Development of Novel Algorithms

Exponential quantum speedup in simulating coupled classical oscillators

By Team: Quantum Cats

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Womanium Quantum + AI Project 2024

Problem Statement

Implementing algorithm of exponential speedup of harmonic oscillator based on simplification assumptions in the following paper and utilizing ClassiQ:

Exponential quantum speedup in simulating coupled classical oscillators

Ryan Babbush,[1] Dominic W. Berry,[2] Robin Kothari,[1] Rolando D. Somma,[1] and Nathan Wiebe[3,4,5]

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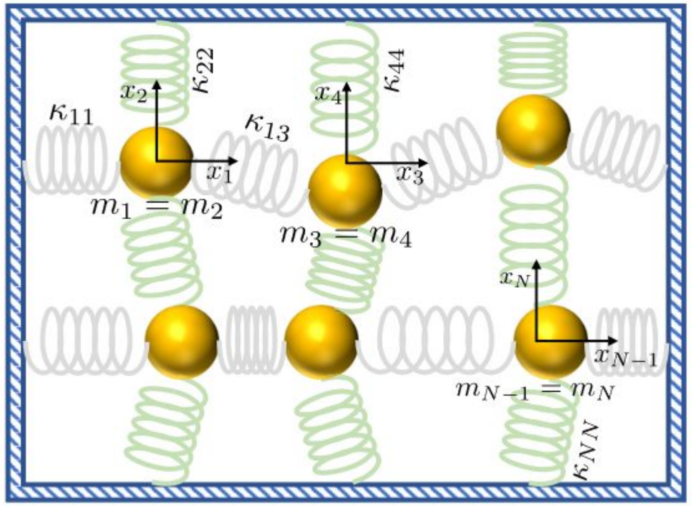


Fig 1 Oscillators - arXiv:2303.13012v3 **[quant-ph]**

$$\mathbf{H} := -\begin{pmatrix} \mathbf{0} & \mathbf{B} \\ \mathbf{B}^\dagger & \mathbf{0} \end{pmatrix}$$

$$|\dot{\psi}(t)\rangle = -i\mathbf{H}|\psi(t)\rangle$$

$$|\psi(t)\rangle \propto \begin{pmatrix} \dot{\vec{y}}(t) \\ i\mathbf{B}^\dagger \vec{y}(t) \end{pmatrix}$$

$$\begin{pmatrix} \dot{\vec{y}}(t) \\ i\mathbf{B}^\dagger \vec{y}(t) \end{pmatrix} = e^{-it\mathbf{H}} \begin{pmatrix} \dot{\vec{y}}(0) \\ i\mathbf{B}^\dagger \vec{y}(0) \end{pmatrix}$$

key equations from paper - arXiv:2303.13012v3 **[quant-ph]**

Project Solution Part I

- Simple case of the Glued Tree Problem
  - Proof of concept
  - Initial state would set to zero
  - All the masses and the spring constants are equal to 1 for all the elements

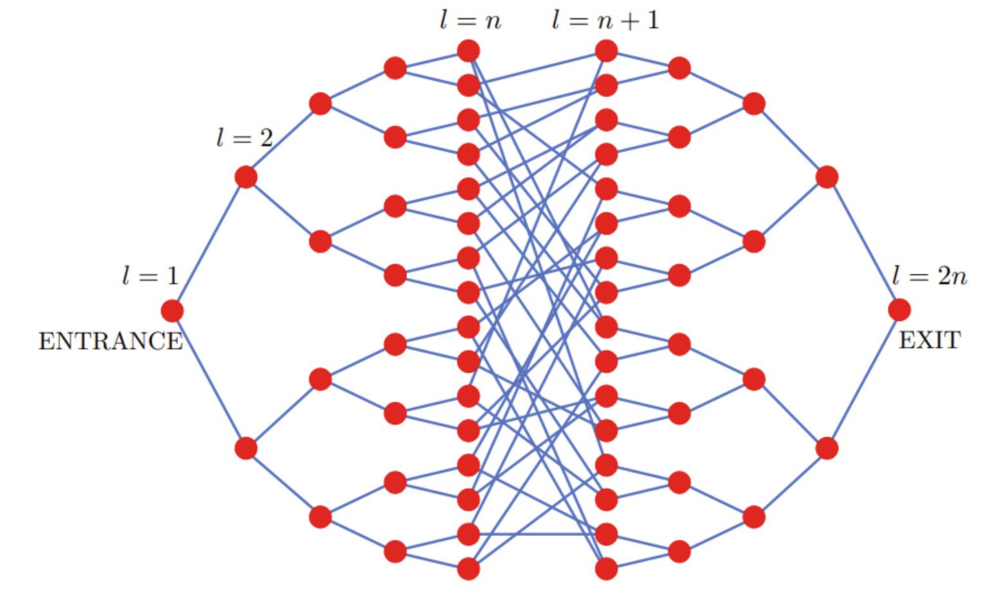


Fig 2 Glued Tree Diagram arXiv:2303.13012v3 **[quant-ph]**

Project Solution Part II

- Generalized Case
- Access to Kappa Matrix, Mass Matrix, Position Matrix
- Impacting the state preparation and the Hamiltonian Simulation
- All the building Blocks represent the Grover Search
- A set of Ancilla Qubits plus one Ancilla for the inequality test

