in layers
- Moving the resource consumption from RAM to CPU
- Double-digit precision on the results

Further resources

- myQLM documentation
  https://qlm.bull.com/doc/qat-tutorial-myqlm/index.html
- Atos QLM documentation
  https://qlm.bull.com/doc/qat-tutorial-qlm/index.html
- Quantum annealing benchmarking routines
  https://qlm.bull.com/doc/qat-tutorial-qlm/advanced_combinatorial_optimization.html
- myQLM GitHub page
  https://github.com/myQLM

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