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QUANTUM COMPUTING IN CREATION GEOSCIENCE

Mark McGuire and Kathryn McGuire, 2455 Edison St. NW, Uniontown, OH 44685 kgmeyer@cedarville.edu

ABSTRACT

Quantum computing has great potential in speeding up many problems. Rather than stepping “down” from a classical Newtonian realm into the more complicated quantum realm we use the same processes as the phenomena being researched.

In geoscience, quantum computing has many potential applications. For example, quantum computing can be used for simulations of radiometric dating. By simulating the decomposition of atoms, a better idea of how these decompose can be created. Simulating typical, unaccelerated decomposition would be the first step in this area of research. This can be done by creating a qbit (quantum bit) for each atom and connecting them such that if the atom higher in the chain decomposes, the next one down decomposes. This algorithm will likely not provide a quantum speedup by itself. However by embedding it in a simulated crystal (Xia 2020, Cai et al 2020), radiohalos and fission tracks could be studied. This could also assist in the study of accelerated nuclear decay.

The flood heat problem could also be an interesting study. Similarities have been noted between the thermal properties of objects and the noise on a quantum device. Most study in this area has been focused on improving quantum computers (Sinha et al. 2022) but it could be used to simulate the systems of the earth under extreme conditions (Casalegno et al. 1999).

There is also work being done on using quantum computing to speed up or improve computational fluid dynamics programs (Gaitan 2020, Steijl 2019, Lin et al. 2009). Unlike the other subjects in this proposal, this relies on a quantum computer’s ability to solve differential equations more effectively than a classical computer. It could allow for larger scale or more fine-grained simulations of sediment flows.

It is known that there are useful algorithms that provide a speedup for similar problems, or have the potential to provide speedup when our quantum computers improve sufficiently. Further research is needed to determine which of these areas of study are included in the subset of problems that can be better solved by quantum methods.

KEYWORDS

quantum computing, geoscience, quantum physics, computation

THE AUTHORS

Mark McGuire is a developer at IBM with multiple certificates in quantum computing. His interests include optimizing high performance computations and lowering barriers for scientists who wish to utilize quantum computing.

Kathryn McGuire has her BS in Geology from Cedarville University, and has begun work on her Master’s of Geographic Information Science program at Kent State University. Since her time at Cedarville she has worked in GIS and data management for Northeast Ohio Regional Sewer District and Washington College, where she has learned several programming languages and many GIS tools.

Quantum Computing and Creation Geoscience

M.A. McGuire, littlemarkmcguire@gmail.com and K.G. McGuire

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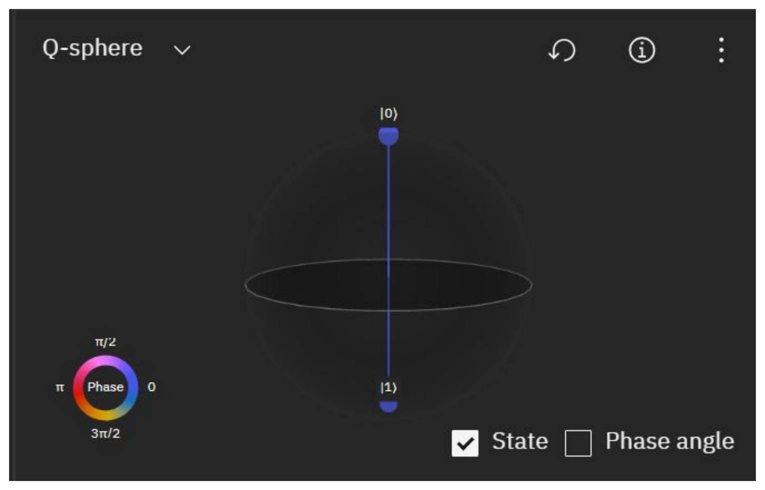
Abstract

Quantum computing has great potential in speeding up many problems. Rather than stepping “down” from a classical Newtonian realm into the more complicated quantum realm we use the same processes as the phenomena being researched. In geoscience, quantum computing has many potential applications. For example, quantum computing can be used for simulations of radiometric dating. By simulating the decomposition of atoms, a better idea of how these decompose can be created. Simulating typical, unaccelerated decomposition would be the first step in this area of research. This can be done by creating a qubit (quantum bit) for each atom and connecting them such that if the atom higher in the chain decomposes, the next one down decomposes. This algorithm will likely not provide a quantum speedup by itself. However by embedding it in a simulated crystal (Xia 2020, Cai et al 2020), radiohalos and fission tracks could be studied. This could also assist in the study of accelerated nuclear decay. The flood heat problem could also be an interesting study. Similarities have been noted between the thermal properties of objects and the noise on a quantum device. Most study in this area has been focused on improving quantum computers (Sinha et al. 2022) but it could be used to simulate the systems of the earth under extreme conditions (Casalegno et al. 1999). There is also work being done on using quantum computing to speed up or improve computational fluid dynamics programs (Gaitan 2020, Steijl 2019, Lin et al. 2009). Unlike the other subjects in this proposal, this relies on a quantum computer’s ability to solve differential equations more effectively than a classical computer. It could allow for larger scale or more fine-grained simulations of sediment flows. It is known that there are useful algorithms that provide a speedup for similar problems, or have the potential to provide speedup when our quantum computers improve sufficiently. Further research is needed to determine which of these areas of study are included in the subset of problems that can be better solved by quantum methods.

