



Seminar in Quantum Computational Methods

Adiabatic Quantum Computing

Manish Lohani

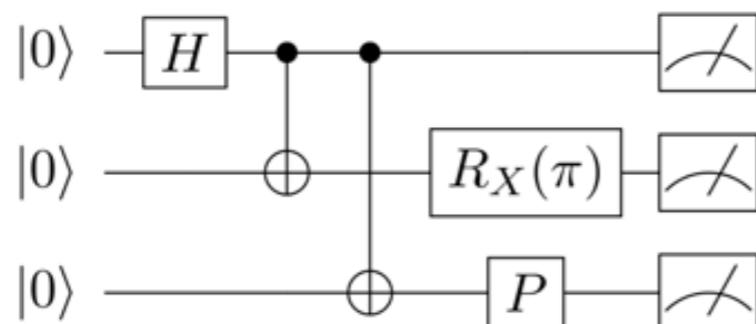
therefore, the problem is, how can we simulate the quantum mechanics? There are two ways that we can go about it. We can give up on our rule about what the computer was, we can say: Let the computer itself be built of quantum mechanical elements which obey quantum mechanical laws. Or we can turn the other way and say: Let the computer still be the same kind that we thought of before—a logical, universal automaton; can we imitate this situation? And I'm going to separate my talk here, for it branches into two parts.

4. QUANTUM COMPUTERS—UNIVERSAL QUANTUM SIMULATORS

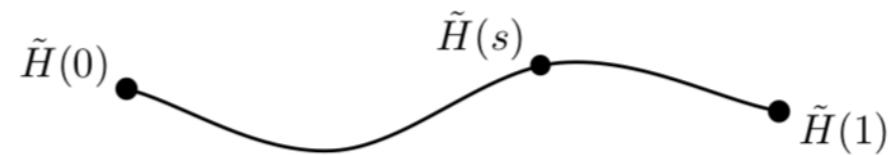
The first branch, one you might call a side-remark, is, Can you do it with a new kind of computer—a quantum computer? (I'll come back to the other branch in a moment.) Now it turns out, as far as I can tell, that you can simulate this with a quantum system, with quantum computer elements. It's not a Turing machine, but a machine of a different kind. If we disregard the continuity of space and make it discrete, and so on, as an approximation (the same way as we allowed ourselves in the classical case), it does seem to

Quantum Computing

Circuit Methods



Analog Methods



*Simulating Physics with Computers , Richard P. Feynman

**International Journal of Theoretical Physics, Vol 21, Nos. 6/7, 1982

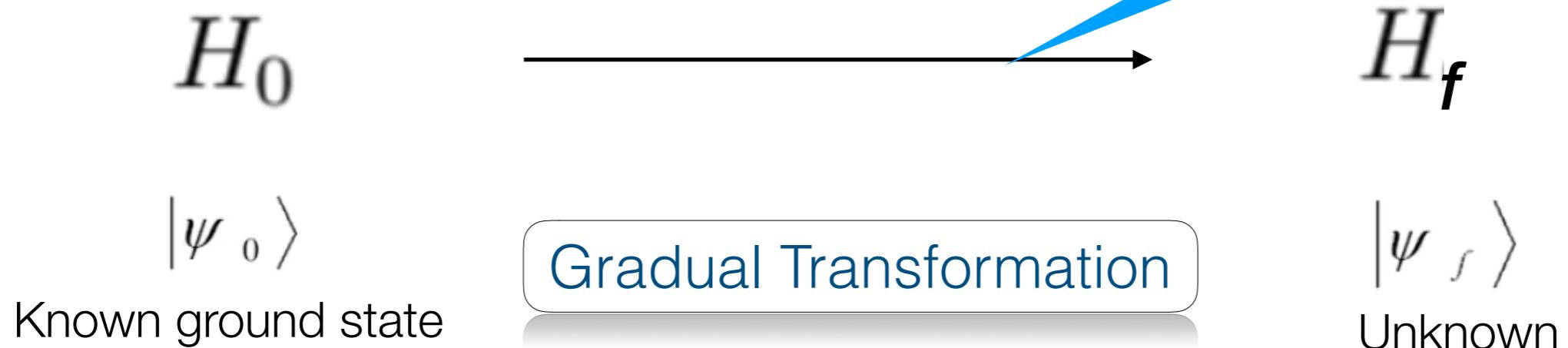
Adiabatic Quantum Computing

By Farhi, Gutmann and Sipser in 2000^[1]

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Adiabatic evolution



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Adiabatic evolution

H_0



H_f

$$H(s) = (1 - s)H_0 + s H_f$$

Gradual Transformation

$|\psi_0\rangle$

Known ground state

$|\psi_f\rangle$

Unknown

Initial Hamiltonian

Final Hamiltonian
(of which ground
state encodes
solution of problem)

