The 2nd Quantum Revolution (Overview)

- The 1st quantum revolution brought us inventions such as the transistor, the laser, and the atomic clock.
  ↳ However, they did not use the full power of quantum mechanics.
- The 2nd Revolution is a 3-legged stool.

Quantum Computing
- simulation
- communication

Bad ↑

Sensing
- gravitational waves
- Axion dark-matter searches
- single molecule NMR

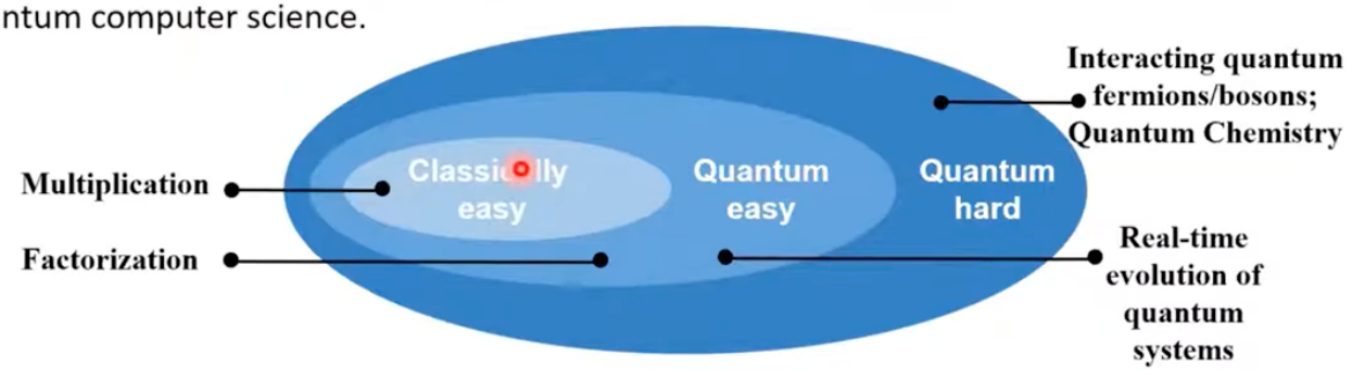
↗ Good.

Materials
- Topological insulators
- Twisted bilayer graphene
- Majorana fermions (?)

Quantum states are extremely sensitive to external perturbations

A new way to store information
1. Superposition
2. Entanglement
3. Massive parallelism.

Classification of problem complexity is an on-going research topic in quantum computer science.



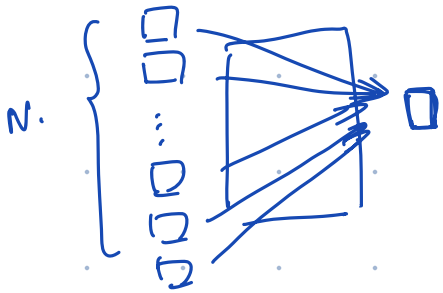
What is Computation?

- A computation is a mapping from an N-bit input to an M-bit output.

$$f: \{0,1\}^N \rightarrow \{0,1\}^M$$

We can denote this mapping as $\mathcal{Z}(N, M)$.

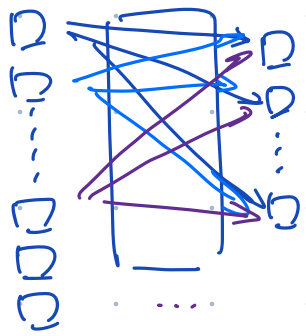
- How many functions are there?
  - ↳ Consider the case of $M=1$.



  - the input space has $S=2^N$ distinct inputs
  - For one fixed input, the # of possible outputs is 2.
  - The total number of functions are:

$$\mathcal{Z}(N, M=1) = 2^S = 2^{2^N}.$$

  - ↳ Consider the case M

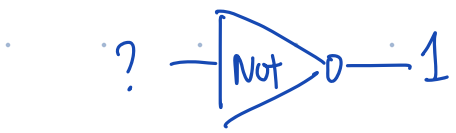


  - the input space has $S=2^N$ distinct inputs
  - For one fixed input, the number of possible outputs is 2^M
  - The total number of functions are:

$$\mathcal{Z}(N, M) = \underbrace{(2^M)^{2^N}}_{\text{\# of output slots/input}} \quad \text{\# of input slots.}$$

Basic Gates

- Identity, Not, Zero, One
- Energy consumption of computation.
  - ↳ Charlie Bennet showed that in principle, the minimum energy required to compute a function is 0, unless you erase information.
  - ↳ Erasing information happens when a computation is irreversible
    - ↳ irreversible means: given the output, you can't figure out the input.

↳ 

Not is reversible.
Given the output, you can find the input.

↳ 

AND is irreversible
You can't uniquely determine the input.

- ↳ Bennett shows that any irreversible computation can be written as a reversible one,
  by keeping copies of the intermediate results ("garbage bits").

- ↳ There exists a link between conservation of information & energy.