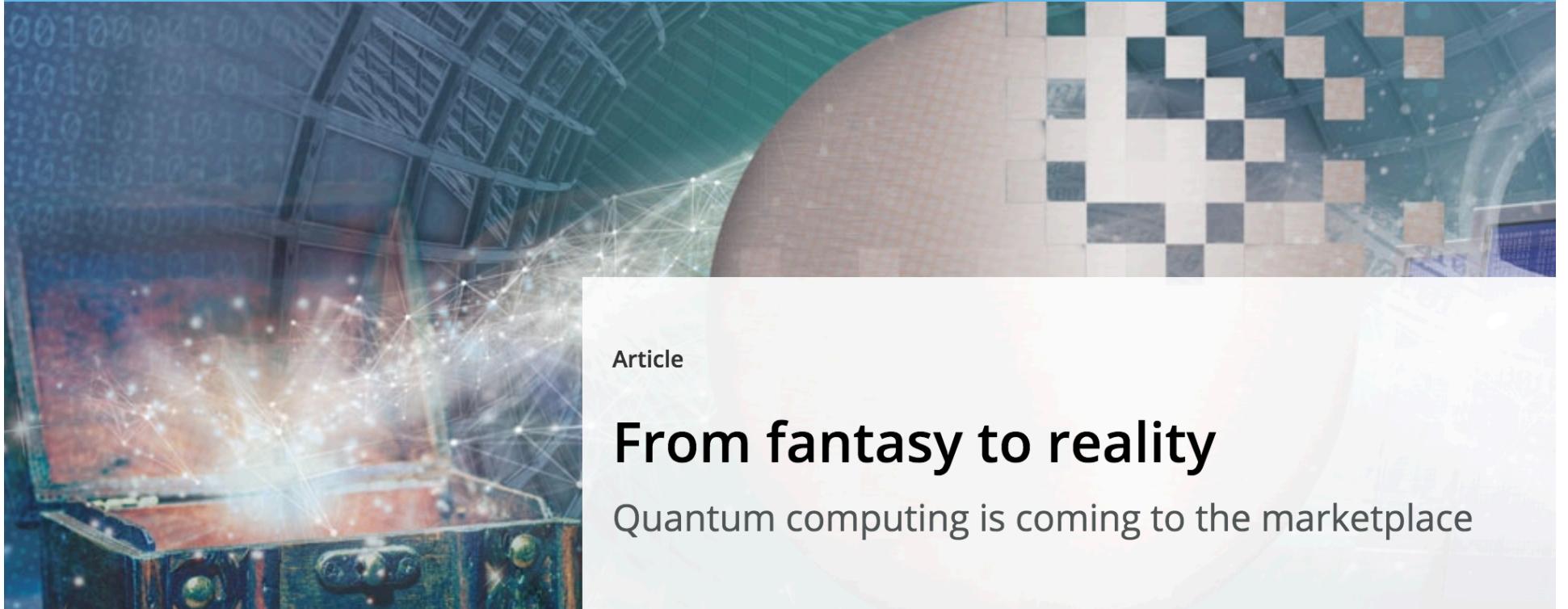


EXTENDING A DISTANCE-BASED CLASSIFIER IMPLEMENTED AS A SINGLE QUBIT PERCEPTRON



X39.81





Article

From fantasy to reality

Quantum computing is coming to the marketplace

Related

[David Schatsky, Ramya Kunnath Puliyakodil](#)

April 26, 2017

Accenture Labs

Innovating with Quantum Computing

Enterprise experimentation
provides view into future of
computing



OUR THINKING > THE OUTSIDERS >

THE OUTSIDERS

QUANTUM COMPUTERS: SOLVING PROBLEMS IN MINUTES, NOT MILLENNIA

FEB 2018



ONE GROWTH AREA
HE'S WATCHING
**QUANTUM
COMPUTING**

Quantum Computing Applications: A Patent Landscape Report



Patinformatics, LLC®
Patent Landscape Reports

Quantum Computing is Global

- Over and over we see five year predictions
- All of the big players are in on the action
 - IBM (50),
 - Google (73) ,
 - Microsoft (software)
 - Nokia (bought Bell Labs, NJ, ?)
 - Ali BaBa (China)
 - D-wave (2000 QA)
 - Rigetti (19)



Quantum Computing is Big Money

- Current machine cost: **\$15,000,000**
- The payoff is expected to be huge
 - 3% of the world's total energy used to make fertilizer (Habor process from 1913)
 - Bacteria can make ammonia for free using a protein they make (also free)
 - Quantum chemistry should solve this



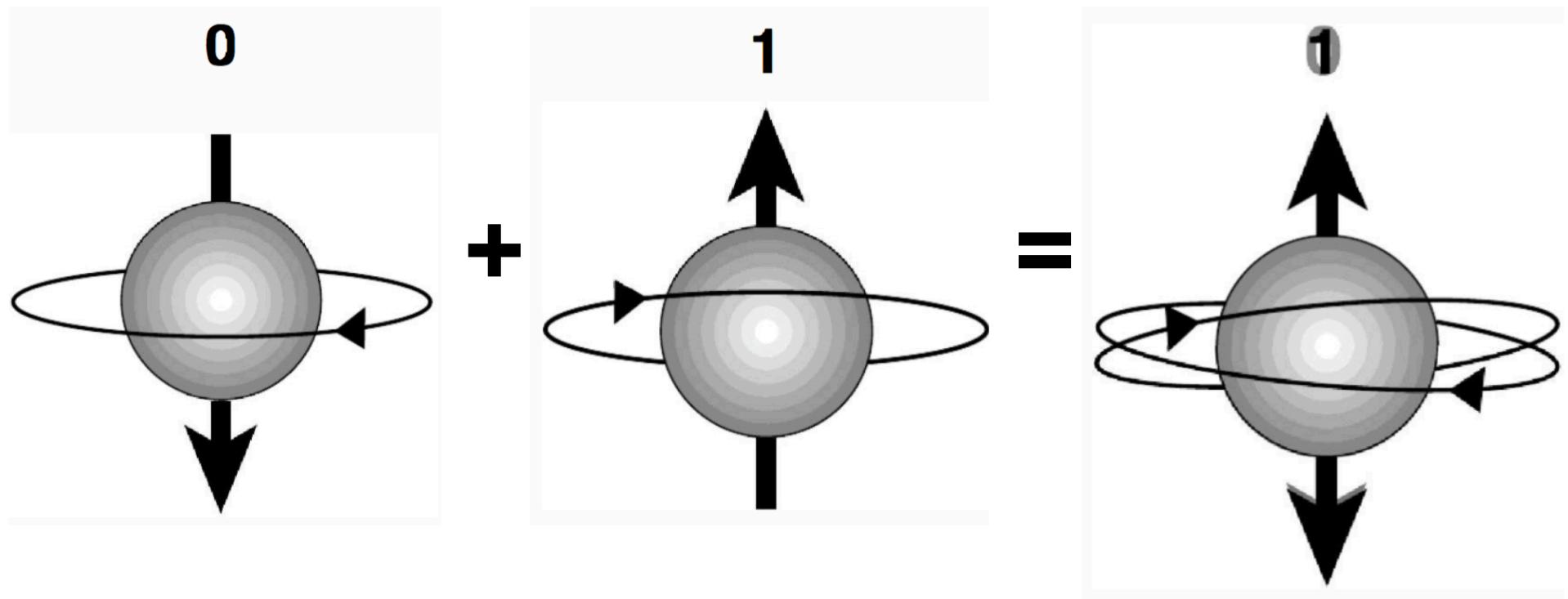
What is Quantum? What is Computing?

