DISCLAIMER

I am **not** a champ in this topic, yet, so a question asked will most probably lead to a nice, never ending, discussion than a sure shot correct(super satisfactory) answer. So you are most welcome to ask... 😁

All the hypothetical scenarios are made in the spirit of the concept and not with any other intention.

What/Who do you need for building a Quantum Computer

Image Credits: one of those Tensorflow Talks

An Army with uniquely specific and crazy skill set!

A lot of...

- Physicists
- Math guys
- Material Science Engineers
- Computer Scientists and Architects (us)

A BIG BUDGET

Image Credits: one of those marvel wallpapers

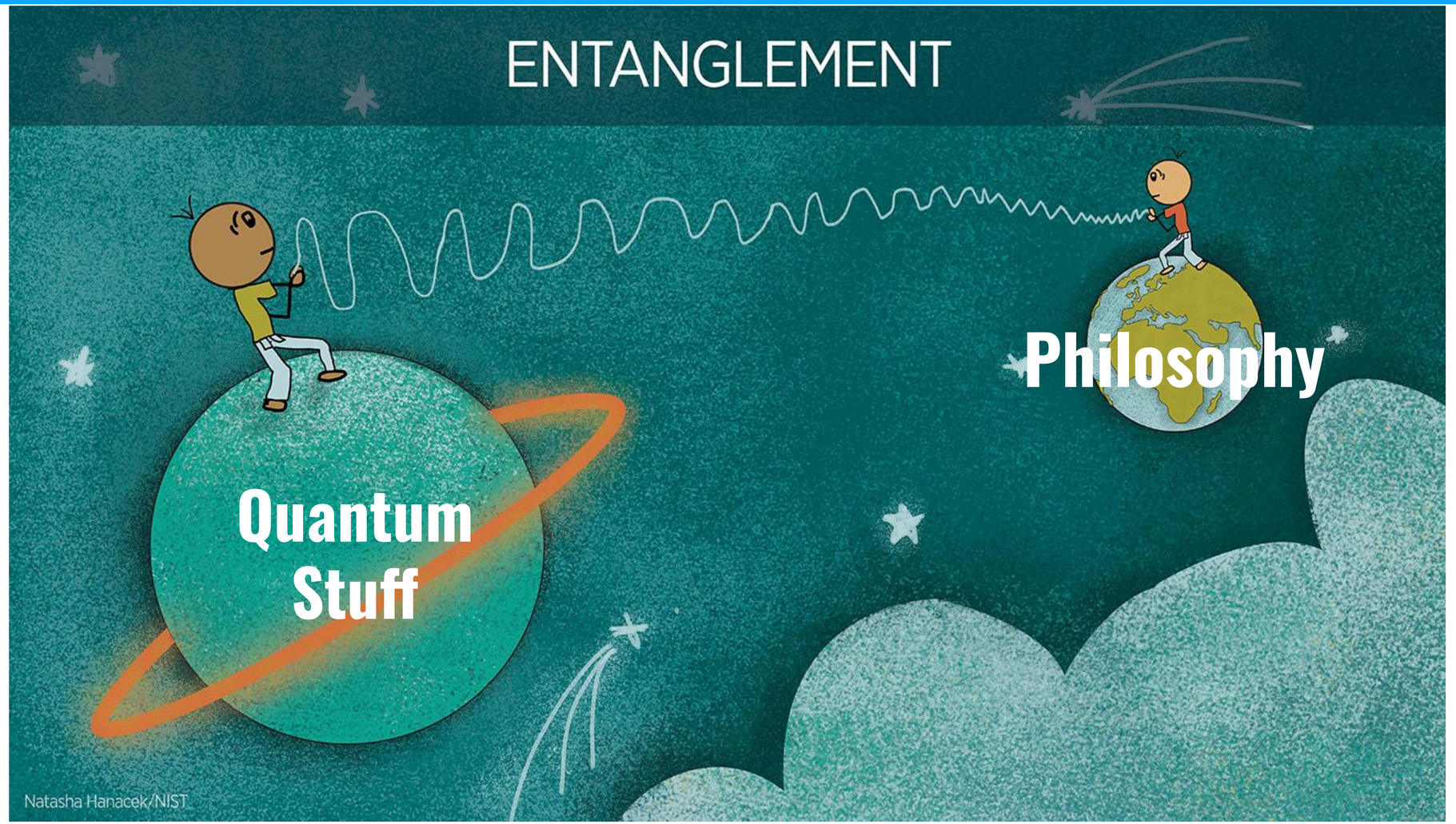
Quantum Computing for Computer Architects

The Prologue

G S Nitesh Narayana

Why this topic?

- Build Interest for this budding topic
- Give a different perspective
- Motivate us to push for actual ‘Supremacy’
- Expand (may be even quantumize) our way of thinking
- Because it's just ¡crazy and cool!



