Hybrid Quantum Computing

Phys 309: Quantum Computing

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Good stories have a good beginning!

The founding members (fathers and mother) of quantum science

Image taken during one of the Solvay conferences, when quantum theory was still an infant

Image source: http://24.media.tumblr.com/tumblr_m9pgtmujE01qzlfumo2_1280.jpg

but...

Was this story a good one?

Confusion:

Bohr Vs Einstein

Heissenberg Vs Schrodinger

World war...

Overall, no large public interest...

1994

Peter Shor

Discrete log algorithm

AKA Shor's factoring algorithm

1995

Groover Search Algorithm

Potential usecase in everyday life and general computer science algorithms

More people's interest aroused

not so fast ...

Decoherence and noise (Shor 1997)

TBT: Back to the 80's and early 90's

R. P. Feynman, Seth Lloyd

Quantum simulation

Ideas on how to circumvent noise and decoherence

Quantum Algorithms skyrocketed

Up until now ...

Realizing quantum computation proves to be hard due to interaction with environment

Remedy??

NISQ era: Combine Quantum and Classical Algorithms

That's where we come into the scene

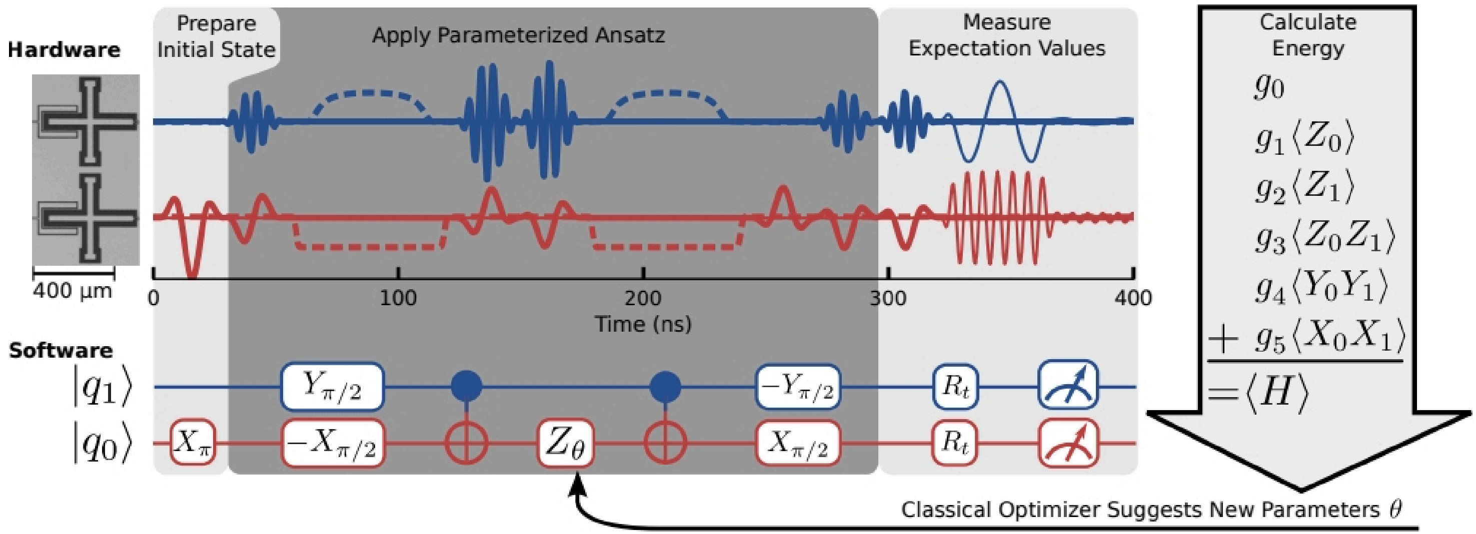
My final paper focuses on this part

Algorithm 1 Hardware-efficient optimization of quantum Hamiltonian problems

Map the quantum Hamiltonian problem to a qubit Hamiltonian H
Choose a depth d for the quantum circuit that prepares the trial state
Choose a set of variational controls $\vec{\theta}_1$ that parametrize the starting trial state
Choose a number of samples S for the feedback loop and one S_f for the final estimation
Choose a number of maximal control updates k_L
while E_f has not converged **do**
    procedure QUANTUM FEEDBACK LOOP
        for $k = 1$ `to` k_L **do**
            Prepare trial states around $\vec{\theta}_k$ and evaluate $\langle H \rangle$ with S samples
            Update and store the controls $\vec{\theta}_k$
        end for
        Evaluate $E_f = \langle H \rangle$ using the best controls with S_f samples
    end procedure
    Increase d, k_L, S, S_f
end while
return E_f

Abhinav Kandala et al (2017)

A visual representation coming up ...

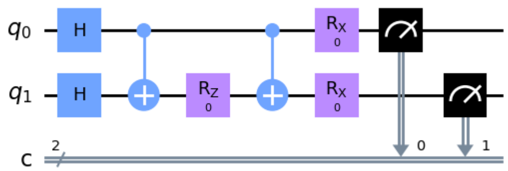


P. J. J. O'Malley et al (2017)

- Hardware (micrograph <- two Xmon transmon qubits):
  - Single qubit rotation performed using microwave pulse sequences
  - DC pulse for two-qubit entangling gates
  - Microwave spectroscopy tones for qubit measurements
- Software
  - Preparation of a Hartree-Fock state
  - Apply unitary coupled cluster ansatz
  - Apply efficient partial tomography to measure the expectation values

