变分量子算法原理和MindQuantum实现

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目录

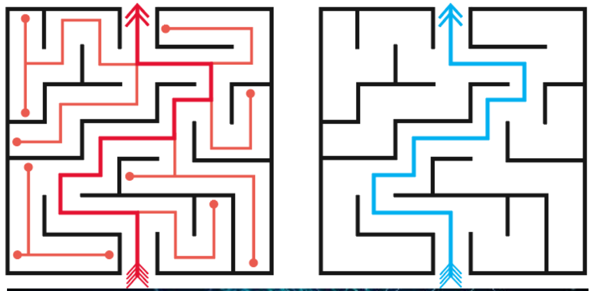
量子计算的颠覆性思想

以0和1作为基础　　　　指数空间的操作能力　　　　随机计算

量子计算 = 经典计算 + 量子叠加/纠缠 + 量子并行 + 量子相干 + 量子测量

指数计算空间　　　　波函数（复数）计算

量子计算　　　　经典计算



单凭量子计算机存在的可能性，已经对目前的加密系统造成威胁。

The possibility of quantum computers alone has already threatened the current encryption system.

例子: 计算 $f(x) = x^2$

经典计算机： $f(1), f(2), f(3), \ldots$

量子计算机：

$$|1\rangle|f(1)\rangle + |2\rangle|f(2)\rangle + |3\rangle|f(3)\rangle + \cdots$$