- Quantum mechanics is it's own thing.
- Many Worlds Interpretation
- Jung's synchronicity (Pauli-Jung consciousness)
- The Secret
- Deepak Chopra



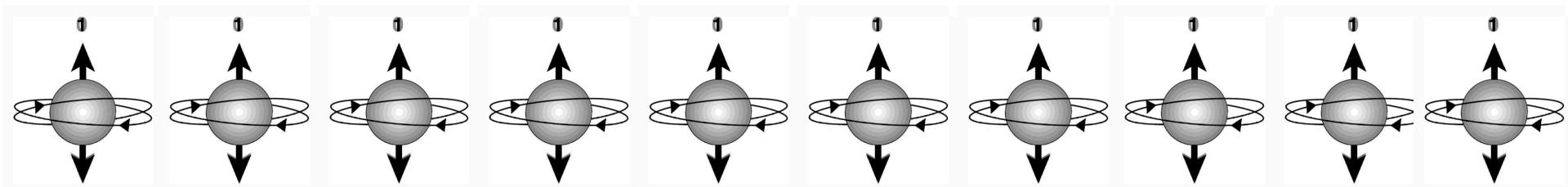
What is Quantum?

- Quantum bits, or qubits (not like coin flips)



Binary Digits to Quantum Bits

- However, 10 qubits can store all integers from 0 to 1023 ***at the same time***



- 1 Tb of data can be stored in 40 qubits

This is why simulating a quantum computer is hard !

Binary Digits to Quantum Bits

- 40 qubits need 1 Tb of RAM to describe their full state – QRAM?



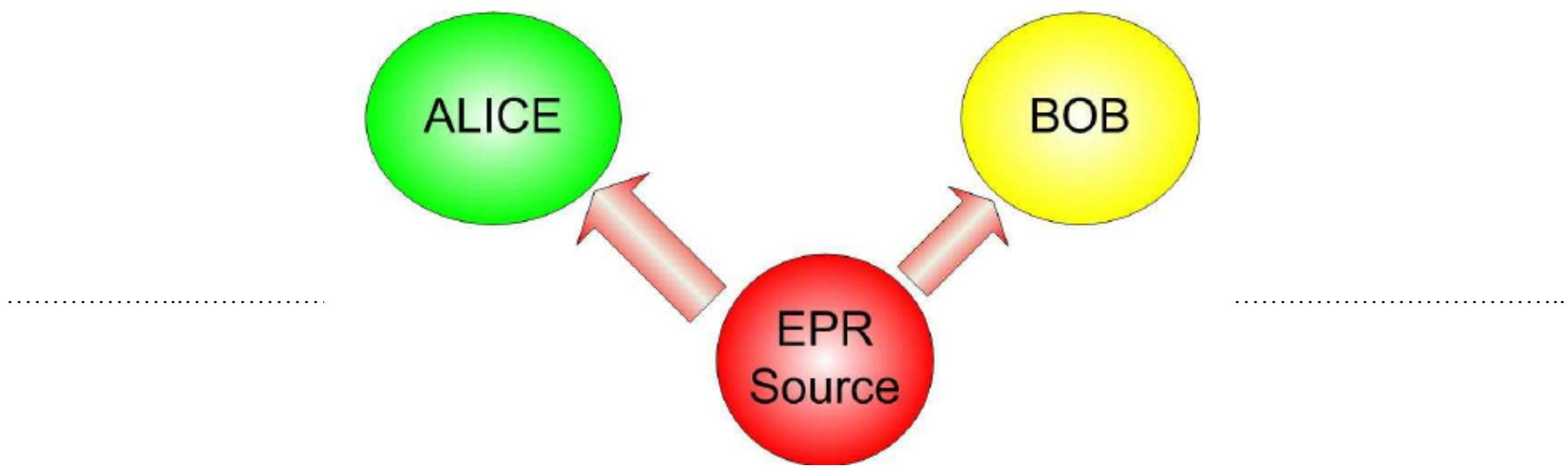
Binary Digits to Quantum Bits

- 40 qubits need 1 Tb of RAM to describe their full state – QRAM?
- Qubits are themselves probability distributions, properly harnessed, they could speed up calculations of many simultaneous probability processes
 - Training Deep Boltzmann machines (speed)
 - Exact log objective function is P-hard (accuracy)



Entanglement

- Qubits can be correlated with each other
- Note that bits cannot
- We call this correlation “**quantum entanglement**”



Wait, there's more

- Qubits can be correlated with each other
- Note that bits cannot
- We call this correlation “**quantum entanglement**”
- Importantly, We can use entanglement to model data structures (later in this talk)