I agree with Scott Aaronson here

Image Credits: somewhere in nist.gov

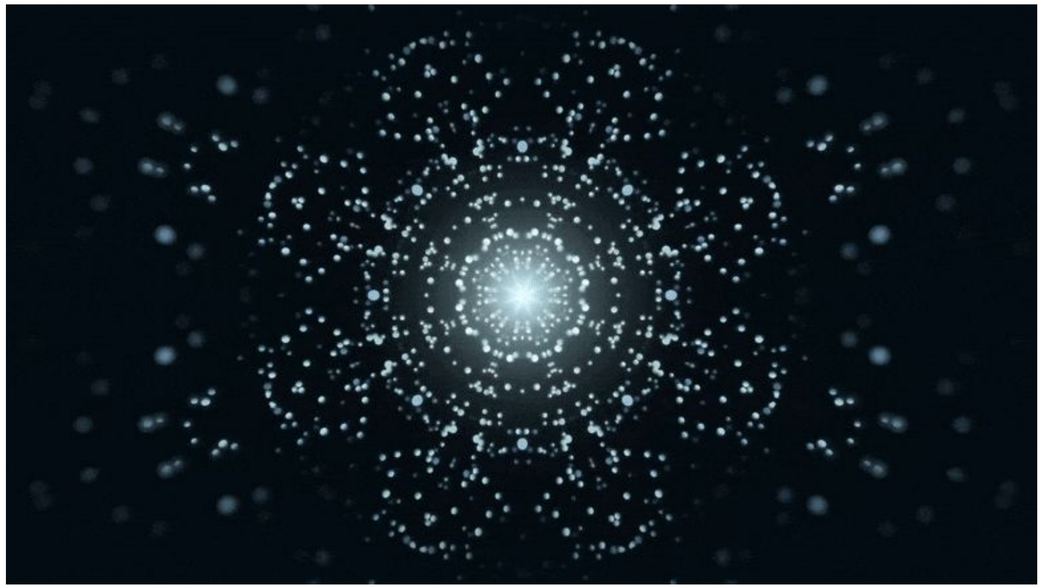
- Once there was a cat, known mostly as the Schrodinger's Cat...
- It was put inside a box...
- ...
- let's not bother the poor cat, lets say its outside the box living happily

Image Credits: somewhere in news.berkeley.edu and Jorges personal cat pics stash

Consider this Situation

- Eventually Some time in your PhD...
- You have submitted a paper to a conference
- Now till the moment you get the result email...*
- It's in both a state of acceptance and a state of rejection at the same!😉
- This situation of a state of being and not being is nothing but :
  superposition! -> Quantum Stuff

* or eventually when the conference updates its website!



“ Nothing is actually clear in the QUANTUM REALM… well except for the ¡MATH!”
- me 🤘

Image Credits: somewhere in scitechdaily.com

A Quantum Computer from the quantum most level

- Stores info in “qubits”
  - Analogous to our 0 and 1 classical bits and ‘states’

- Three weird things about qubits
  - Superposition
  - Measurement
  - Entanglement

- A qubit state is represented as follows

$$|\Psi\rangle = a|0\rangle + b|1\rangle$$

$$|a|^2 + |b|^2 = 1$$

help from RSA Conf 2019

Superposition

- Qubit can simultaneously store some amount of 0 and 1
- Qubit as shown earlier:

$$|\Psi\rangle = a|0\rangle + b|1\rangle$$

  - “Coefficients” express the amount of 0 vs 1
  - I.E the likelihood, if you read it, whether you’ll get 0 or 1

- Probability, if read the qubit, that it will read as 0 is $|a|^2$

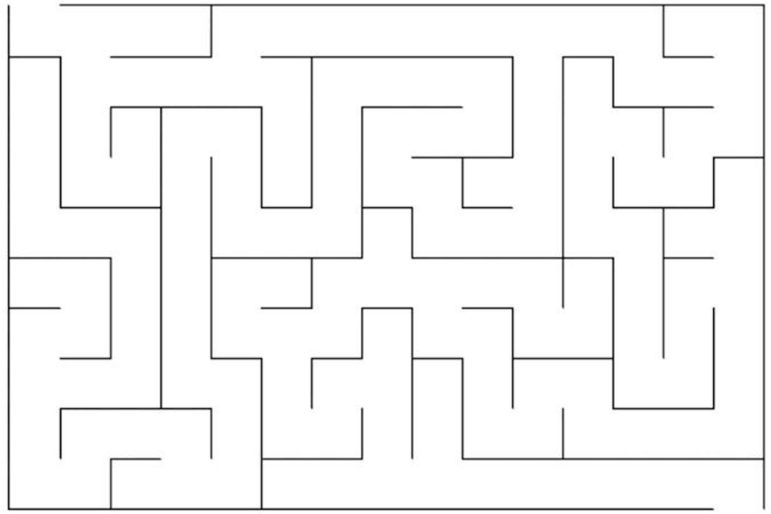
$$|a|^2 + |b|^2 = 1$$

“The principle of quantum superposition states simply that a quantum particle can exists in 2 distinct locations at the same time”