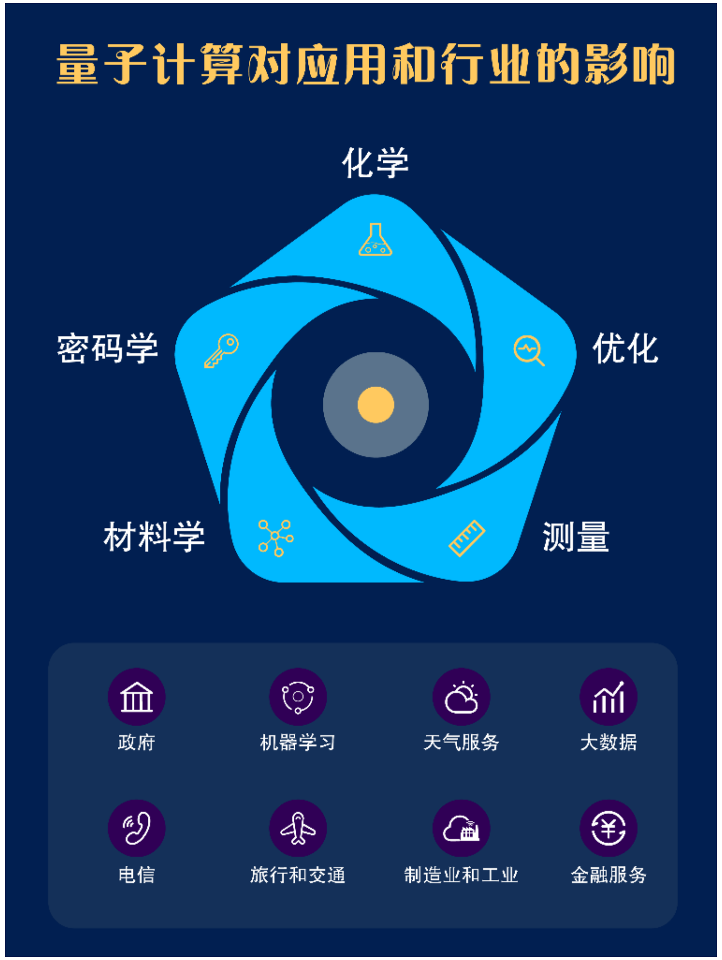
大数分解问题： $n = p \times q$

例子：

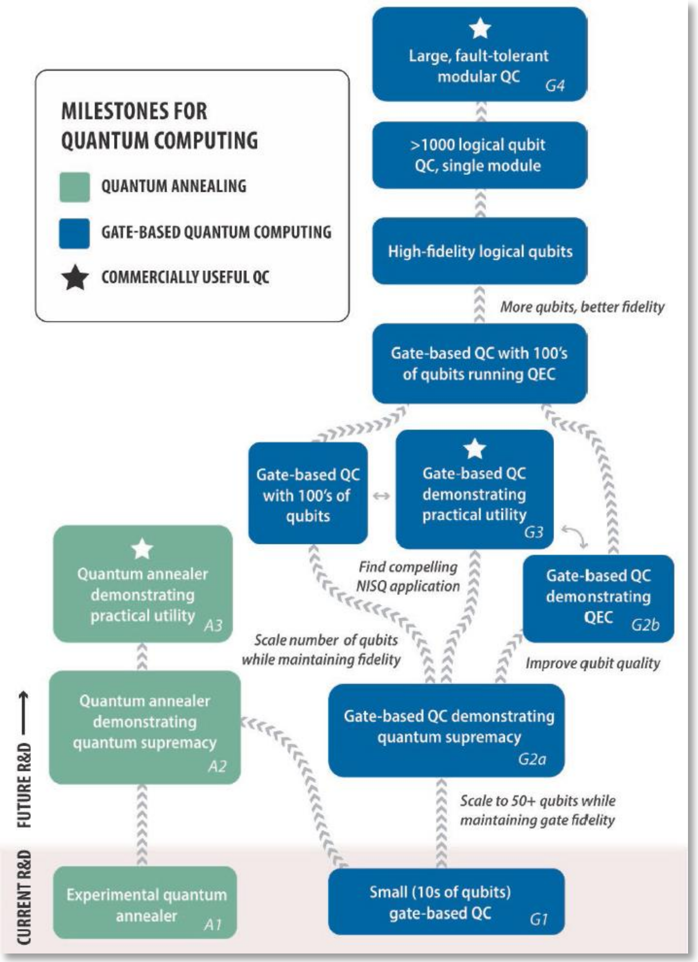
$$15 = 3 \times 5$$
$$21 = 3 \times 7$$

量子计算应用和路线图

量子计算应用

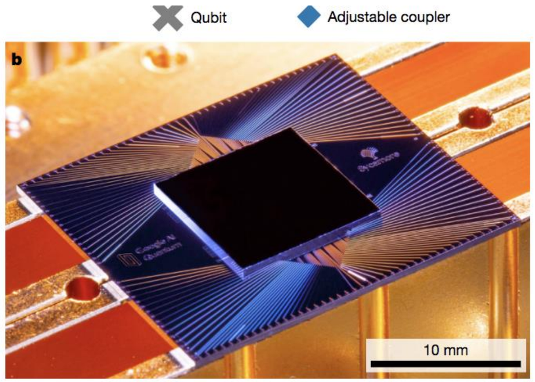


欧盟量子计算路线图



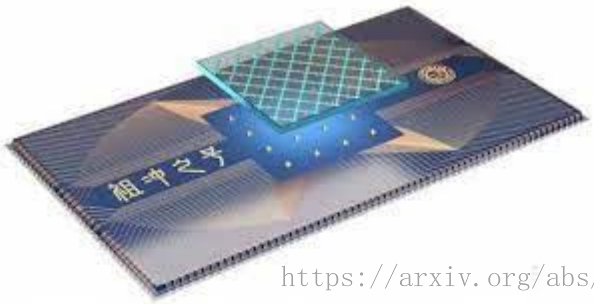
量子计算最新进展

2019 年谷歌宣布利用53超导比特芯片达成量子计算“霸权（优越性）”



