Duckbergs

QuEra Challenge

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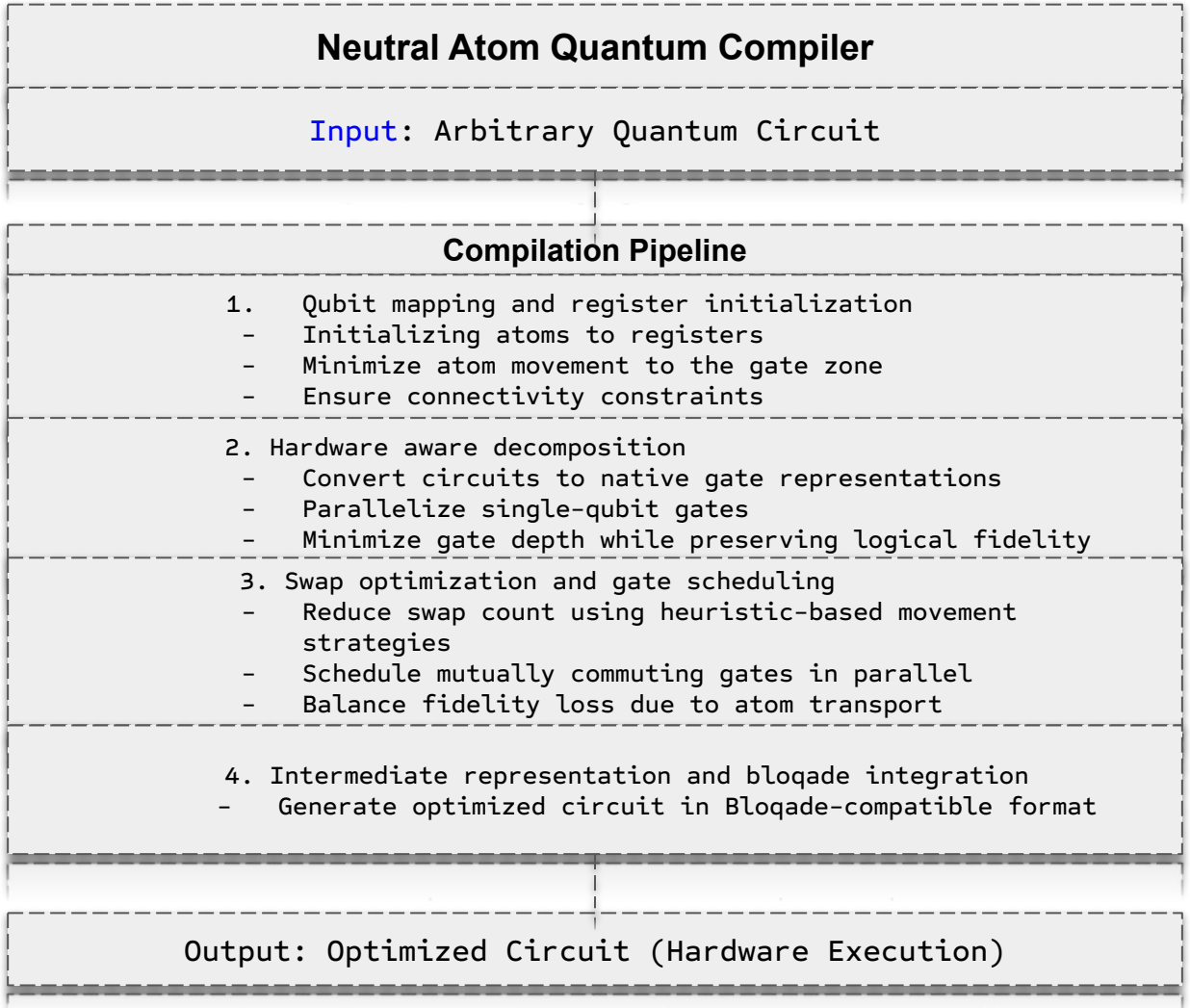
Quantum Circuits VS Hardware Implementations

Compiler Approach

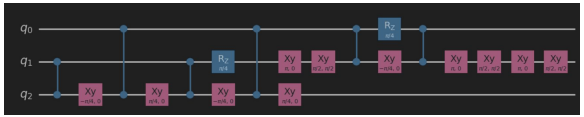
Optimization? We saw something bigger!