help from RSA Conf 2019

Fundamentals of Superposition :P

Things get weider



How a simple Classical computer will solve a maze

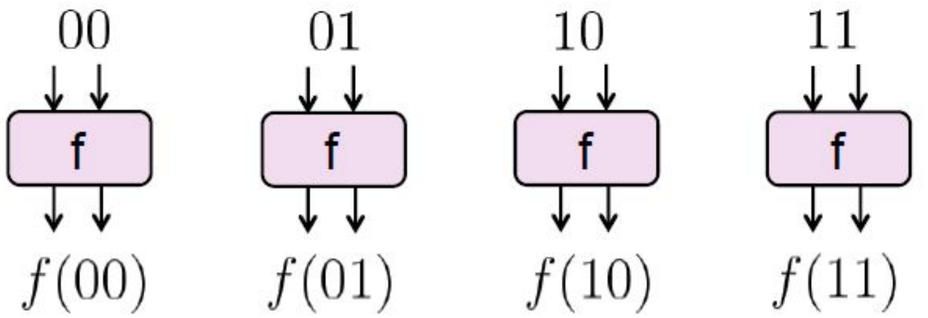
How a Quantum computer will solve a maze

Image Credits : somewhere in medium

Quantum parallelism

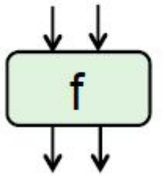
Superposition of computations

★ Classical circuit



★ Quantum circuit

$$\frac{1}{2}\left[|00\rangle + |01\rangle + |10\rangle + |11\rangle\right]$$



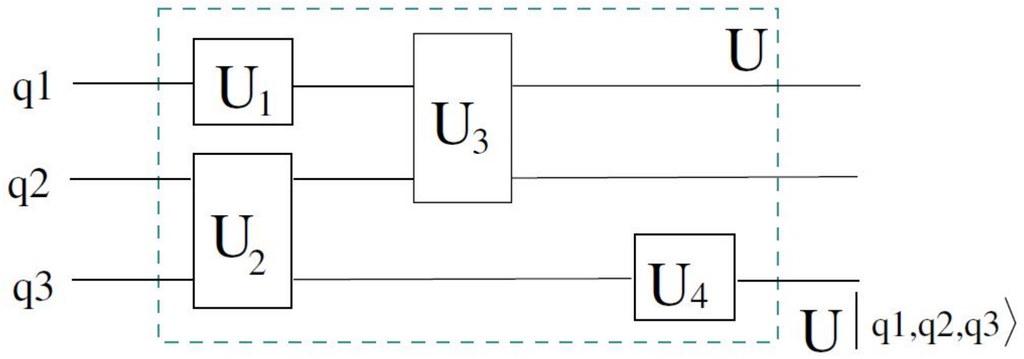
All function evaluations in a single run

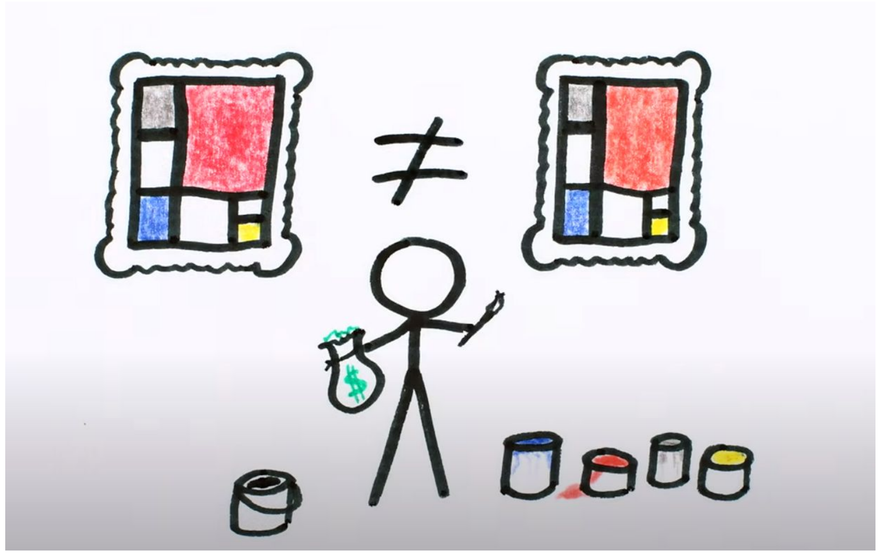
$$\frac{1}{2}\left[f(00)|00\rangle + f(01)|01\rangle + f(10)|10\rangle + f(11)|11\rangle\right]$$

Image Credits: RSA Conf 2019

Gates and weird stuff

- Gates
  - Some sort of operations on a set of qubits
  - The output is a superposition proportional to each of superposed inputs
  - The output overwrites the input qubit, so once the operation is completed the input values are no longer available