https://doi.org/10.1038/s41586-019-1666-5

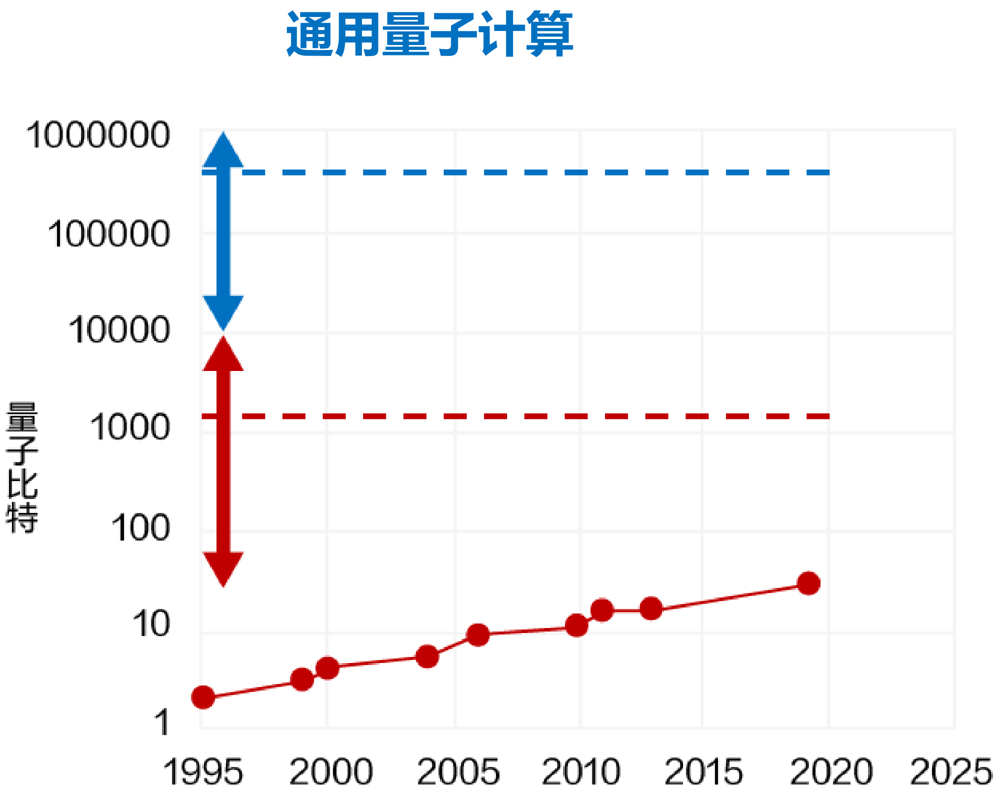
2021 年中科大利用62超导比特芯片达成量子计算优越性

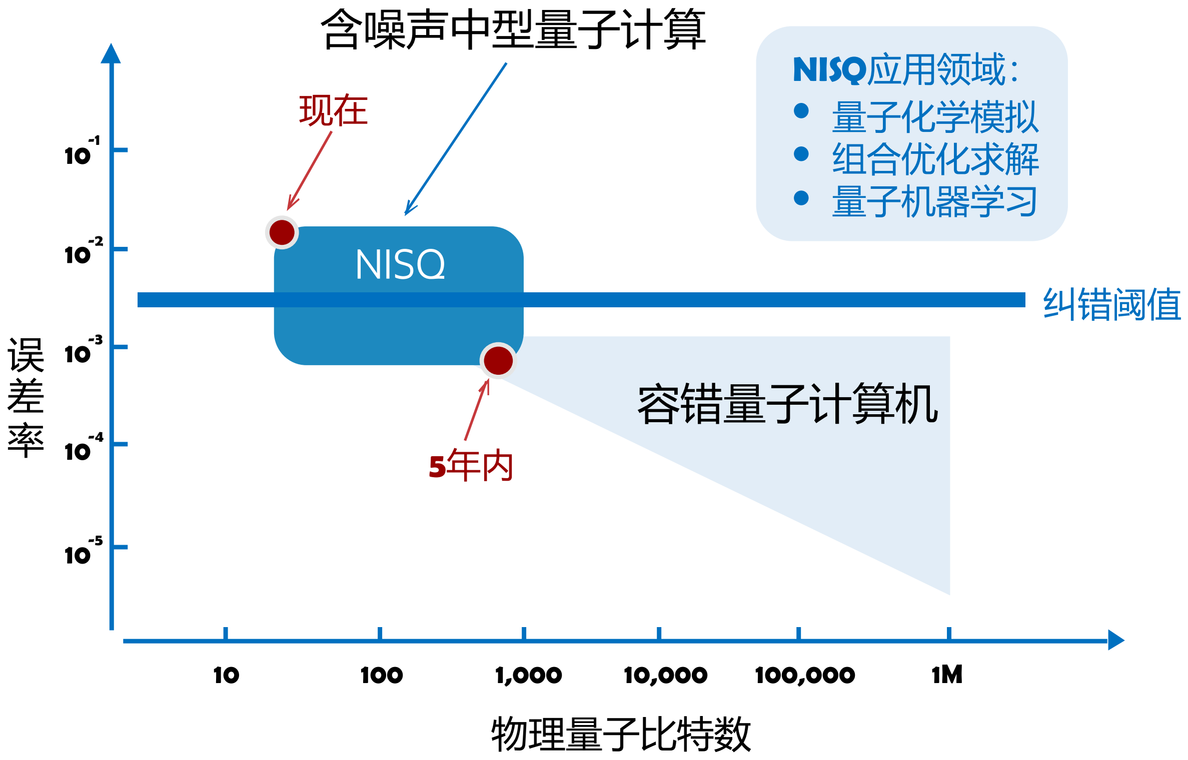


https://arxiv.org/abs/2106.14734

NISQ时代

NISQ = Noisy Intermediate-Scale Quantum





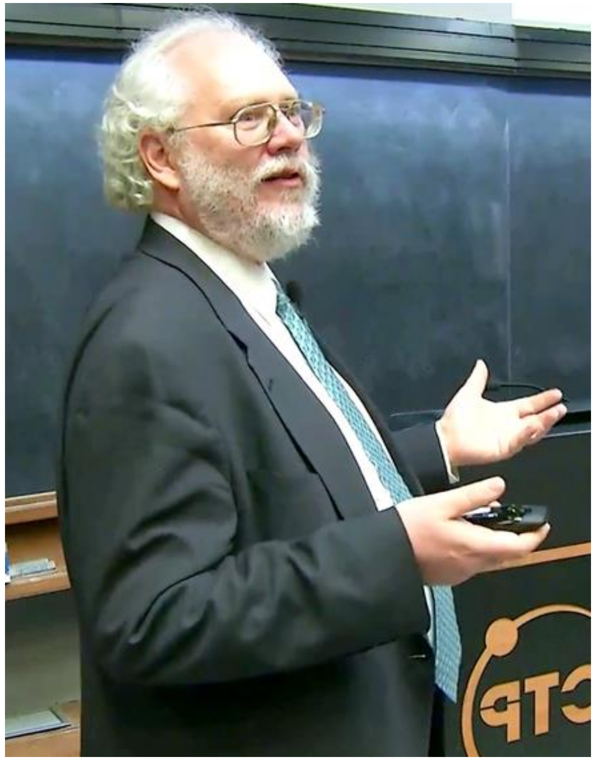
量子算法的简史

ARTICLE

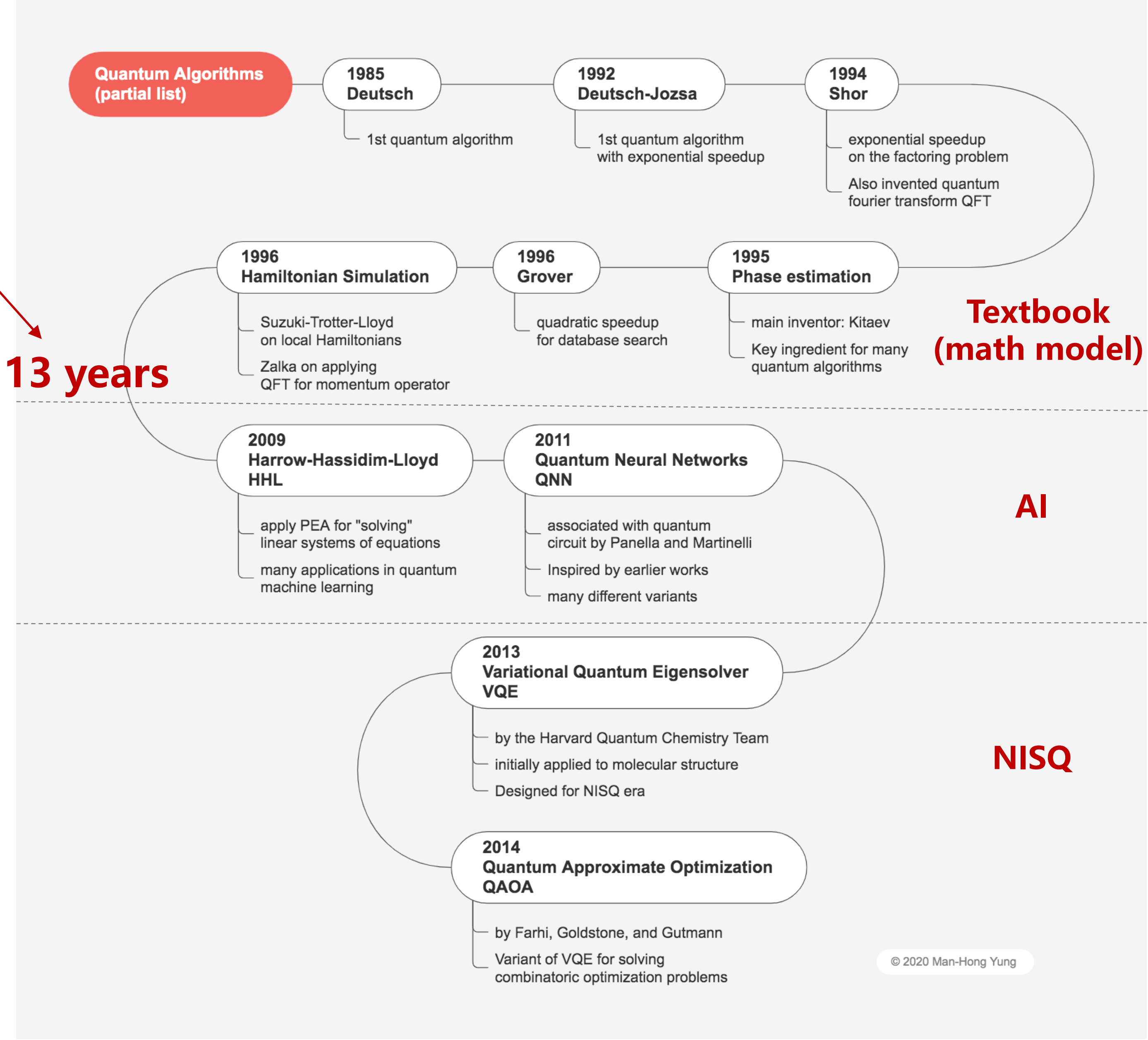
Why haven't more quantum algorithms been found?

Author: Peter W. Shor [Authors Info & Affiliations](#)

Publication: Journal of the ACM • January 2003 • https://doi.org/10.1145/602382.602408