- A chance to prototype a **neutral-atom quantum compiler**.
- **Automating** neutral-atom quantum circuit compilation

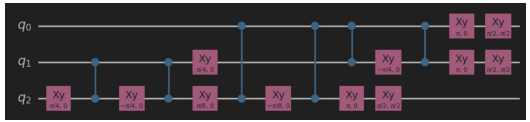

Neutral Atom Quantum Compiler
Input: Arbitrary Quantum Circuit
Compilation Pipeline
1. Qubit mapping and register initialization
- Initializing atoms to registers
- Minimize atom movement to the gate zone
- Ensure connectivity constraints
2. Hardware aware decomposition
- Convert circuits to native gate representations
- Parallelize single-qubit gates
- Minimize gate depth while preserving logical fidelity
3. Swap optimization and gate scheduling
- Reduce swap count using heuristic-based movement strategies
- Schedule mutually commuting gates in parallel
- Balance fidelity loss due to atom transport
4. Intermediate representation and bloqade integration
- Generate optimized circuit in Bloqade-compatible format
Output: Optimized Circuit (Hardware Execution)

Challenge Solutions

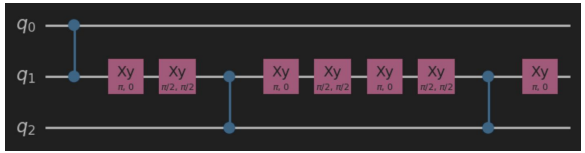
Challenge #1.1



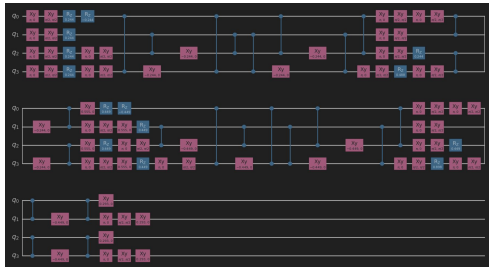
Challenge #1.2



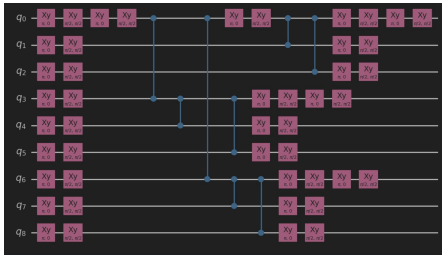
Challenge #2



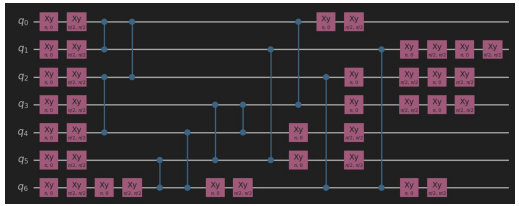
Challenge #3



Challenge #4



Challenge #5

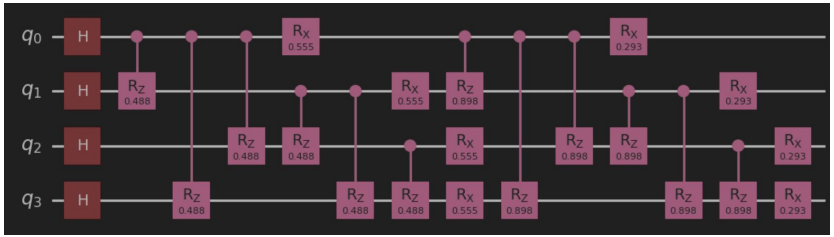


Solution Costs

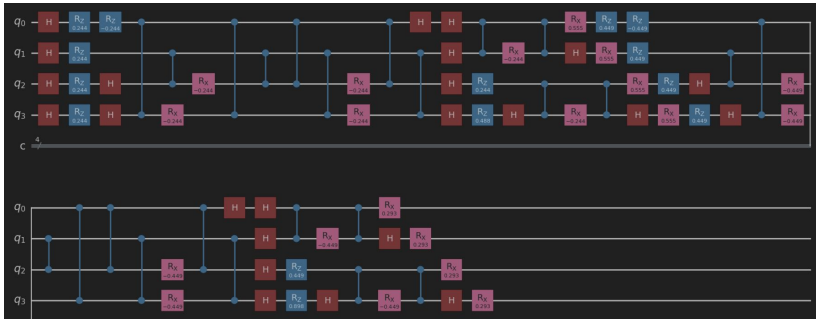
	Time	Touches	Moves	Overall
Challenge 1.1	5.40	4	2	8.27
Challenge 1.2	18.40	10	8	23.18
Challenge 2	7.43	6	3	15.40
Challenge 4	26.51	14	8	30.22
Challenge 5	21.24	17	7	34.40

Circuit 3

Recreated Circuit in Qiskit



Optimized Circuit



Using the original circuit's effective unitary as a target, the optimized circuit unitary has fidelity of 1 up to numerical roundoff error.

Intermediate Representation (IR)

```
ir_code = {
    "Position": [[0,1,2,3],[0,1,50,51],[0,1,50,51],[0,1,50,51]],
    "operator":[("move", [], True), ("move", [], True), ("rxy", [0,1], False,
np.pi/2, np.pi/2), ("cz", [], True)]
   }
```

- Efficient representation of circuit
- Enables a full compiler pipeline integrates:
  - Decomposition
  - Scheduling
  - Routing
  - Mapping