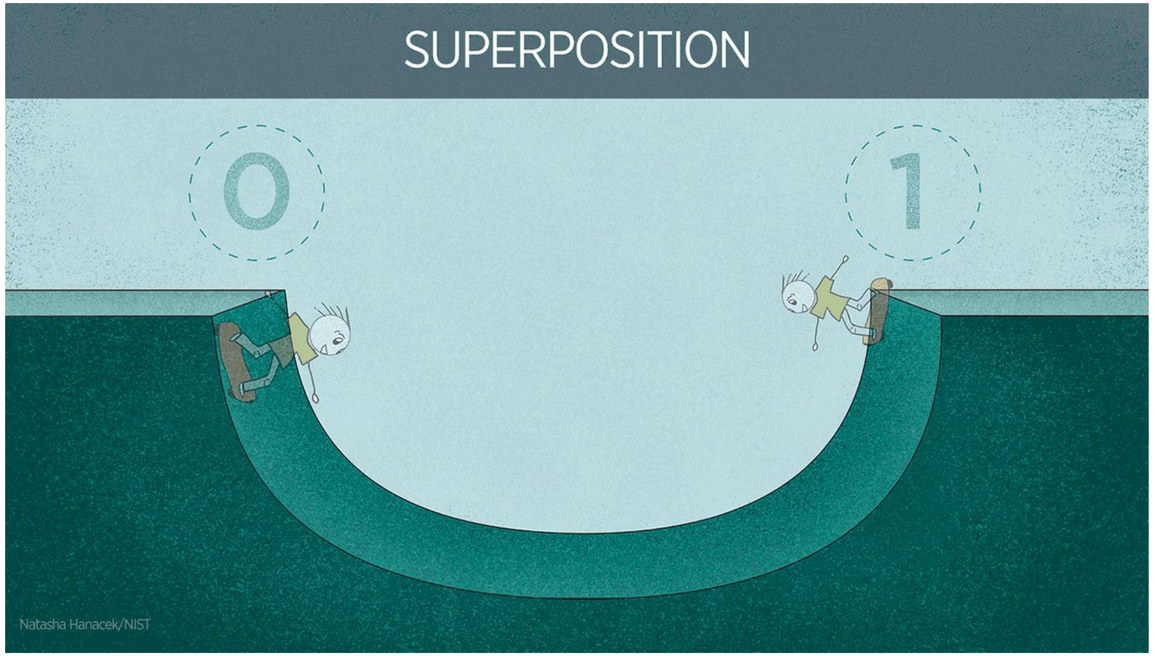


No cloning theorem : Minute Physics

help from RSA Conf 2019

Measurement not so weird

- Reads the value
- BUT after measuring it, the qubit is what you read (no more superposition)

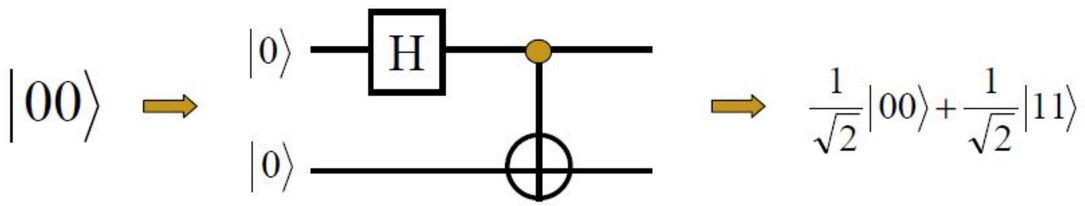


- A property that is not measured need not exist.
- Measurement is an active process that alters the system being measured.

Image Credits: somewhere in nist.gov

Entanglement is truly weird!

- It is the most powerful and least understood behavior of quantum mechanical physical systems.
- It is the driving engine behind all quantum algorithm implementations,
  - quantum teleportation
  - quantum key distribution
  - superdense coding
  - quantum error correction.
- If you read the first qubit, you know the value of the 2nd one,
  - Even if, after entangling them, you move them to different galaxies!



“Its almost romantic how entangled qubits remain connected no matter the space between them”

Image Credits: from one of the boring references (see reference section)

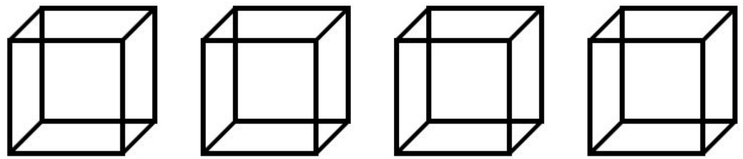
Entanglement less weirder...

- Raul went to Diya and asked her for a mango tea and a green tea packet.
- She gives him 2 identical tea bags

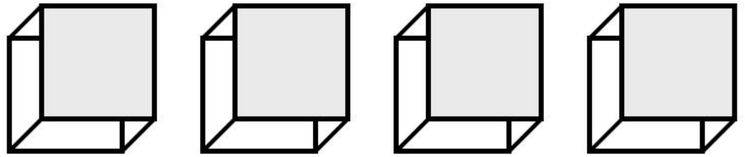
- Once he uses one and tastes it, he will immediately know what flavor the other tea bag is of!
- Here 2 tea bags were initially entangled!

