Quantum Computing
Implications and Potential Impacts on Machine Learning

Lesson 10 – Section 4

Agenda

What is Quantum Computing
What can it be used for
What tools exist today

What is Quantum Computing?

We first must start with a clear understand of classical computing or CC

CC is based on a binary system of 1s and 0's

To encode information we use bits which are either on of off (1 or 0)

'A' for example is 065 or 1100001 and 'a' is 097 or 1000001

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CC Review

In CC bits formed bytes (8 bits)

These can be combined into larger and larger collections of information:

- –kilobytes (KB) 1000 bytes or 10^3 bytes or 8K bits
- –megabytes (MB) 1000KB
- –gigabytes (GB) 1000MB
- –terabytes (TB) 1000GB
- –petabytes (PB), exabytes (EB), zettabyte, (ZB), yottabyte (YB)... etc.

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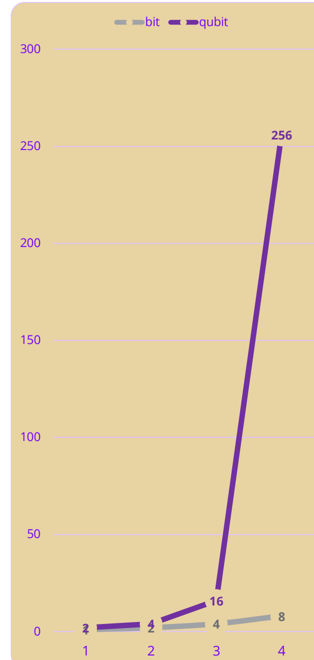
Difference between a quantum speed up and current microprocessors

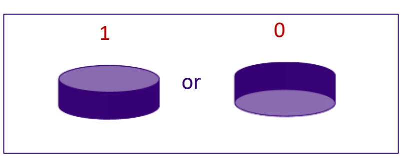
- We've been increasing the number of bits we can process against from 8-bit to 16, 32 and now 64-bit processors.
- Theoretically, quantum is x^2 an exponential speed up.

bit	qubit
1	2
2	4
4	16
8	256
16	65536
32	4.29E+09
64	1.84E+19
128	3.4E+38

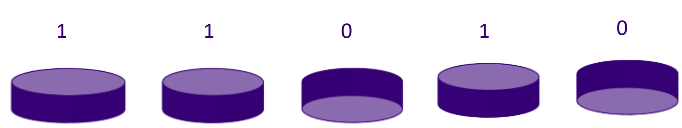


Binary Representation vs. Quantum

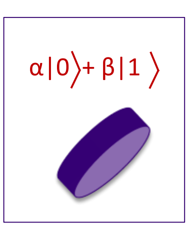
Classical Bit



One out of 2^N Possible Permutations



Qubit



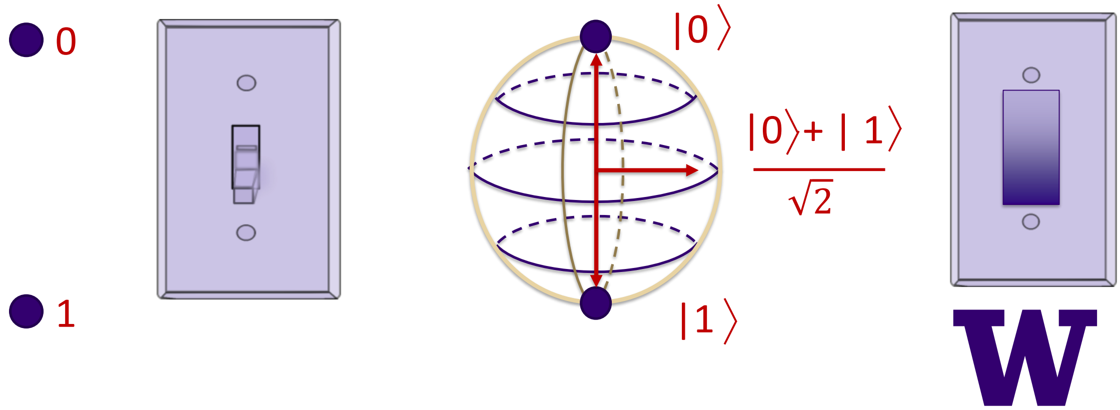
<u>ALL</u> of 2^N Possible Permutations

$a_1|0000 \ldots 0]+a_2|1100 \ldots 0]+a_3|1110 \ldots 0]+a_3|1111 \ldots 1]$

States of a Qubit

Classical Bit

Quantum Bit



Parallel Computing at the Atomic Level

Qubits increase storage capacity exponentially

Can do operations on all superpositions…like parallel computation only much better

- One math operation on 2^n numbers encoded with n bits requires 2^n steps or 2^n parallel processors
- The same operation on 2^n numbers encoded by n qubits takes 1 step

This makes complex problems much easier

Important Concepts for Quantum Algorithms

Superposition – alignment and initialization

Quantum interference

– constructive vs. destructive

Entanglement

Wavelets

Measurement

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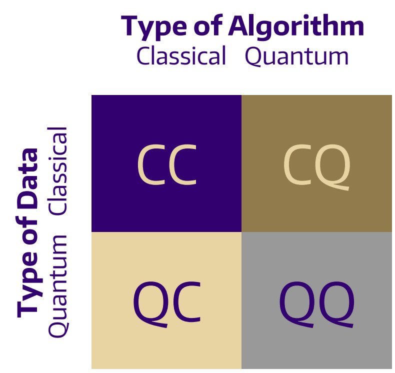
Will Quantum replace Classic Computing?

Will Quantum Replace Classic Computing?

Not all problems are applicable to quantum computing

Many, if not most computing can easily and efficiently be conducted

As we do more, we'll find even more interesting ways to use them, but for now, classic computing is safe from extinction



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How QC Works

We determine the number of qubits needed

- Initialize the qubits by aligning them to the same superposition state

Use quantum algorithms to "entangle" them into a common pool of potential interactions

- Use interference to cause quantum state changes—that hopefully reinforce the signal and reduce the noise.

Lastly we use algorithms to measure these states

Hardware Challenges

Qubits are fragile—they are susceptible to noise

- Breakthroughs in "topological" qubits are trying to address this by separating the memory from the calculation—storing it "globally"

Qubits also require extreme cold—colder than deep space (455°F) at -459°F—near absolute zero

- Quantum computers they are building need to be kept at -452°F
- Cryogenic systems are needed in order to maintain these temperatures

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Software Challenges

Familiarity with "cloud" computing is helpful

Quantum computing is unlike classical computation systems and requires its own language

- Because of the difference in the way that qubits work and encode information, it's a bit like programming a "tide pool" of qubits—there's a lot of complexity and power in that capability

Today you can access SDKs that allows a developer to remotely access a simulated quantum computer

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Summary

- >Quantum hardware, software and applications will be significantly different than classical systems.
- >They are not ubiquitously better at all computing applications
- >Eventually we could choose a Quantum accelerator as easily as we select GPUs and FPGAs
- >This area is changing rapidly and will radically change the way we do computing in the future

Emerging Trends

Lesson 10

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