The Dynamic Duo

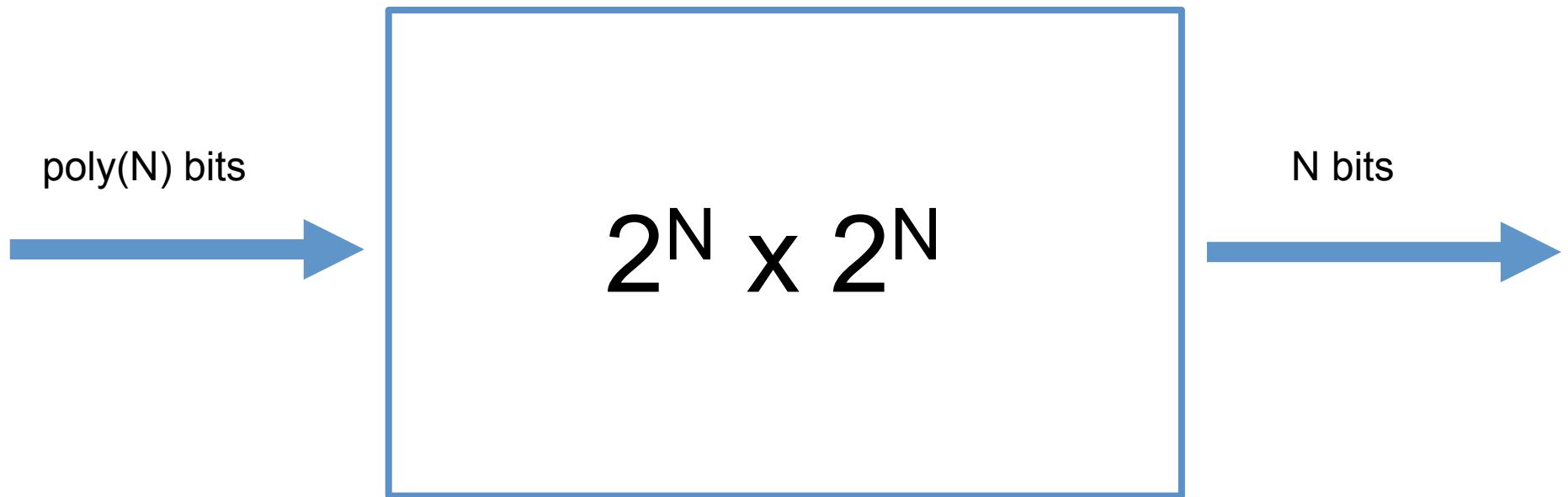
- What are the two properties of a qubit we want to exploit in computation?

If it sounds too good to be true

- Measurement destroys quantum states
 - Get one read out only
- Qubits are probabilistic
 - You only get one answer, not all
- Real world devices are colder than space
 - Expensive
 - Errors creep in (decoherence)

Formulating a problem

- Pipeline problem
 - “Big-memory small pipe”