Image Credits: somewhere in google

- Consider a 4 cube system drawn without a particular frame of reference as shown



- The moment I show you a cube south face brought forward :



- Your mind will immediately be fixed to that shown frame of reference to all cubes.

Image Credits: from one of the boring references (see reference section)

Power of Entanglement

- If a group of qubits is entangled, it's impossible to describe collective state by talking about the states of individual qubits.
- With 3 entangled qubits, the state will be a super positions of :

$$\alpha|000\rangle + \beta|001\rangle + \gamma|010\rangle + \delta|011\rangle + \varepsilon|100\rangle + \zeta|101\rangle + \eta|110\rangle + \theta|111\rangle$$

$$|\alpha|^2 + |\beta|^2 + |\gamma|^2 + |\delta|^2 + |\varepsilon|^2 + |\zeta|^2 + |\eta|^2 + |\theta|^2 = 1$$

- If a set of n qubits is NOT entangled, the state can be expressed compactly with 2n coefficients
  - for each of n qubits, coefficient of 0 and coefficient of 1

- If they are entangled, it takes 2^n coefficients
  - for each of the 2^n states, coefficients of that state
  - therefore holds a superposition of 2^n different values at the same time

- Without entanglement QC would be no more powerful than Classical Computer

Consolation for Entanglement weirdness

“If you think you understand quantum mechanics, you don’t understand quantum mechanics.”

— Richard P. Feynman

A Cost-Effective Entangling Prefetcher for Instructions

1st Alberto Ros
Computer Engineering Department
University of Murcia
Murcia, Spain
aros@ditec.um.es

2nd Alexandra Jimborean
Computer Engineering Department
University of Murcia
Murcia, Spain
alexandra.jimborean@um.es

Teleportation

- Unfortunately Teleportation in Quantum Computing as not this cool 😔
- Teleportation is more related to transfer of information rather than transfer of matter.