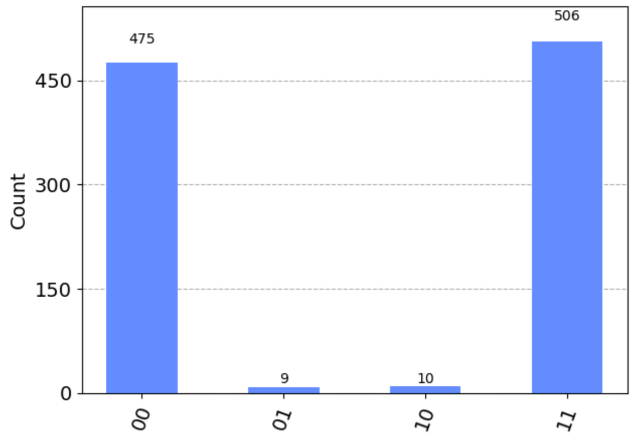
Compute total energy from measurements and provide the result to a classical optimizer to determine the new parameters, repeat b and c till you get optimal results.

Simple modified set-up



Pauli Z matrices used to represent cost hamiltonian, Pauli X matrices used to represent mixing hamiltonian

These gates combined to form circuit shown

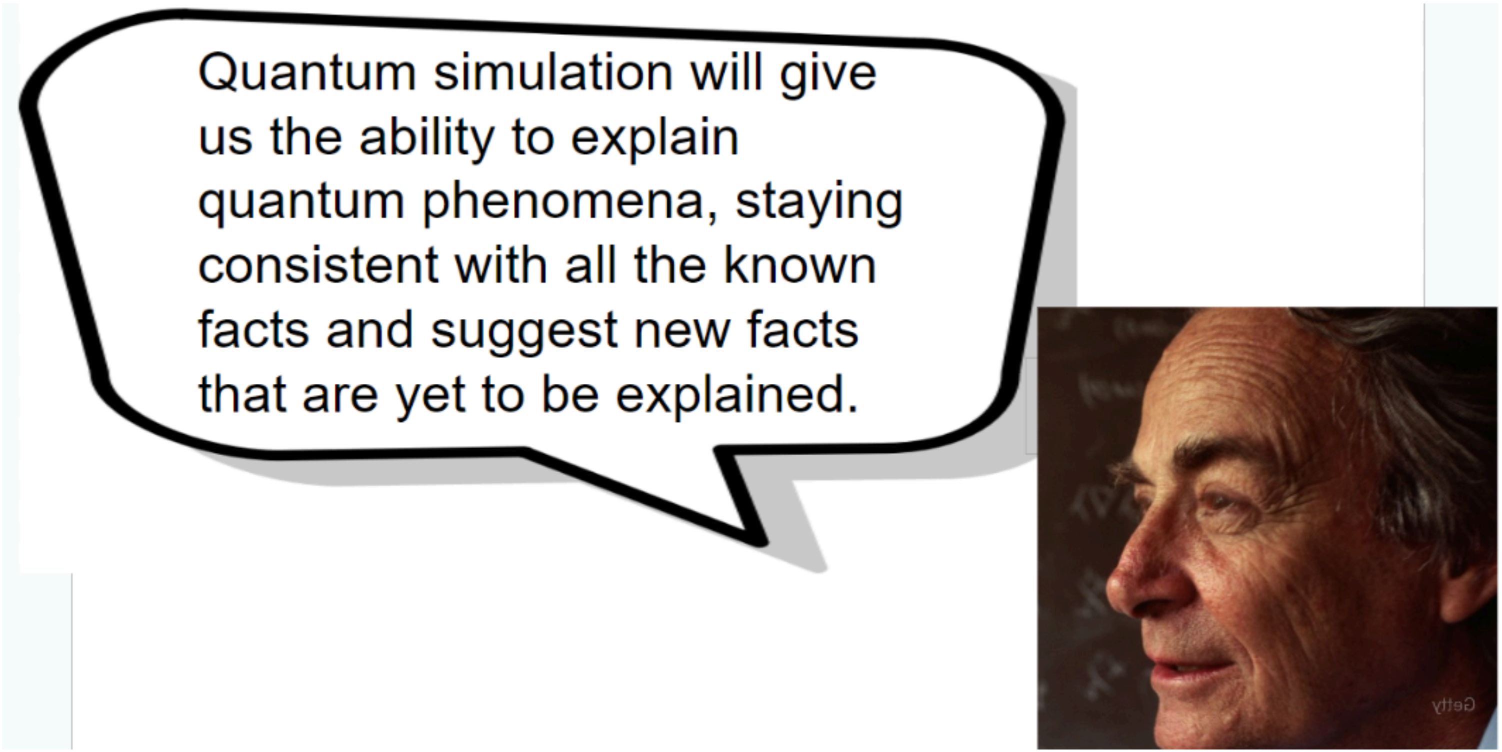


Our algorithm works for a simple case of using Pauli X and Pauli Z to represent our hamiltonian. Again, with different hamiltonians, the expectation is that the algorithm still works but more thought needs to be put in the encoding of data.

A realization of this simple model may be done using ion traps, which provide well defined hamiltonians that can be used to describe the system. This choice gets rid of the disadvantage associated with cooling resources thus bringing us nearer and nearer to quantum computing/simulation actualization.

With more research into decoherence and physical realization of quantum systems, the potential of scalability might be attained. A drawback, however, is that some hamiltonians may take a longer time to minimize, thus making things hard when the simulation involves a bigger number of parameters for these complicated hamiltonians, even with the physical realization available to us.

Final word...



With these quantum algorithms in place and future discovery of better ways to realize quantum computation, we will eventually realize this idea.

References

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