Why I ignore the pipeline

Mapping classical problems to the quantum

Understanding how qubits can be used to do statistics in Hilbert space



a quick quantum classifier

K-Nearest Neighbors

Robust

Simple to explain

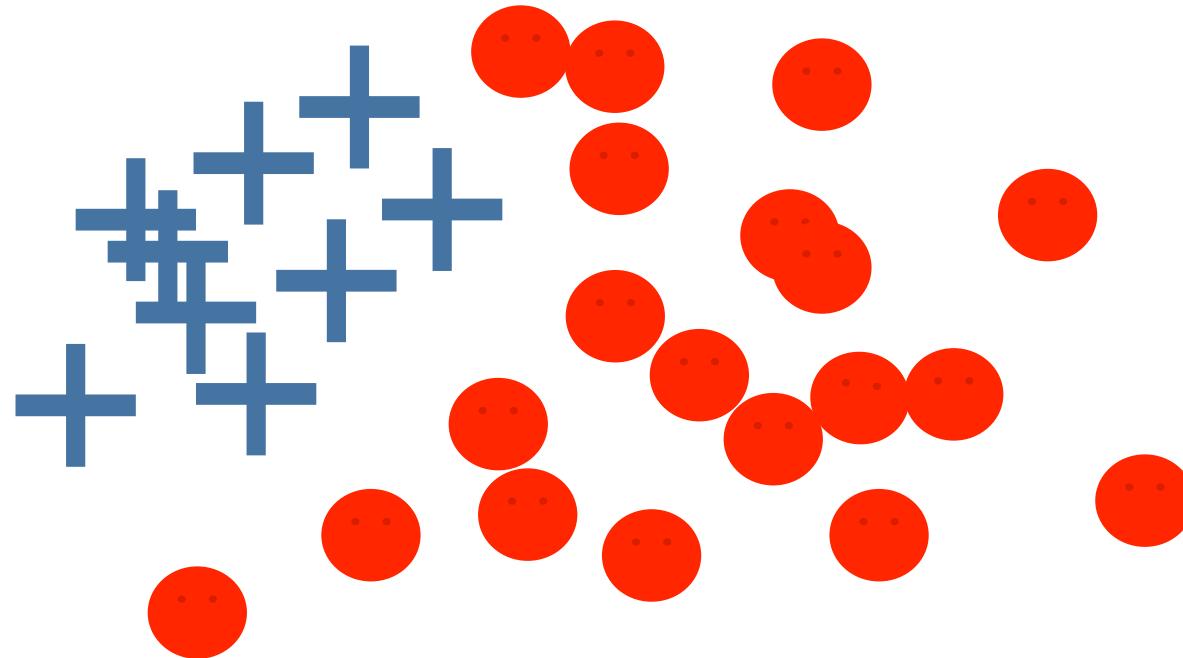
Intuitive

Math is pretty simple



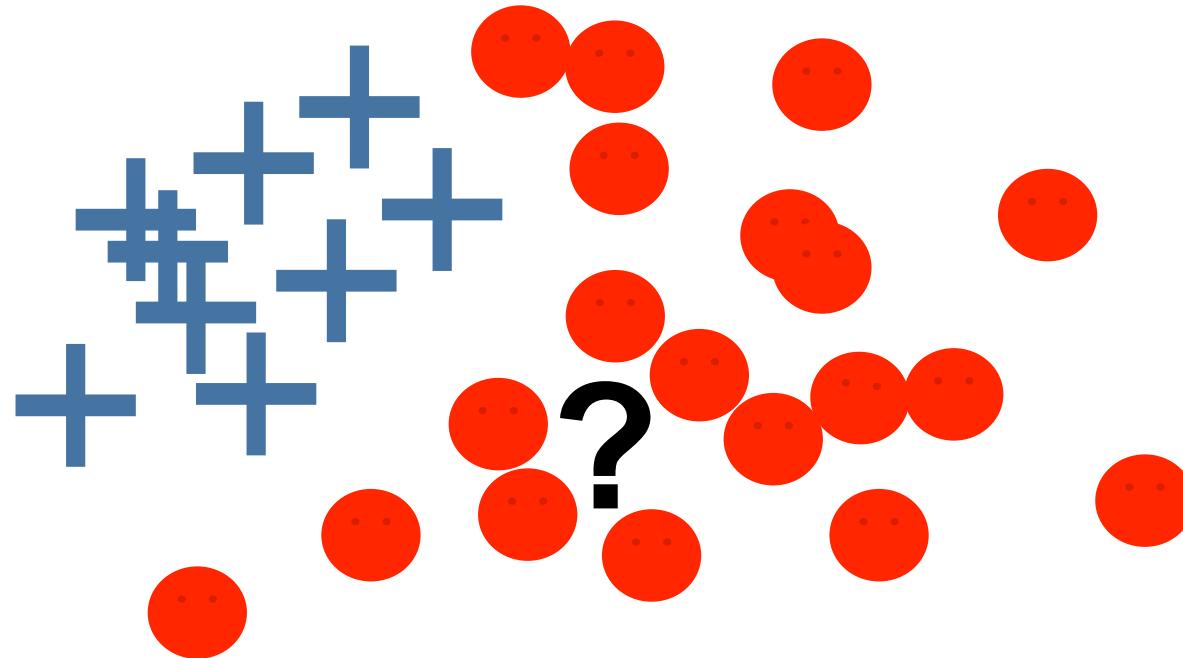
Fences make good neighbors
don't

K-Nearest Neighbors in a nutshell



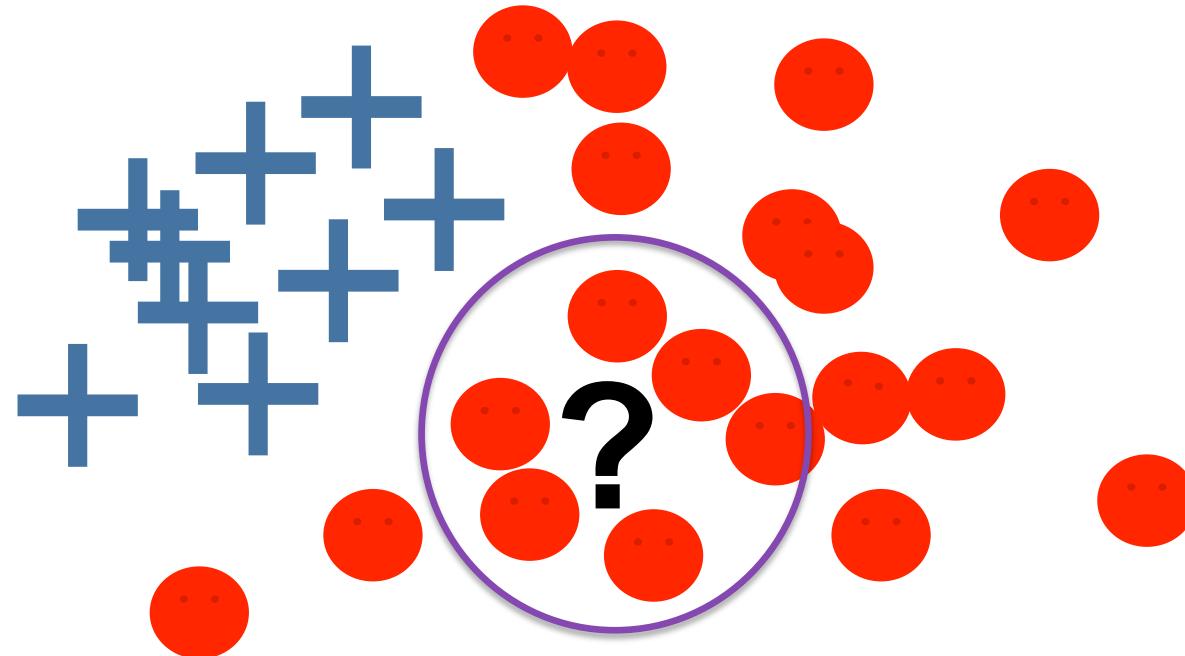
Fences make good neighbors
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K-Nearest Neighbors in a nutshell



Fences make good neighbors
don't

K-Nearest Neighbors in a nutshell



a quick quantum classifier

K-Nearest Neighbors

Robust

Simple to explain

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HARDLY EVER USED



NATIONWIDE CHILDREN'S
*When your child needs a hospital, everything matters.*SM

Fences make good neighbors
don't

K-Nearest Neighbors is S-L-O-W

We have to compute:

- 1) Read in data and vectorize
- 2) Calculate similarity vector (inner product)
- 3) Sort the inner product
- 4) Get k-nearest neighbors, then vote

Do these steps for every new data point



Fences make good neighbors
don't

K-Nearest Neighbors in a nutshell

- It doesn't generate a model, so every single prediction requires all steps
- * Also assumes that you know what features are useful for prediction