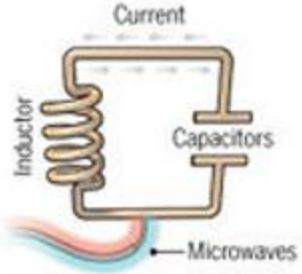
picture from Wikipedia



量子计算实现路径

超导

Superconducting loops



A resistance-free current oscillates back and forth around a circuit loop. An injected microwave signal excites the current into super-position states.

Longevity (seconds) **0.00005**

Logic success rate **99.4%**

Number entangled **9**

Company support
Google, IBM, Quantum Circuits

Pros
Fast working. Build on existing semiconductor industry.

Cons
Collapse easily and must be kept cold.

硅量子点

Silicon quantum dots

These "artificial atoms" are made by adding an electron to a small piece of pure silicon. Microwaves control the electron's quantum state.

Longevity (seconds) **0.03**

Logic success rate **~99%**

Number entangled **2**

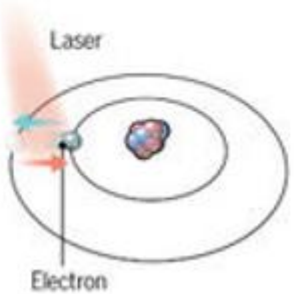
Company support
Intel

Pros
Stable. Build on existing semiconductor industry.

Cons
Only a few entangled. Must be kept cold.

离子阱

Trapped ions



Electrically charged atoms, or ions, have quantum energies that depend on the location of electrons. Tuned lasers cool and trap the ions, and put them in super-position states.