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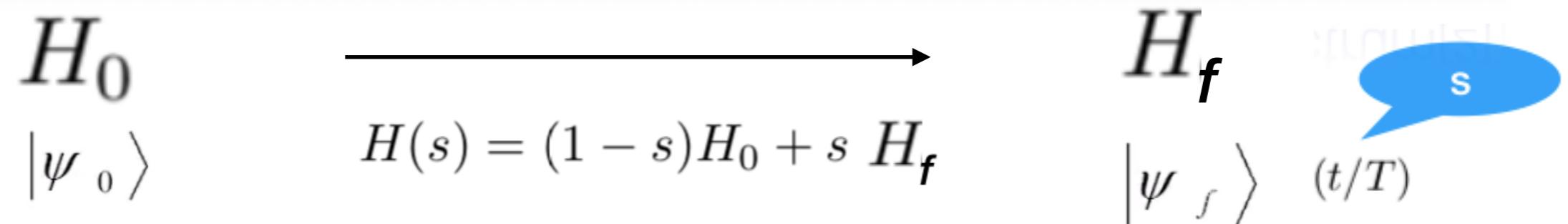
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Based on Adiabatic Theorem

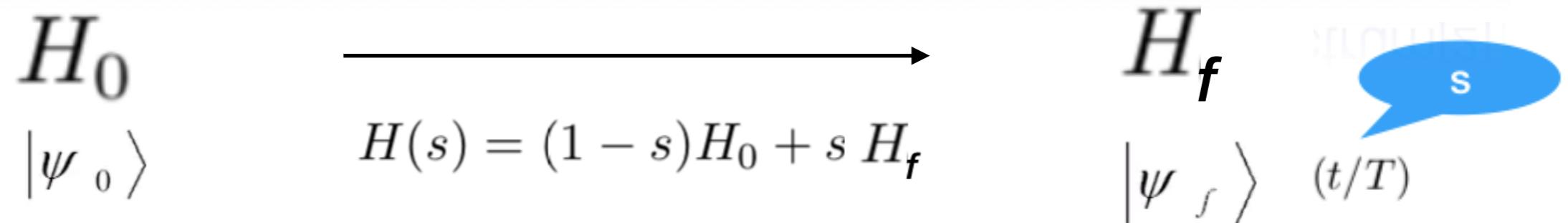
Adiabatic Theorem

A physical system remains in its instantaneous eigenstate if a given perturbation is acting on it slowly enough and if there is a gap between the eigenvalue and the rest of the Hamiltonian's spectrum[2]



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If evolution time is big enough,
State of system at time $T \sim$ Ground state of $H(T)$

$$T = \frac{1}{g_{min}^2 (t)^2}$$

Where

$$g_{min} = \min_s(E_1(s) - E_0(s))$$

Variational Quantum Eigensolver (VQE)

Peruzzo and Mc- Clean et al. in 2014^[3]

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Hybrid Quantum- Classical Algorithm

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Hybrid Quantum- Classical Algorithm

Goal :

Obtain an approximation for lowest energy and associated configuration for a quantum system