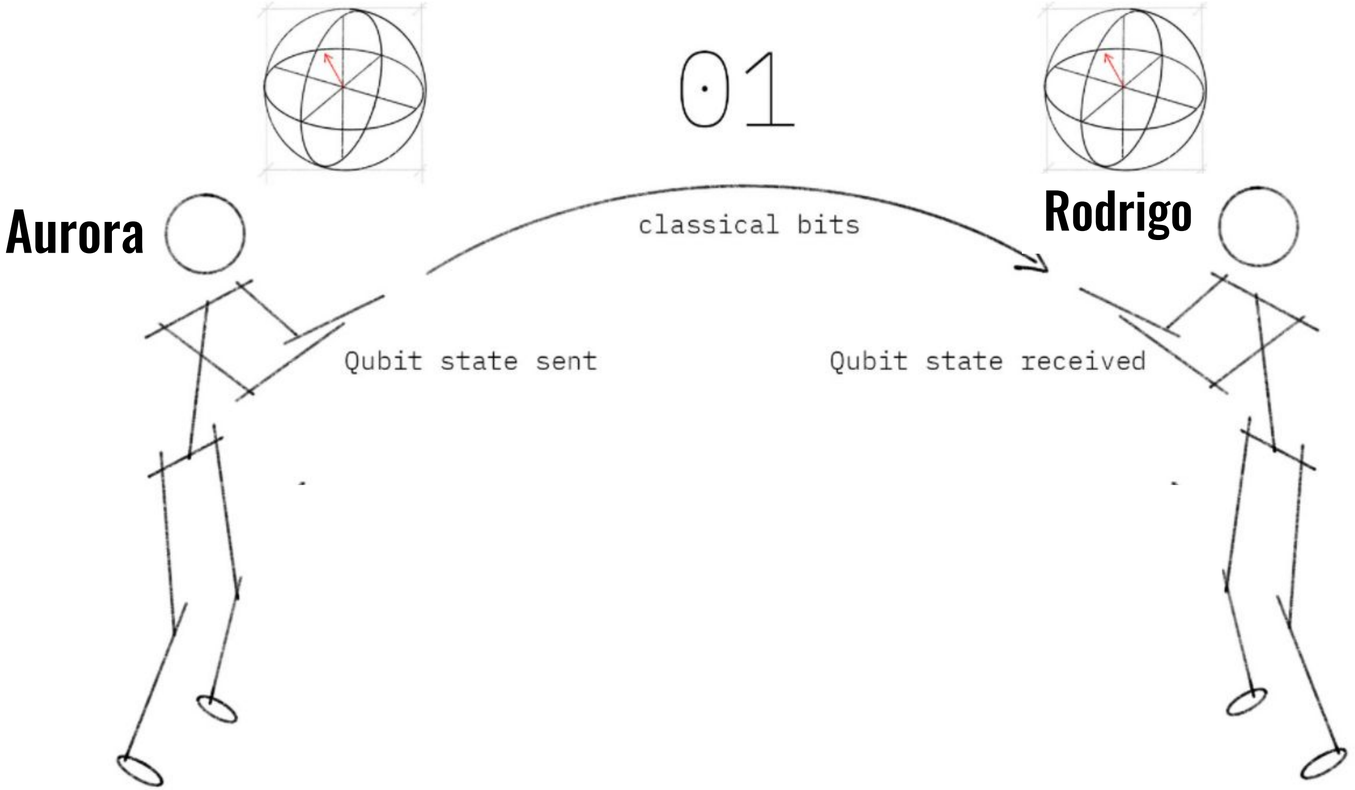
Image Credits: somewhere in marvel gifs

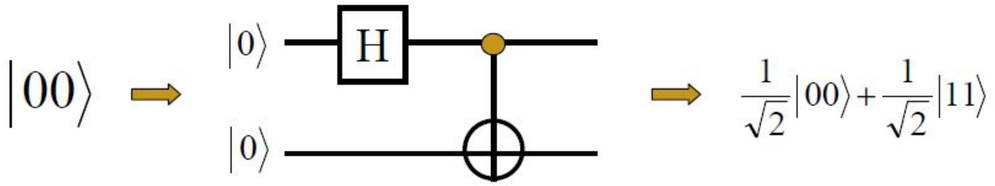
Quantum Teleportation

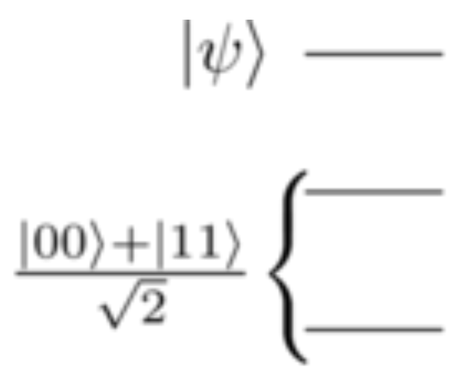
- Consider a situation... (hypothetically speaking!)
  - What's app is dead and so are other simple means of sending info,
  - You can just send some really basic bits in a very quite channel nothing more
  - ...

- So Aurora has to send some quantum stuff info to Rodrigo but how?
  - Just send the amplitudes?
  - Give up and be silent?

$$|\Psi\rangle \quad = \quad a|0\rangle + b|1\rangle$$







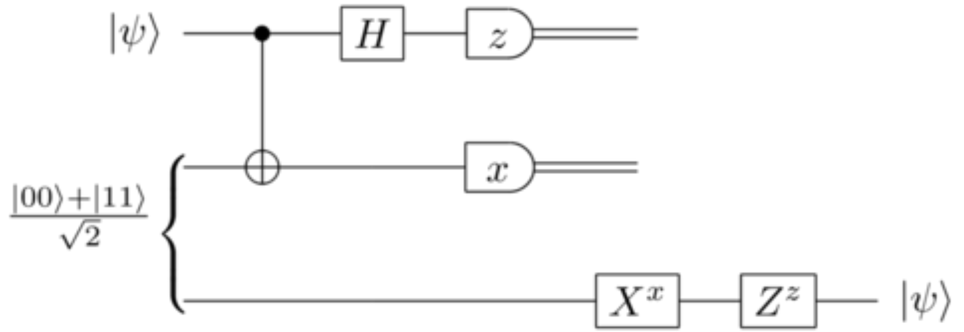


Image Credits: somewhere in QISKIT

Does teleportation enable faster-than-light communication?

Few Crazy solutions using Quantum Computing

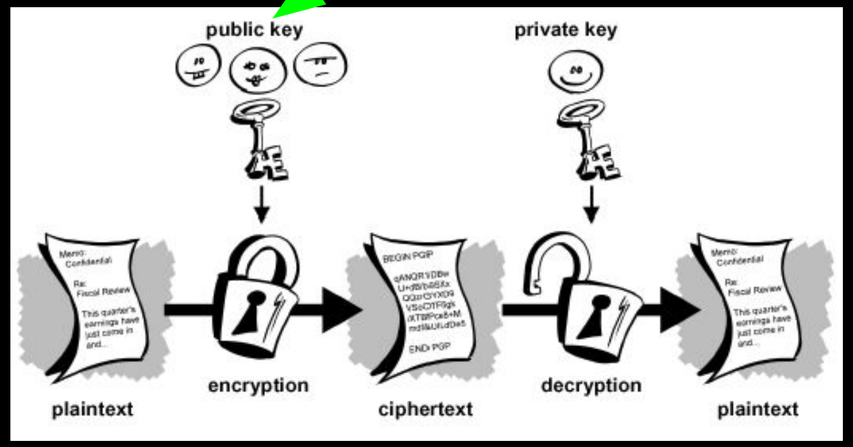
Shor's Algorithm

Prime Factorization Problem: Given an Integer N, find its prime factors

15 = 3 x 5 9999999942014077477 = 3162277633 x 3162277669

Time to solve:

$$\begin{cases} 2^{O[\ln(N)^{1/3}]} & \text{classical} \\ O[\ln(N)^2] & \text{quantum} \end{cases}$$