Longevity (seconds) **>1000**

Logic success rate **99.9%**

Number entangled **14**

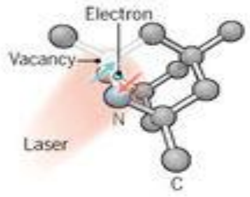
Company support
ionQ

Pros
Very stable. Highest achieved gate fidelities.

Cons
Slow operation. Many lasers are needed.

金刚石色心

Diamond vacancies



A nitrogen atom and a vacancy add an electron to a diamond lattice. Its quantum spin state, along with those of nearby carbon nuclei, can be controlled with light.

Longevity (seconds) **10**

Logic success rate **99.2%**

Number entangled **6**

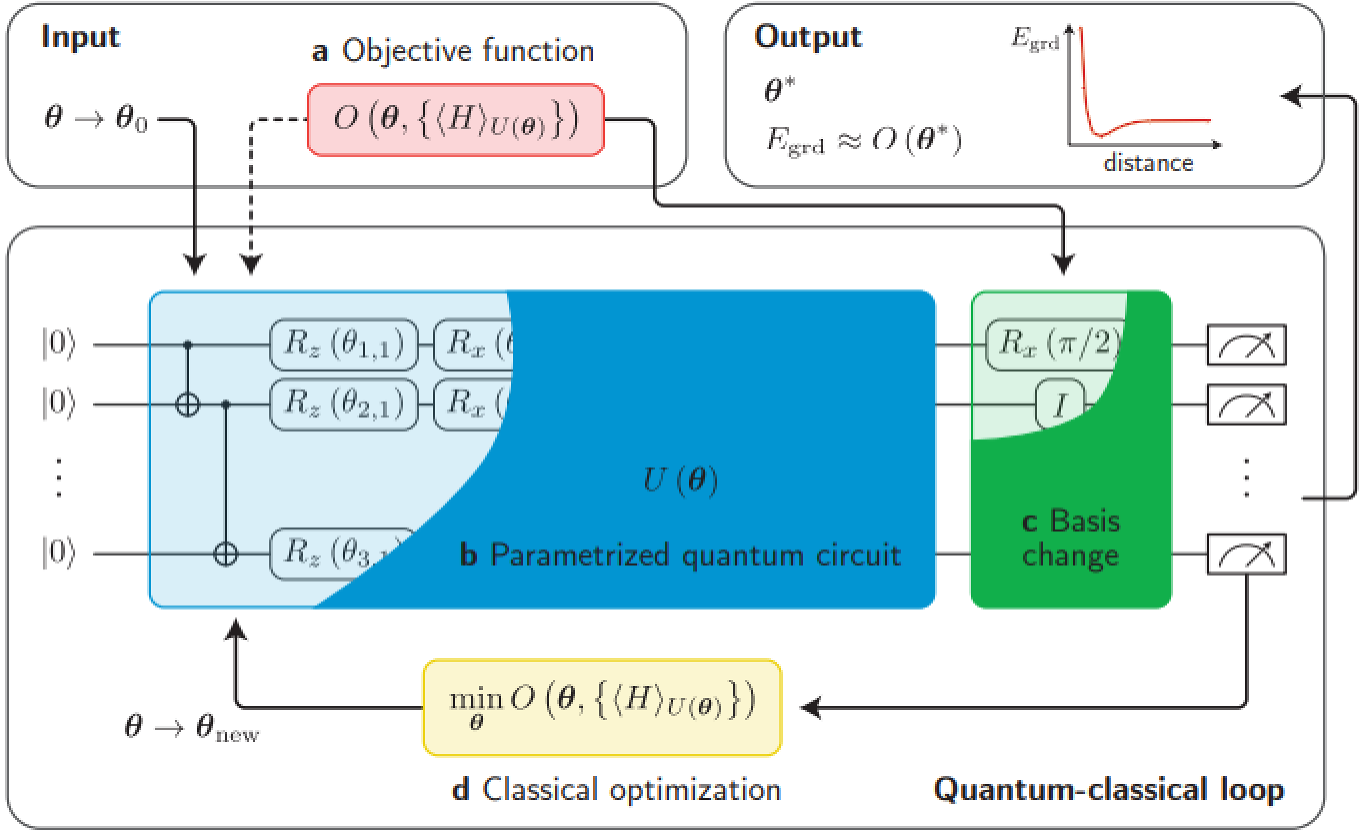
Company support
Quantum Diamond Technologies

Pros
Can operate at room temperature.