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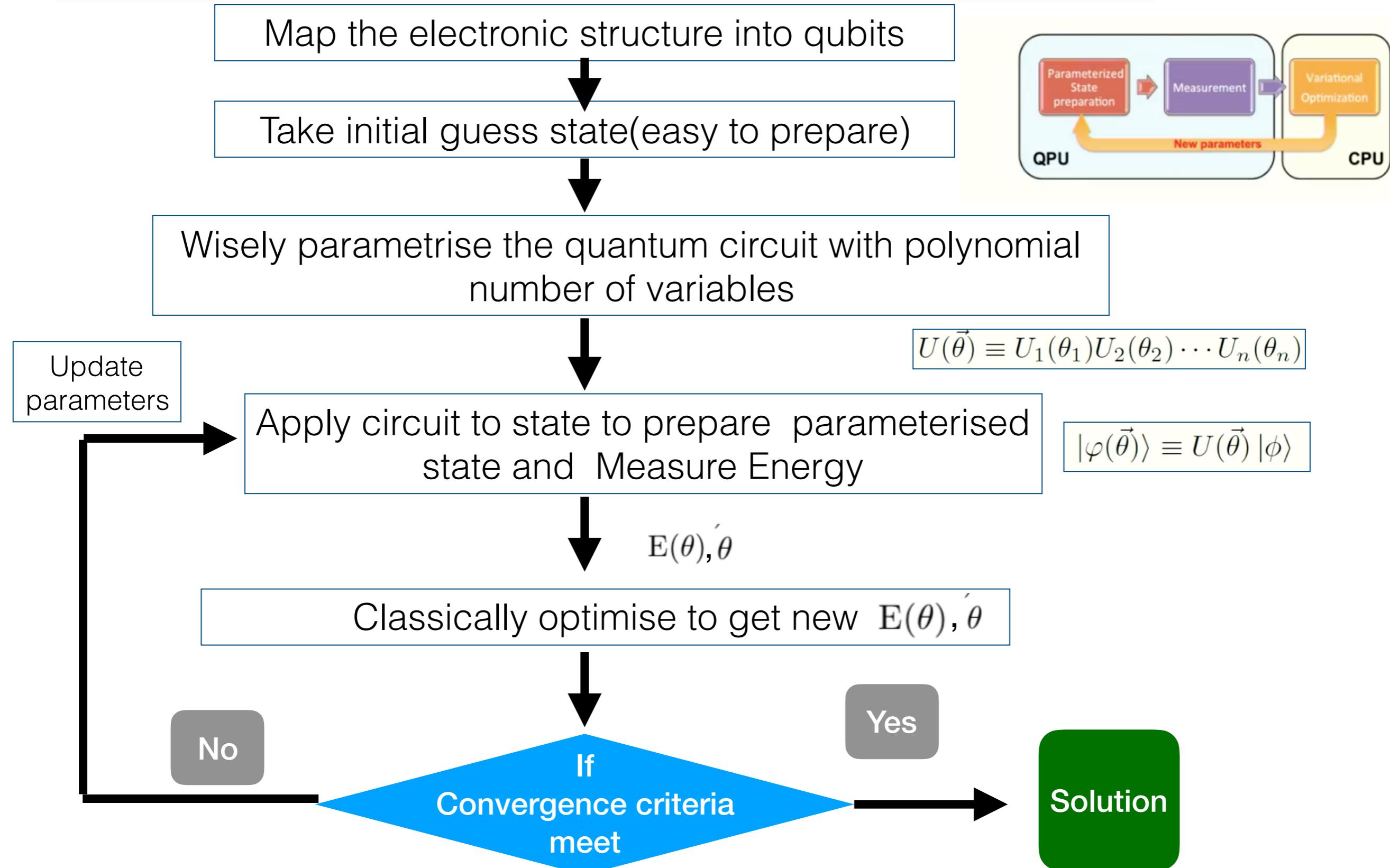
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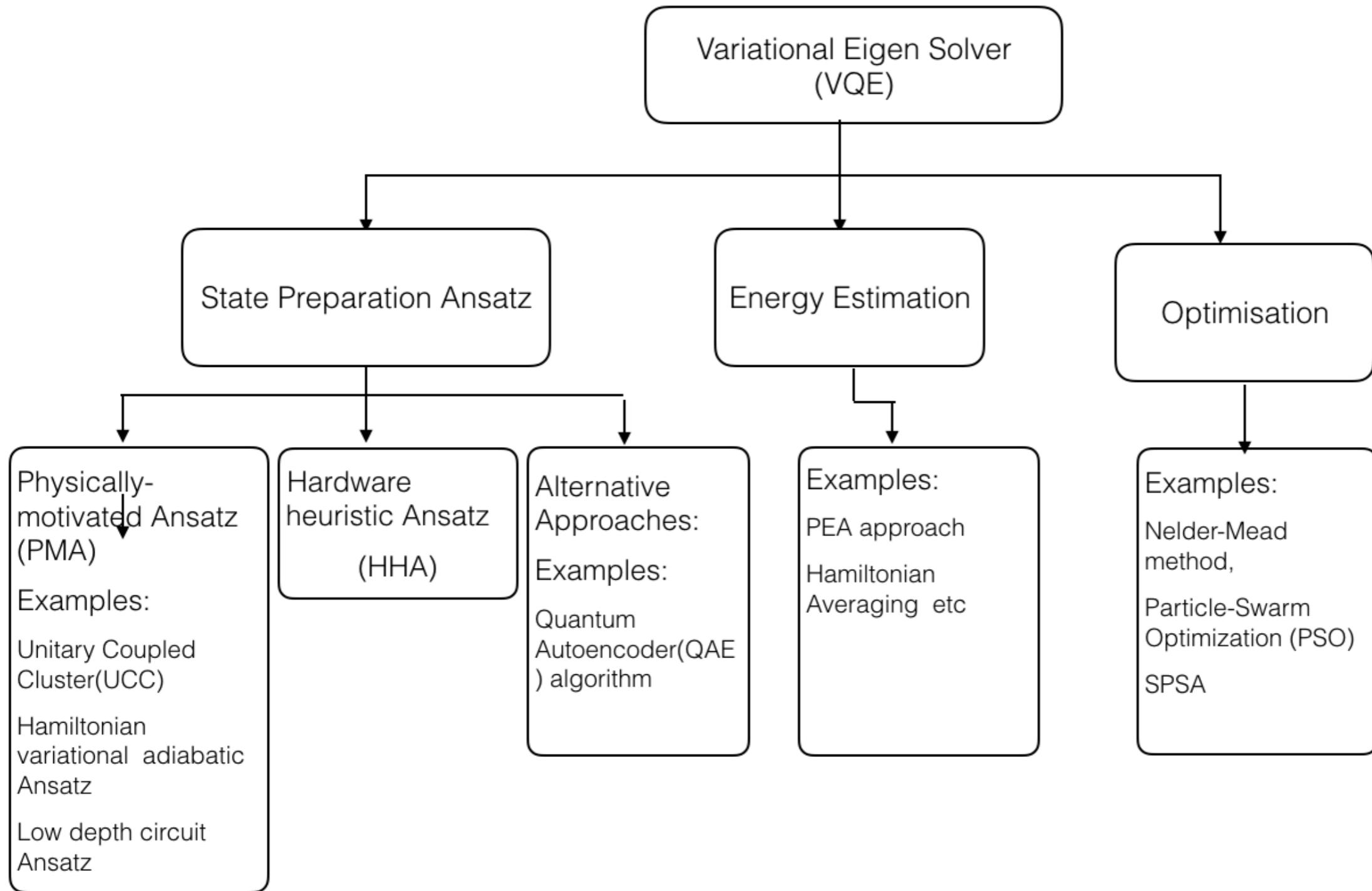
To attain this goal, we make a parameterised guess for the state and minimise the energy with respect to the parameters