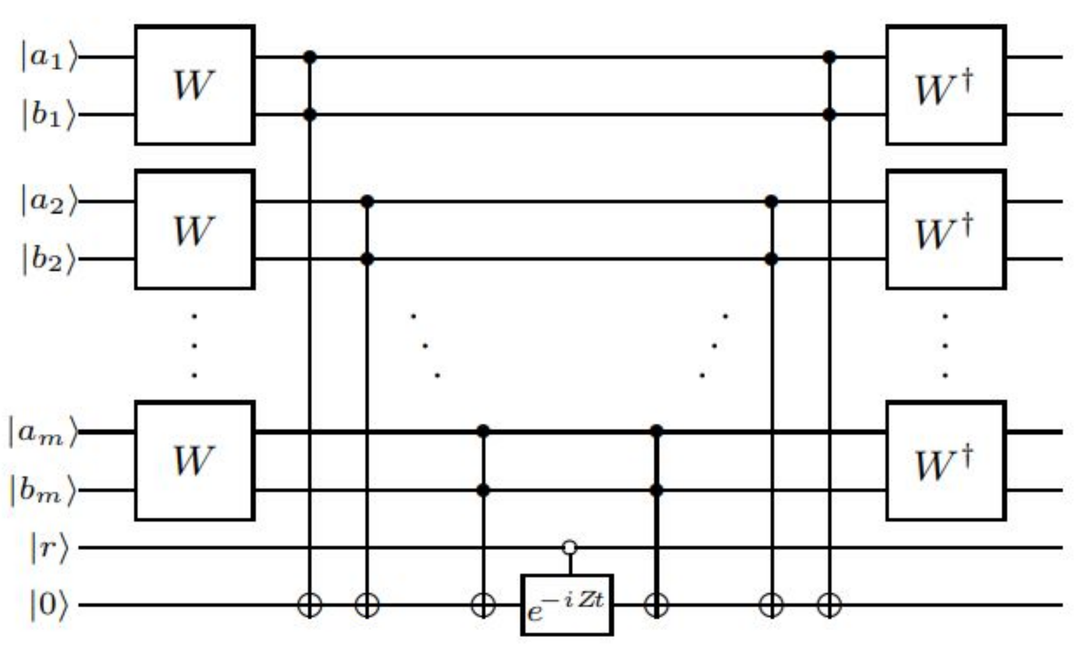
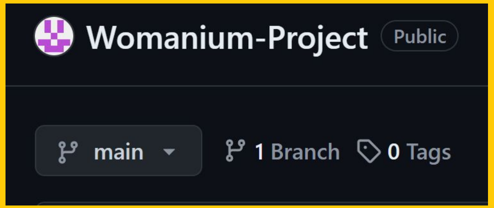


Figure 3: A circuit computing e^{-iTt}.

arXiv:quant-ph/0209131v2

Success!

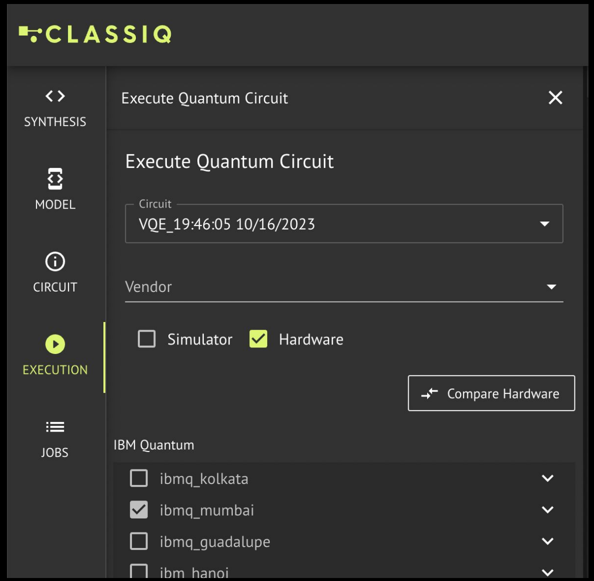
- Members learned a lot, met knew friends, turned in a team project, & had fun!
- Practiced literature review as sought additional outside sources, while tried to get a grasp of problem statement and other past work
- Utilized Github for the first time
- New contributing members to the quantum computing research community
- Implemented theory into practice by coding a proposed quantum algorithm!



Quantum Harmonic Cats Team Github Repo https://github.com/CynthiaCruzSanchez/Womanium-Project

Future Scope

- Run the expansion code on a simulator
    - Analyze result, edit and revise code
        - Repeat as many times necessary
- Search for the optimal quantum computing hardware
    - Make code compatible with desired hardware
        - Implement algorithm on real computer



ClassiQ Website www.https://www.classiq.io/

➢ Will seek to discuss work with outside members to get expert feedback and input, as our beginner experience is our biggest limitation, and we want to ensure best possible work prior to utilizing quantum hardware resources.