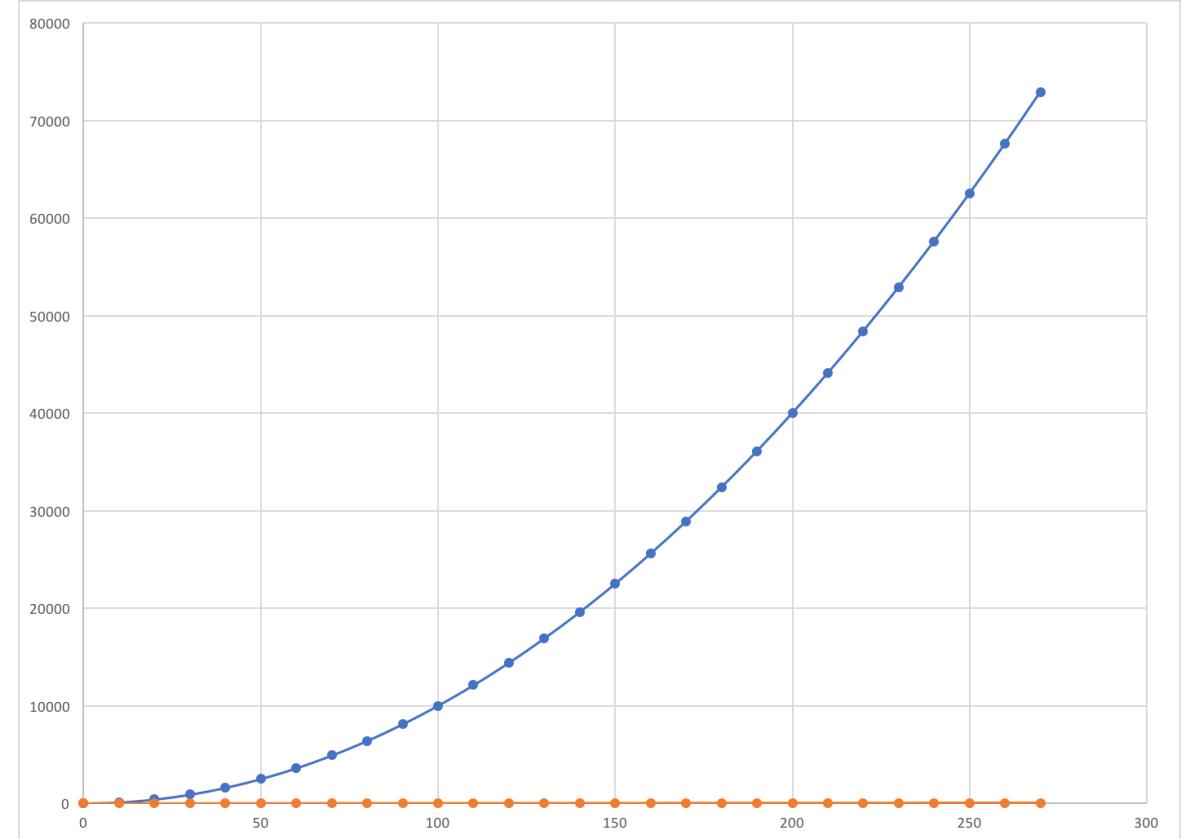
Fences make good neighbors don't

Speed

$\tilde{O}(n * m)$

V

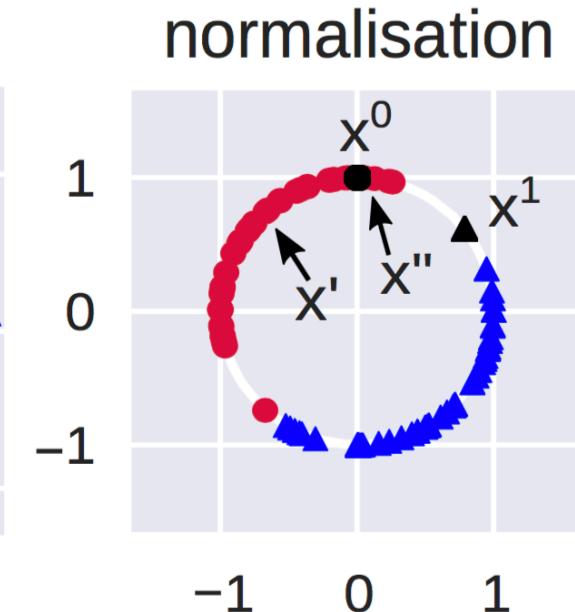
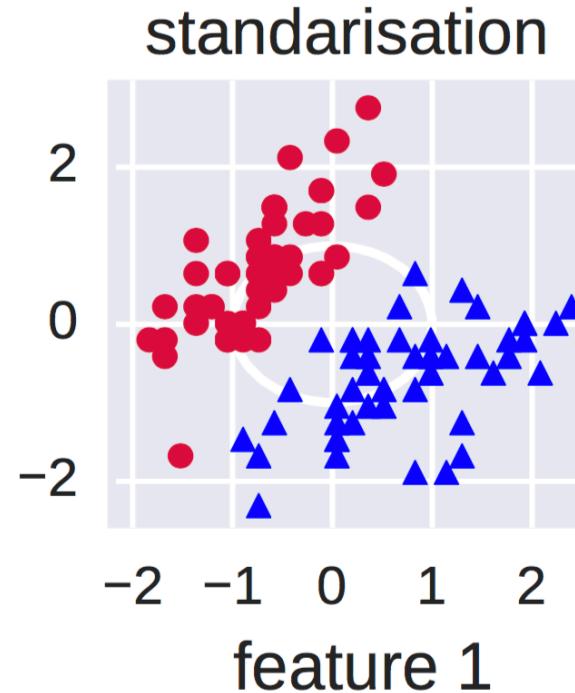
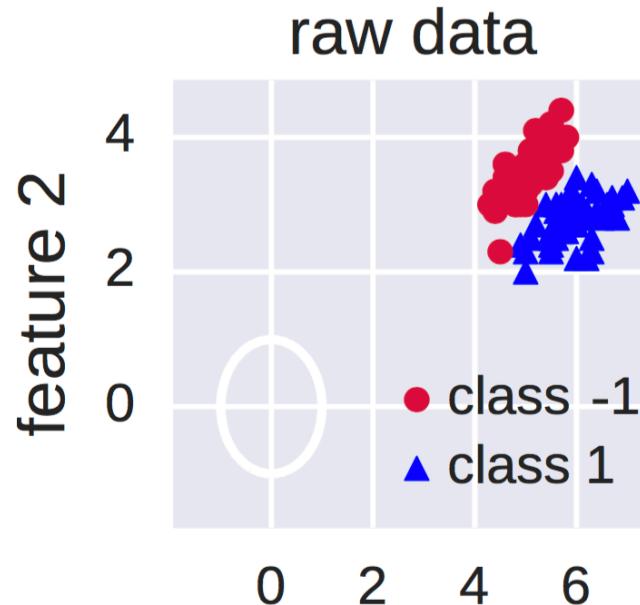
$\tilde{O}(\sqrt{n} \log(n))$



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Fences make good neighbors don't

How do we do quantum K-NN in real life?