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Variational Quantum Eigensolver (VQE)



Variational Quantum Eigensolver (VQE)



Adiabatically Assisted Variational Quantum Eigensolver (AAVQE)^[4]

A. Garcia-Saez, Latorre (2018)

VQE:

PRO	CON
Quantum circuit with variable Set of parameters	May get lost in parameter Space
Gradient search using classical optimisation	Use large number of measurements

AQC:

PRO	CON
Always finds its way to the solution	May be exponentially slow
Can be optimised to pick a more efficient adiabatic path	

Adiabatically Assisted Variational Quantum Eigensolver (AAVQE) [4]

A. Garcia-Saez, Latorre (2018)

$$H(s) = (1 - s)H_0 + sH_P$$

Prepare the ground state of a simple Hamiltonian with $s_0 = 0$ with a quantum circuit using VQE.

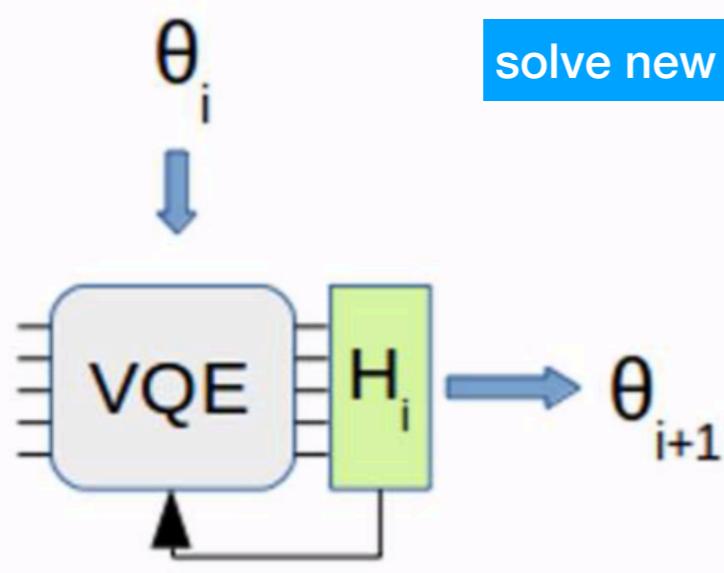
Initial parameterised state preparation

 $\theta_{s_0}^{(f)}$

Add a step Δs , that is $s_{i+1} = s_i + \Delta s$

solve new $H(s)$ with final parameters of previous step

Run a VQE on $H(s_{i+1})$ using as initial parameters $\theta_{s_{i+1}}^{(0)} = \theta_{s_i}^{(f)}$, the final parameters from the previous step.



No

s = 1

Yes

Stop

Adiabatically Assisted Variational Quantum Eigensolver (AAVQE)

AAVQE less vulnerable to stuck into local minima(except few cases at last stages of evolution)

No real time evolution

Adiabatic interpolation is simply to guide the series of VQE

Number of discretisation steps of the adiabatic evolution is matter of choice

Classical optimisation method is also matter of choice

Studies done based on Adiabatic Quantum computing

- Satisfiability
- Exact Cover
- 3-regular 3-XORSAT and 3-regular
- Max-Cut
- Random instances of classical Ising spin glasses
- Search engine ranking
- Adiabatically parameterised states preparation ansatz for VQE
- Adiabatic Quantum Simulation of Quantum Chemistry

THANK YOU