Grover's Algorithm

Unsorted database search: Find a given element in a database of size N

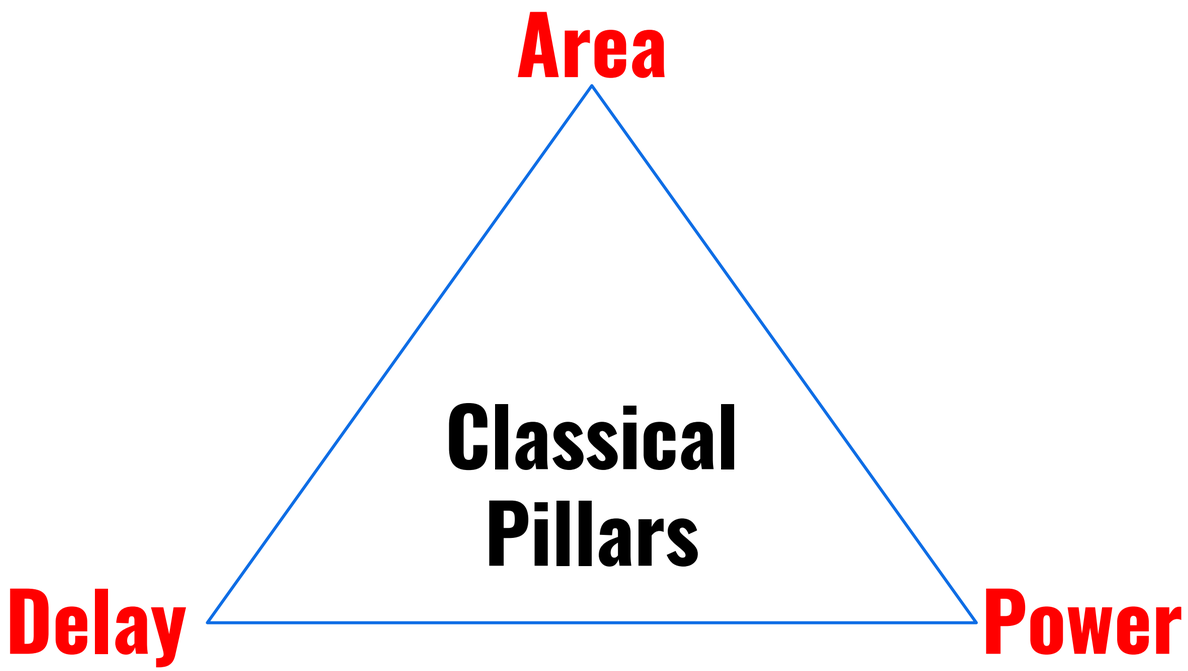
Time taken to solve:

$$\begin{cases} O(N) \\ O(N^{1/2}) \end{cases}$$

Classical

Quantum

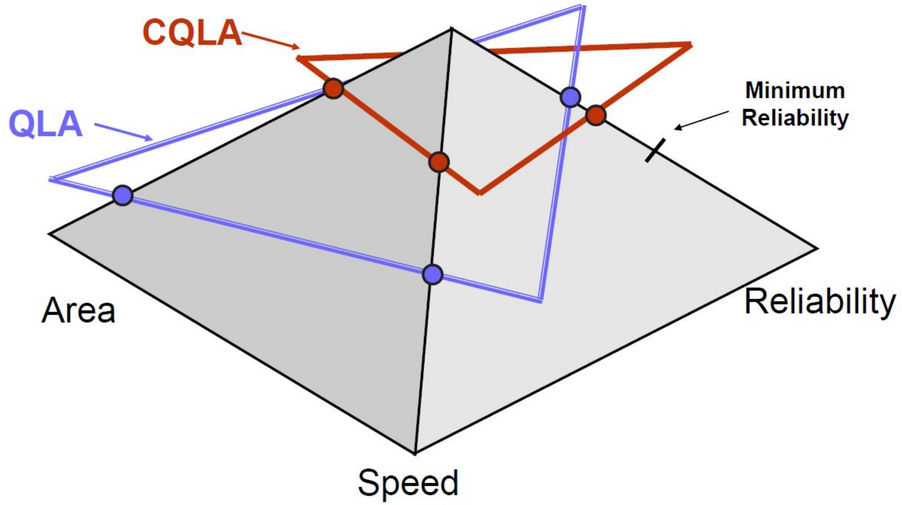
Why then are any one not building these techniques at a scale!?



- Resilience
- Security
- ...

Image Credits:
1. from one of the boring references (see reference section)
2. one of those cult movie reddit threads

QC Pillars



Why not power?
At this point a quantum computer needs about ~ 12 Megawatts.