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When your child needs a hospital, everything matters.

Fences make good neighbors
don't

How do we do quantum K-NN in real life?

Prepare superposition of training vectors

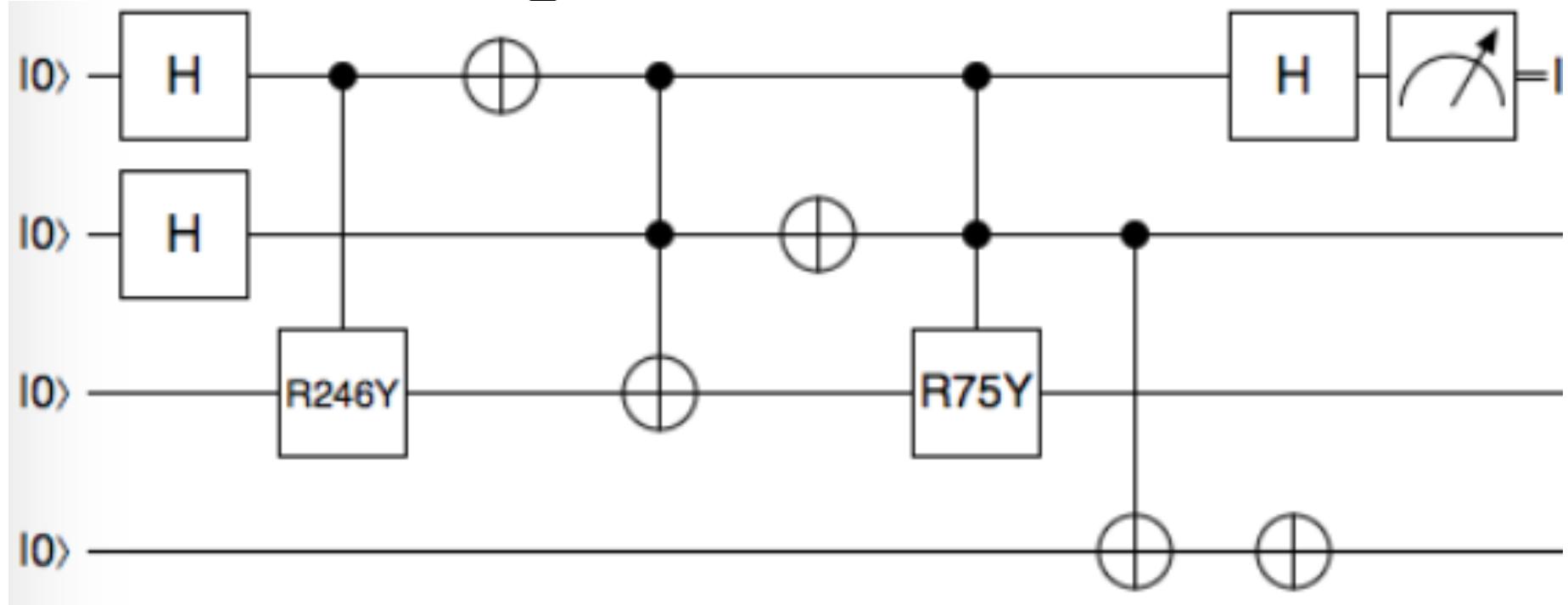
Prepare superposition of test data

Similarity via inner product two

No need to sort



Good neighbors



Superposition

Test data

Positive training

Negative training

Inner product

Measure

Good neighbors

Issues on the quantum end...

- Loading all the data in superposition is a hard task and it's slow
- Given the time to prepare a quantum state with the data, calculation speed may not be faster than a classical computer



