Quantum Simulation

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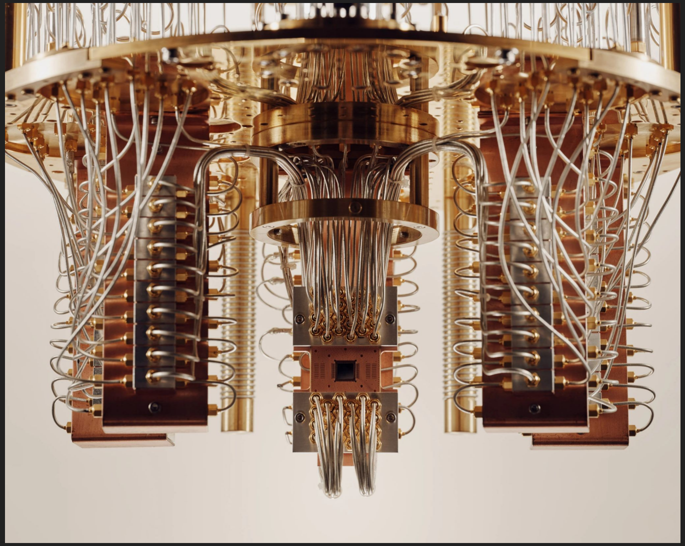
CS 8001

Outline

- Brief overview of what simulation is used for and how we do it now and limitations
- Why quantum computing can help with simulations
- Why it is important to utilize quantum computing for simulations
- Real world example
- Example of quantum computer in Python with Qiskit library
- Closing remarks
- Conclusion and questions

Why simulations? How do we do it now and limitations

- Simulations are used in all domains
- Medical, financial, engineering, defense
- Costly
- Resource intensive
- Specialized hardware
- Moores law



Why we want to use quantum computers for simulation

- Speed
- Versatile
- Massive amounts of data
- Parallelism

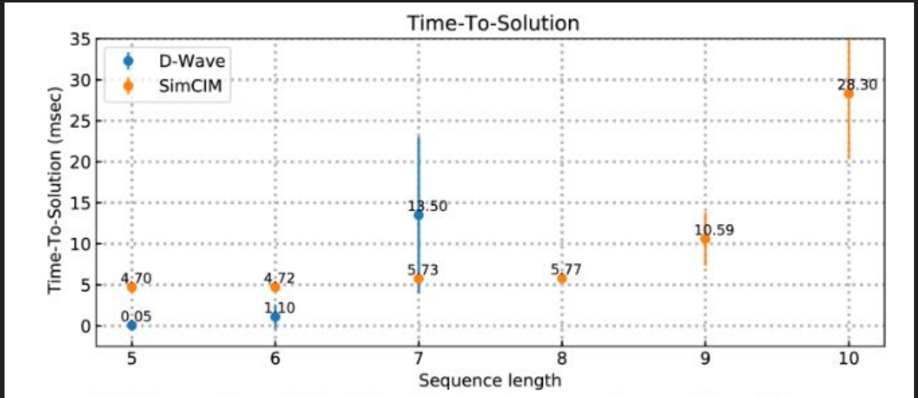
Why is this important?

- DNA sequencing
- used for research and development of new treatments
- increased speed and ability to work with high levels of noise in data
- quantum algorithms could be more accurate and able to evaluate models more efficiently
- some benefits include; earlier detection of diseases, more personalized treatments, better understanding of genetic diseases

Real World Example

https://www.nature.com/articles/s41598-021-88321-5#Sec6

For many mechanical systems, the Hamiltonian takes the form H(q,p) = T(q,p) + V(q)\ , where T(q,p) is the kinetic energy, and V(q) is the potential energy of the system.



Comparison of the performance of quantum and quantum-inspired methods for *de novo* genome assembly based on synthetic data (10 problems were generated for every sequence length): we compare TTS for quantum device D-Wave and quantum-inspired optimization algorithm SimCIM.

- Quantum Annealing
- D-Wave computer
- De novo genome assembly

```python
from qiskit import QuantumCircuit, Aer, execute

# Create a three-qubit quantum circuit
circuit = QuantumCircuit(3, 3)

# Initialize the first qubit to |1⟩
circuit.x(0)

# Apply a Hadamard gate to each qubit
circuit.h(range(3))

# Apply a Toffoli gate to the qubits 0, 1, and 2
circuit.ccx(0, 1, 2)

# Measure the qubits
circuit.measure(range(3), range(3))

# Simulate the circuit using the qasm simulator
backend = Aer.get_backend('qasm_simulator')
job = execute(circuit, backend)
result = job.result()

# Print the counts of each measurement outcome
counts = result.get_counts()
print(counts)
```

```
{'110': 130, '101': 140, '010': 137, '011': 125, '111': 124, '001': 119, '000': 106, '100': 143}
```

Closing remarks and conclusion

- No foreseeable time table
- Very complex with many difficulties yet uncovered
- Potential is enormous
- Inevitable
- The Quantum age