Cons
Difficult to entangle.

Note: Longevity is the record coherence time for a single qubit superposition state, logic success rate is the highest reported gate fidelity for logic operations on two qubits, and number entangled is the maximum number of qubits entangled and capable of performing two-qubit operations.

量子变分算法框架



量子变分算法示意图

a.目标函数:

$$\langle H\rangle_{U(\theta)} \equiv \langle 0| U^{\dagger}(\theta) H U(\theta) |0\rangle,$$

b.参数化量子线路

$$|\Psi(\theta)\rangle = U(\theta) |\Psi_0\rangle,$$

c.基矢变换

d.经典优化器

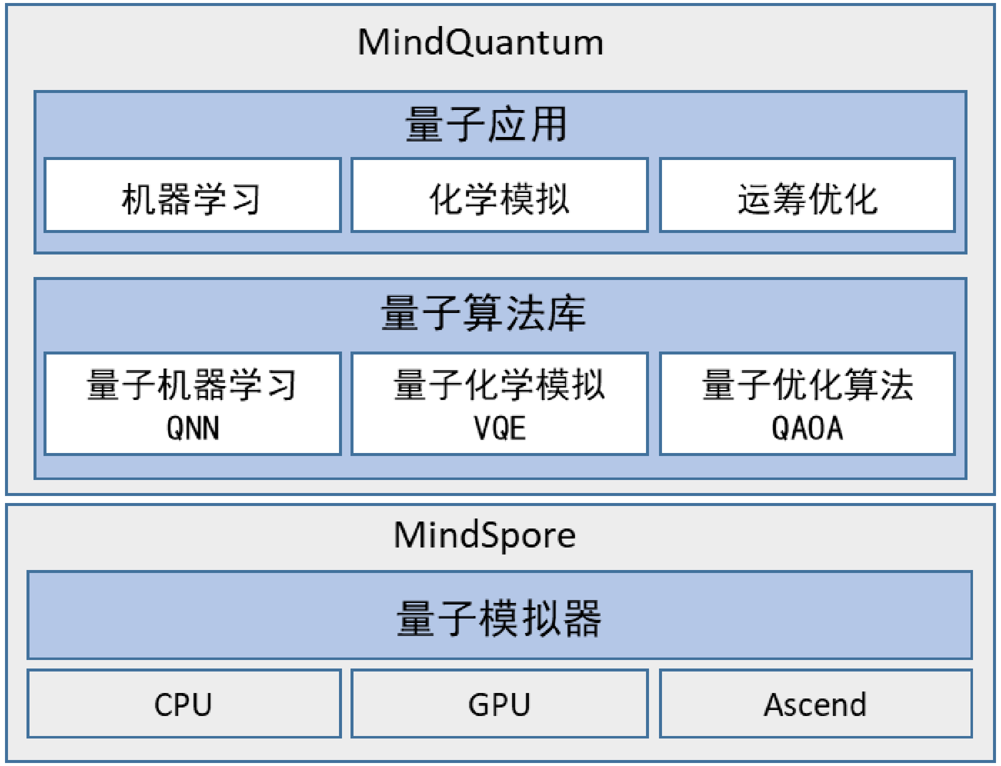
$$\min_{\theta} O\left(\theta, \{\langle H\rangle_{U(\theta)}\}\right).$$