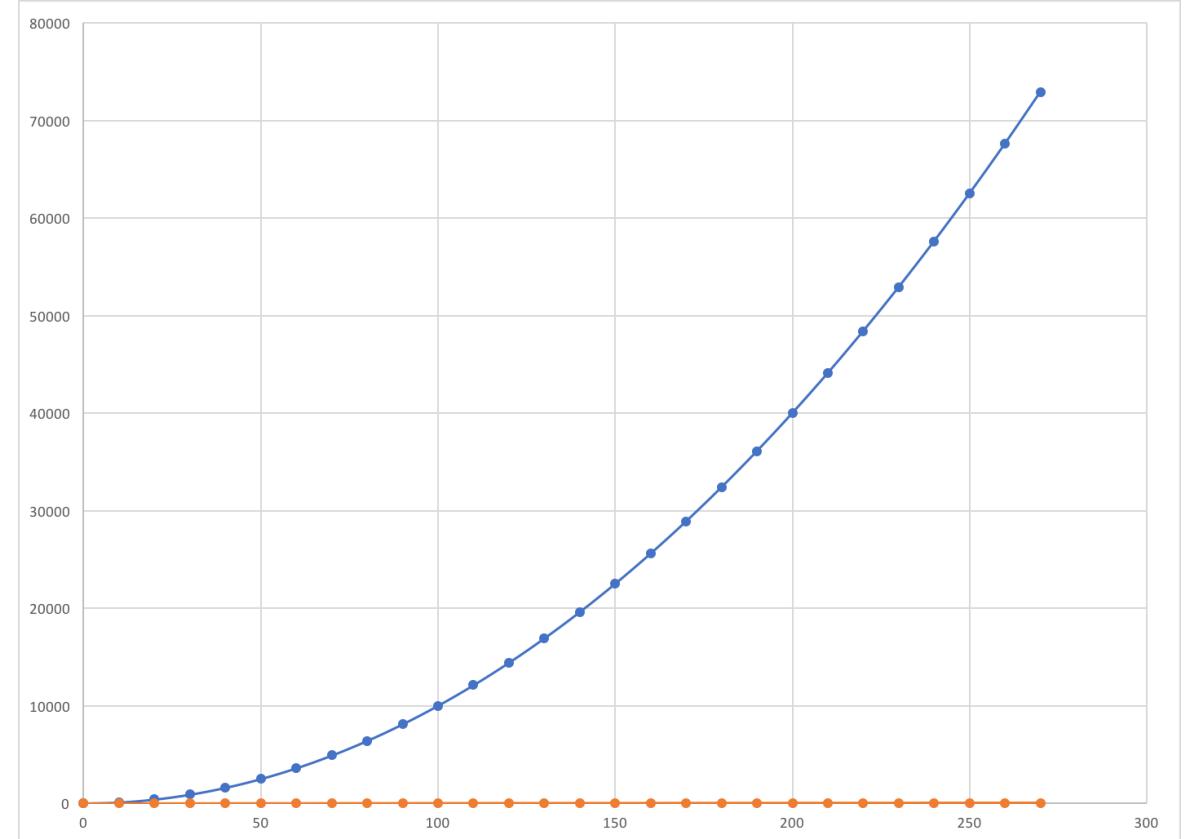
Fences make good neighbors don't

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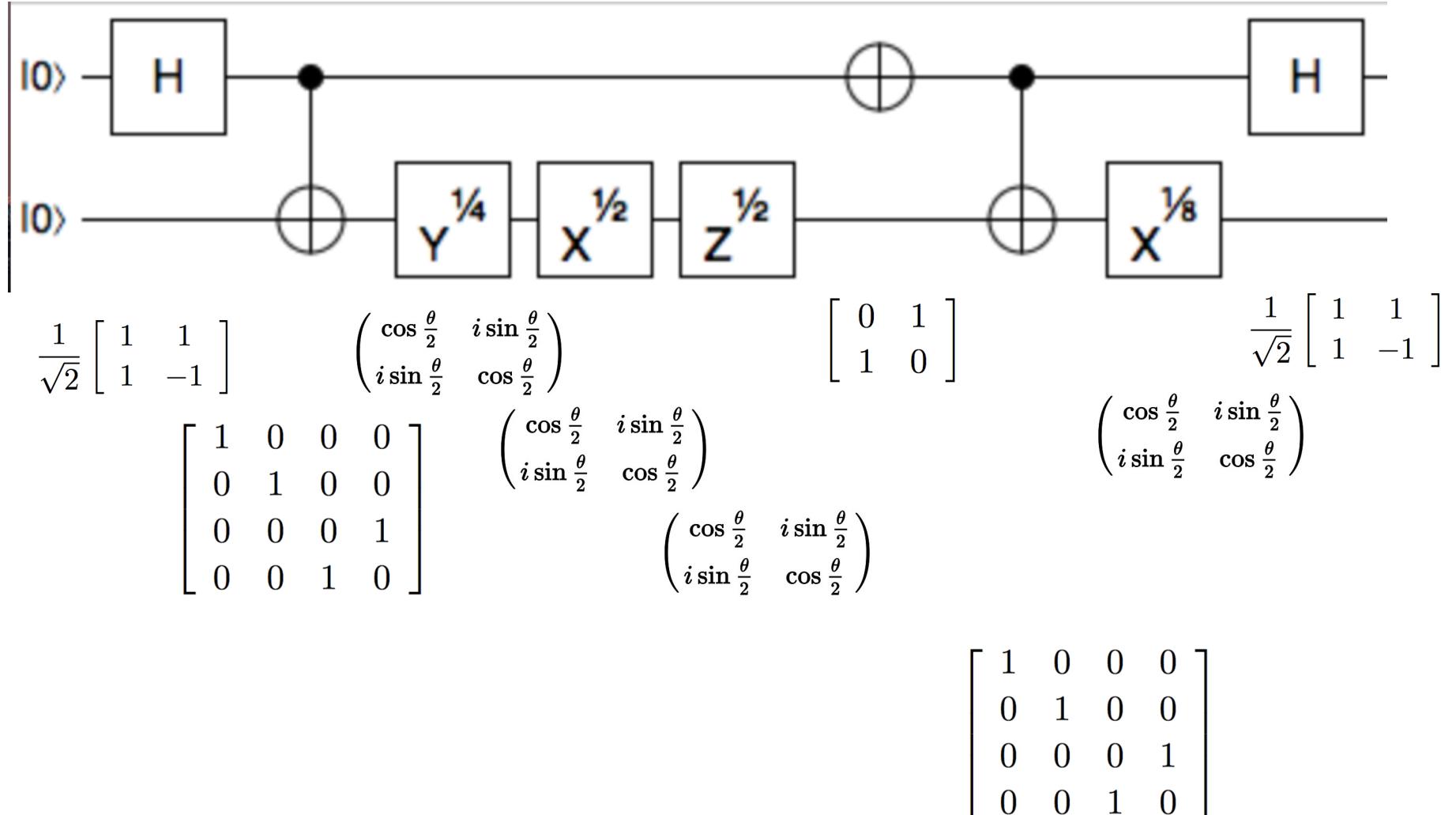
$\tilde{O}(\sqrt{n} \log(n))$