A 100 of those machines could send us "Back to the Future"

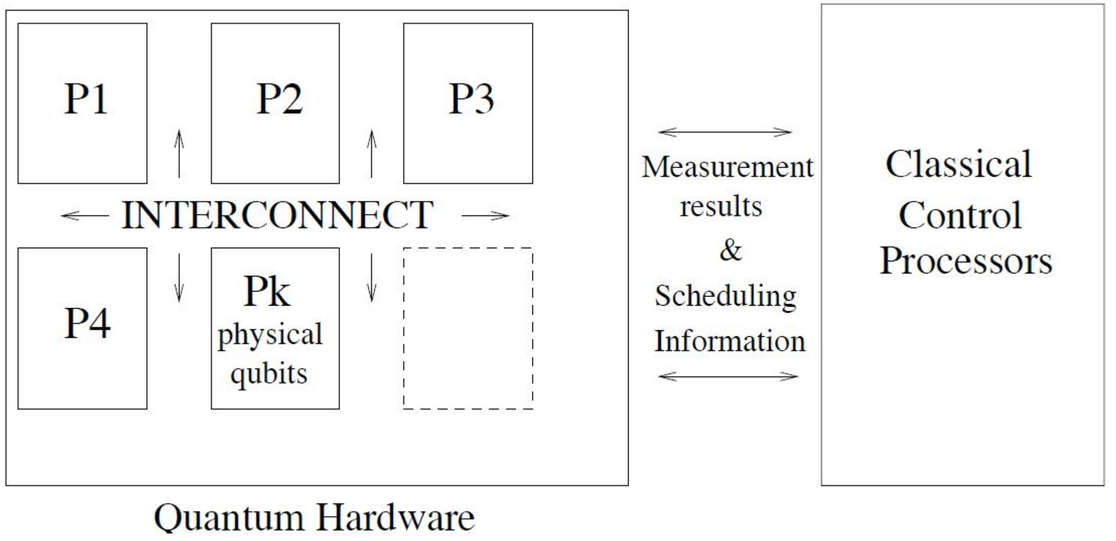
Great Scott!

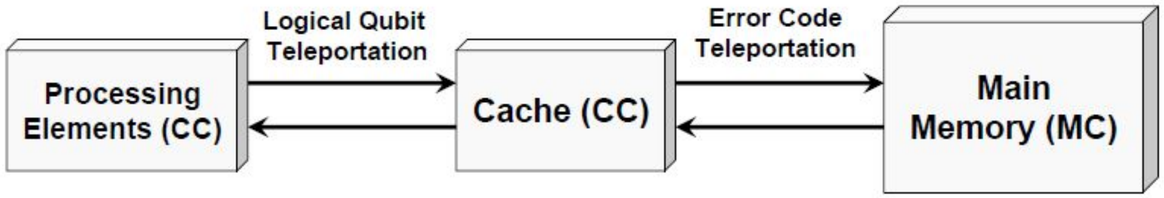
“ The average person can only keep 7 (plus or minus 2) new items in their working memory.”

Image Credits: Jon Labonski UX design

Image Credits: google, Font Credits: fontmeme.com

- Quantum Memory Hierarchy
- Code Hierarchy
- Quantum Register File
- QASM
- Quantum Compiler Design
- …
- More Crazy Stuff





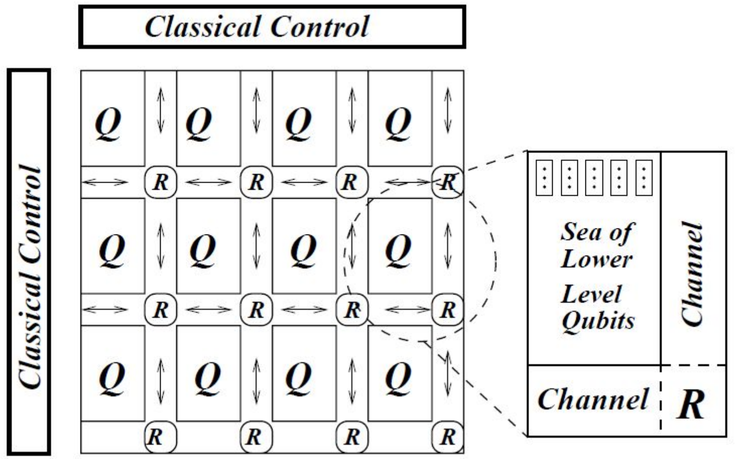
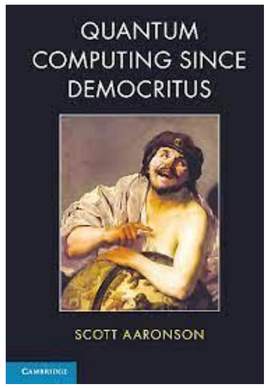


Image Credits: from one of the boring references (see reference section)

References

- Quantum Computing for 
- The Book by Scott Aaronson -> 

- Quantum Computing for Computer Architects Synthesis Lectures
- Quantum Country and IBM
- Reddit threads for QC Nerds!

Image Credits: google and scott's blog

Thanks!

Any questions?

You can find (and not find😎) me at:
nitesh8998.gitlab.io

Image Credits: Google