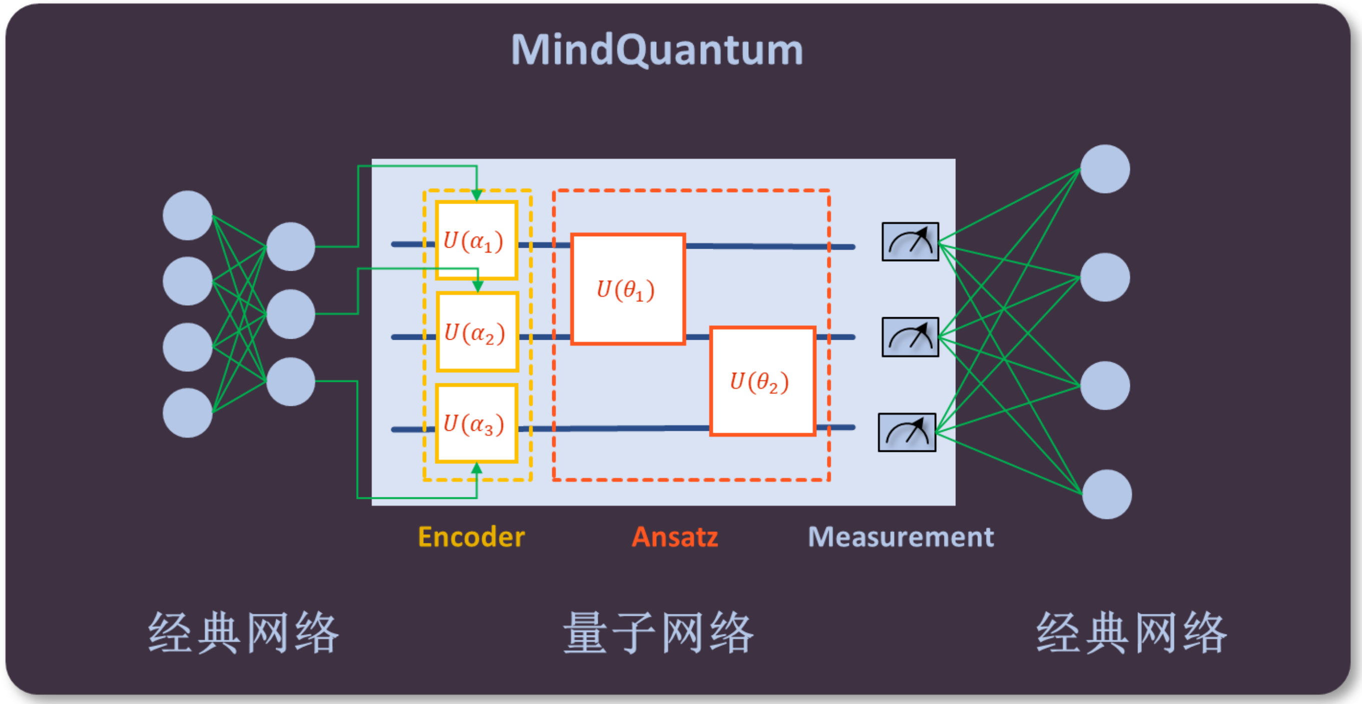
https://arxiv.org/pdf/2101.08448.pdf

用MindQuantum搭建和训练量子神经网络

MindQuantum架构

MindQuantum是结合**MindSpore**和**HiQ**开发的量子机器学习框架，支持多种量子神经网络的训练和推理。得益于华为**HiQ**团队的量子计算模拟器和**MindSpore高性能自动微分能力**，**MindQuantum**能够高效处理量子机器学习、量子化学模拟和量子优化等问题，为广大的科研人员、老师和学生提供了快速设计和验证量子机器学习算法的高效平台。





课上主讲材料：

1.量子逻辑门和量子线路搭建

https://gitee.com/mindspore/mindquantum/blob/master/tutorials/1.parameterized_quantum_circuit.ipynb

2.量子神经网络搭建和训练

https://gitee.com/mindspore/mindquantum/blob/master/tutorials/2.initial_experience_of_quantum_neural_network.ipynb

3.化学模拟算法原理和实操

https://gitee.com/mindspore/mindquantum/blob/master/tutorials/7.vqe_for_quantum_chemistry.ipynb

4.量子近似算法原理和实操

https://gitee.com/mindspore/mindquantum/blob/master/tutorials/5.quantum_approximate_optimization_algorithm.ipynb

5.鸢尾花分类

https://gitee.com/mindspore/mindquantum/blob/master/tutorials/3.classification_of_iris_by_qnn.ipynb

题目：

Bloch球中的点，在**XY**平面上和下分别标记为**0**和**1**， 自己生成数据集利用量子神经网络来进行分类。

提交PR：

https://gitee.com/mindspore/mindquantum/tree/research/meeting/ustc/1126