Basics of Quantum Computing

Quantum computing is a new type of computing that uses Quantum physics rather than Newtonian (Classical) physics. The base unit of information for a quantum computer is a qubit. Rather being in an “on” or “off” state like a regular bit, qubits can have any value on the Bloch Sphere. The Q-sphere pictured right is a modified Bloch Sphere made by IBM to accommodate multiple qubits. Although we can do computations off of any of these states using another qubit, when we attempt to read this superposition it collapses to a binary value. Despite this issue quantum computing has the potential to speed up many computations. To risk oversimplifying, quantum computers are typically used to simulate atomic processes or work with waves and interference. This poster has an additional use case covering a less common, but possibly more useful in the near term, regarding heat dissipation. Quantum computers are rapidly reaching their potential, however there is still a long way to go. Noise and decoherence (qubits losing their value over time) are large issues, as is the size constraint.



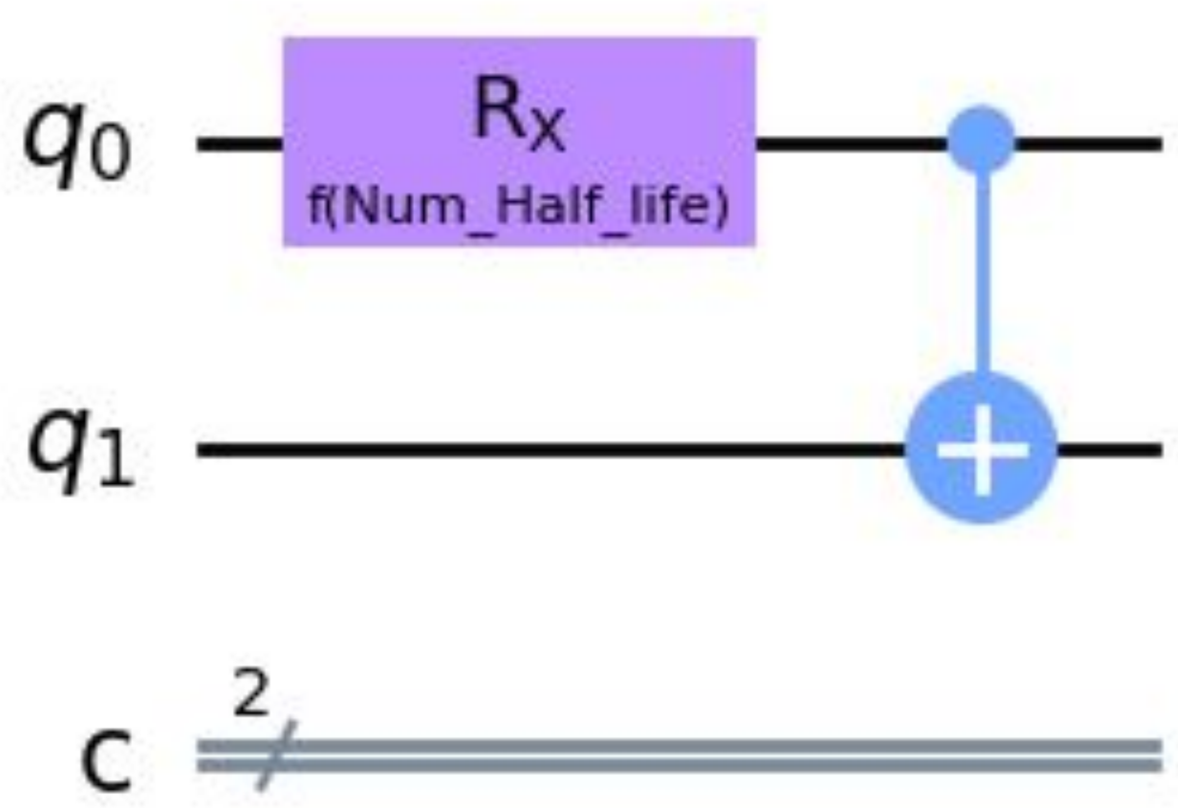
Radiometric Dating

A simple radiometric dating algorithm can be developed using a quantum circuit similar to the following OpenQasm stub.

```
rx(f(Num_Half_life)) q[0];
cx q[0], q[1];
```

Where f(n) is a function that creates the correct probability for q[0] to “decompose” or flip as the number of half lives. The cx is an entanglement gate that if q[0] decomposes, then q[1] will show up.

