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QUANTUM COMPUTING ALGORITHM FOR SPIN MODEL

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ABSTRACT

Presented here is an algorithm for a type-II quantum computer which simulates the Ising model in 1-D. We are implementing Quantum Computing algorithm for time evolution of Ising spins and correlate it to the analysis of Covid-19 data.

INTRODUCTION

- We employ a spin S = 1/2 Ising model to describe the spread of Covid-19.
- We consider that the interaction (contact) between infected and non-infected people can be associated with the interaction between nearest-neighbor magnetic moments in the well-established Ising - model.
- We used 'Metropolis Monte Carlo Algorithm' for simulating the Ising model for a given temperature.
- We performed an analysis of magnetization as a function of temperature.

LITERATURE

- The Ising model is an approach to modelling the magnetic behavior of materials.
- The total energy of the system is determined by the orientation of the spin states:

(a) When a spin points in the same direction as the magnetic field or if adjacent spins point in the same direction, this is a lower energy state. (Fig 1b, Fig 1d)

(b) When a spin points in the opposite direction as the magnetic field or if adjacent spins point in the opposite direction, it is a higher state. (Fig 1a, Fig 1c)

- Similarly, we consider that two people who are infected (or non-infected) by Covid-19 have no effect on each other, so that in this case the interaction is 0 and, otherwise, the interaction is not equal to 0. [2]

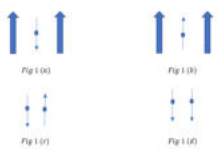

Fig 1: Energy states

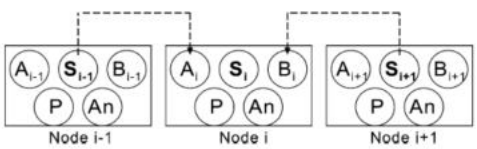

Fig 2: The super positioned qubits for each node are re-initialized after every iteration. [3]

METHOD

The algorithm steps are as follows:

1. Initializing input states, A, B, and S using the random function.
2. Initializing probability |P⟩ with a user-specified temperature.

$$|P\rangle = \sqrt{P}|1\rangle + \sqrt{1-P}|0\rangle \qquad P = e^{-\frac{4J}{T}}$$ [3]

3. Appling quantum circuit gate sequence.
4. Measuring resultant spin for each node.
5. Using resultant spin to re-initialize neighboring nodes.
6. Repeating the above steps using Metropolis Monte Carlo algorithm until equilibrium is reached for each temperature. [3]

Finally, plotting a magnetization vs temperature graph.

ANALYSIS

We used IBMQ's Qiskit jupyter notebooks to simulate the quantum circuit and generalized it in such a way that it takes the number of nodes as a user-input and gives a corresponding quantum circuit.

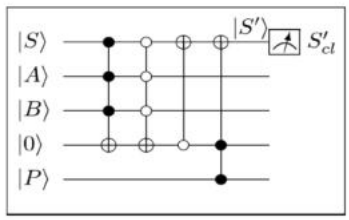

Fig 3: Quantum Circuit for a single node of a 1-D Ising model. [3]

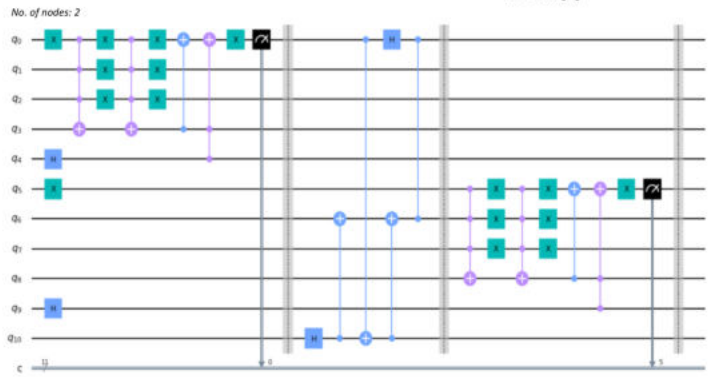

Fig 4: Quantum circuit for 1-D Ising model implemented using Qiskit

RESULTS

Magnetization as a function of temperature for the Ising model.

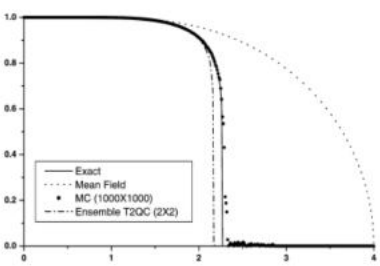

Fig 5: Graph derived from [3]

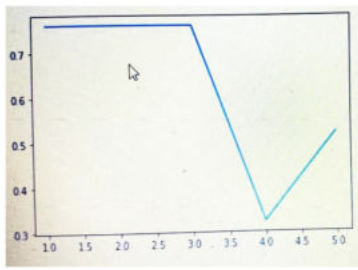

Fig 6: The observed results are for 2 nodes, 12 qubits, 20 runs.

CONCLUSIONS

- We have implemented type II Quantum computing algorithm to use the Metropolis Monte Carlo method to perform time evolution of Covid-19 data.
- The present work highlights the universal character of fundamental concepts in condensed matter Physics and their possible applications to other subject areas.

IMPORTANT REFERENCES

[1] Exact Ising model simulation on a quantum computer, Alba Cervera-Lierta, December 20, 2018, Spain.

[2] Attacking the Covid-19 with Ising-model and Fermi-Dirac Distribution Function, Lucas Squillante, Isys F. Mello, Antonio C. Seridonio, Mariano de Souza; Brazil.

[3] An algorithm for simulating the Ising model on a type-II quantum computer, J.H. Cole, L.C.L. Hollenberg, S. Prawer, Australia

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