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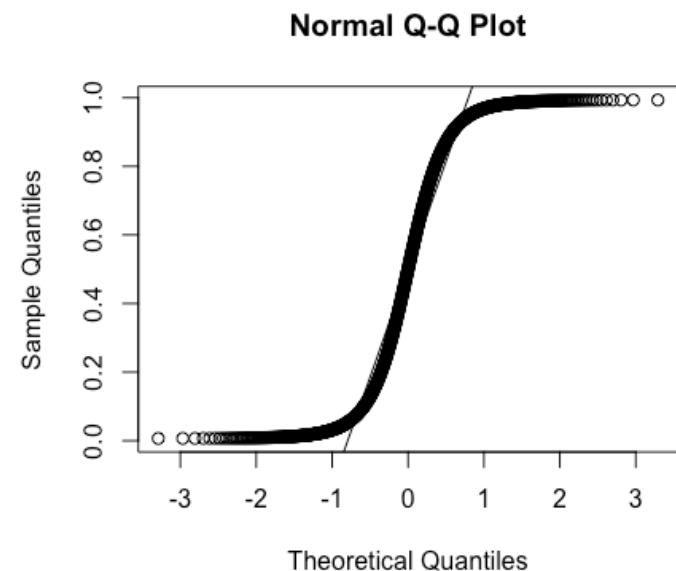
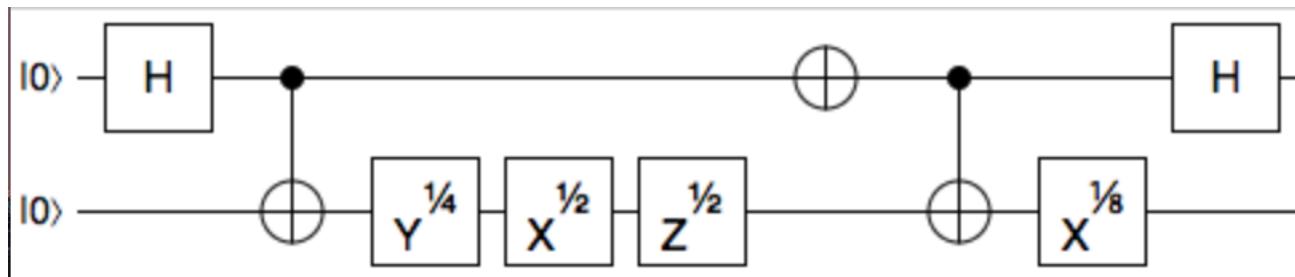
Now for some genetics

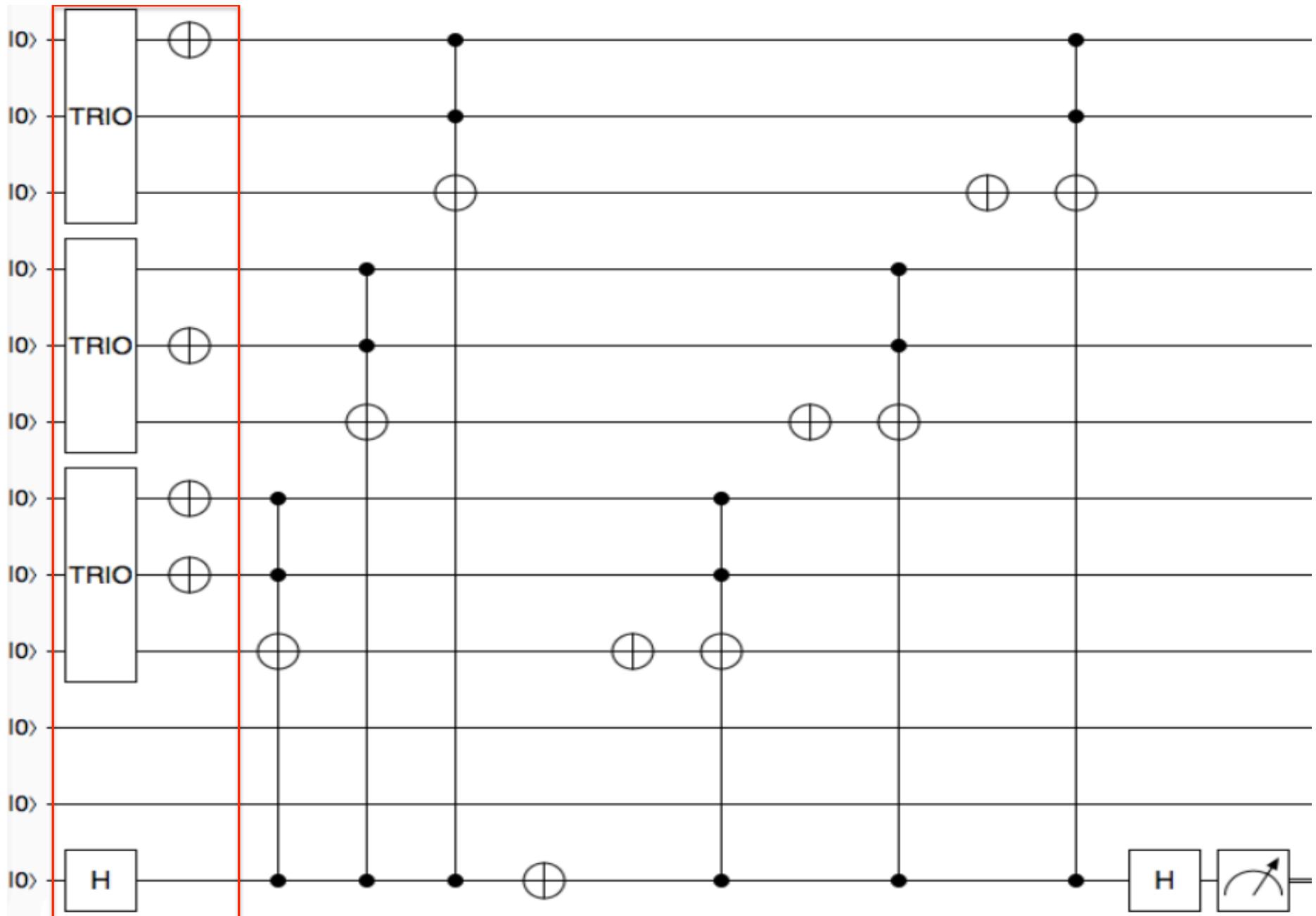
- Basic circuit diagram for this computation



Now for some genetics

- Basic circuit diagram for this computation





<http://algassert.com/quirk>

To sum up

Quantum computing is not just theory

- Algorithmic work suggests great promise
 - **Beware the pipeline problem**
- Applications to genetics
 - Machine learning (KNN, HHL, NN)
- The time to start preparing for quantum is now to soon, not five years from now.



Thank you!

Any questions?