The authors do not expect this alone to provide useful insights, however it is a first step in the direction of simulations that may provide further insight. Quantum computers are noted as effective at simulating crystals, so imbedding this or a similar algorithm in the lattice may allow for more accurate simulation then that allowed by classical computers.



Heat Dissipation

Quantum computers are able to find minimal points of energy functions that classical computers cannot using quantum tunneling. This has obvious application to heat transfer, since that’s just a simple energy function.

A lot of work has been done on the connection between quantum computers and heat as the noise in quantum systems has very similar properties as heat dissipation. Most of the work has been research in dealing with heat to better understand how to minimize quantum noise. Much of that work has been done by the Maryland Quantum-Thermodynamics Hub (QTD). The authors imagine that this work could be reversed to better study the thermal properties of materials.

An added advantage of using quantum noise as a way to simulate thermal action is that it removes the issue that our current quantum computers are noisy. This problem is a large hindrance to researchers as it limits the running time of a quantum program. If we can use this noise, more data could be used and examined before exhausting the computer’s capabilities.

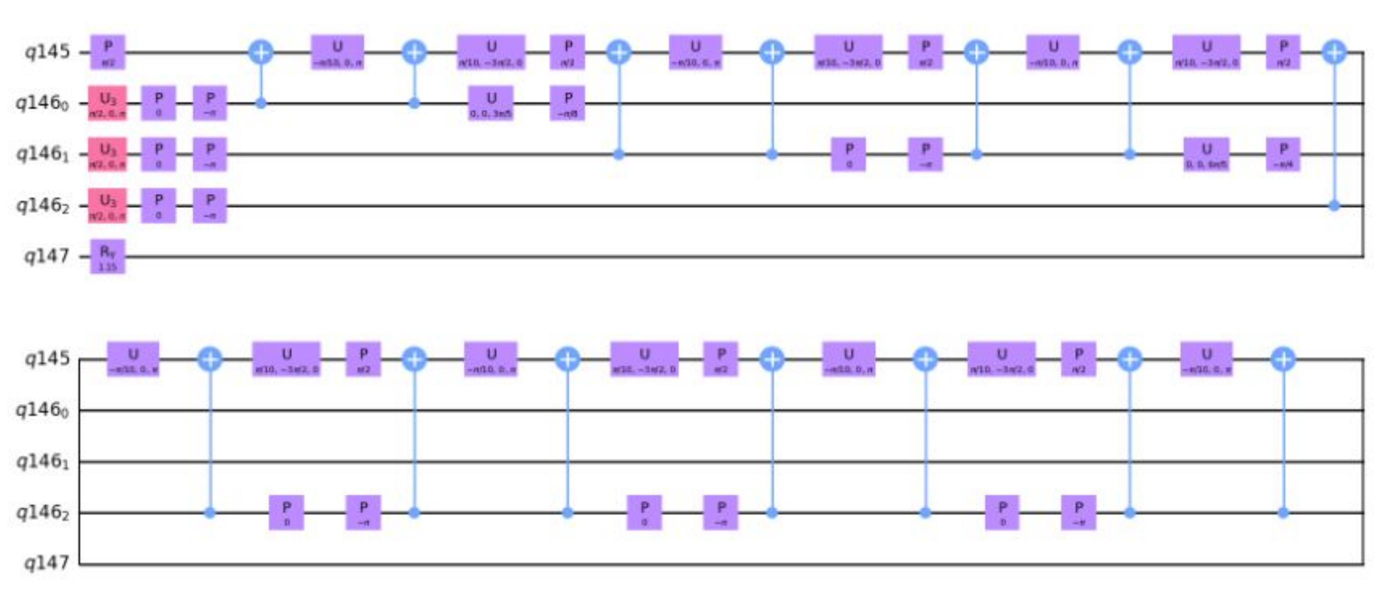
Computational Fluid Dynamics

Recently Classiq, a quantum computing company, and Rolls-Royce released work done on computational fluid dynamics (CFD). Although the papers so far have only modeled small problems, they demonstrate great enthusiasm in the field and a significant amount of research towards making it practical.

A large reason for this enthusiasm is the difficulty in matrix inversion as employed by many CFD programs. The HHL algorithm is able to solve the equation without this computational step.

However, a quantum computer can only do so much at once. A simple 2x2 matrix solved fully on a 5 qubit computer using the HHL algorithm requires over 200 quantum gates in a row (Circuit depth), which may be too many for the result to be distinguishable from noise. Better or larger computers will make this obtainable, but for now a hybrid approach is required. The first 34 layers of this solver is depicted below.

CFD is a computationally intensive task, some applications require powerful computers that are fully equipped with powerful GPUs. A best case scenario for a researcher implies a long wait for results, however there is hope that Quantum computing will provide a significant speedup, allowing for more fine grained and accurate studies.



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