



Quantum Algorithms

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Power of quantum computing

- The obvious advantage of quantum computers over the classical computers is the ability to perform operations in **parallel**
- What does that **parallelism** mean?

Let's say we want to have an input, x , apply some operations to it and get an output.

Let the operations represented by an unknown function $f(x)$, which takes x as input. On a classical computer, we need to apply $f(x)$ to each input consecutively to have a mapping of the function and this increases the complexity.

On a quantum computer, the input (qubit) is already in more than one state – **superposition**

We can apply one operation $f(x)$ to one qubit and have different outputs!



Does this mean we can carry out multiple calculations in parallel such that four players can play Crysis, Doom, PUBG, Half-Life simultaneously on a single quantum computer?

Not quite...



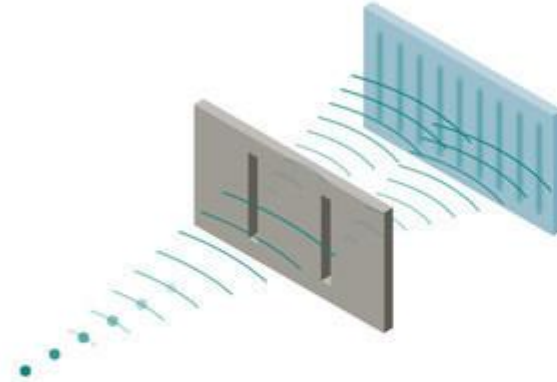
When a measurement is made on multiple qubit system, you have information on only one state.



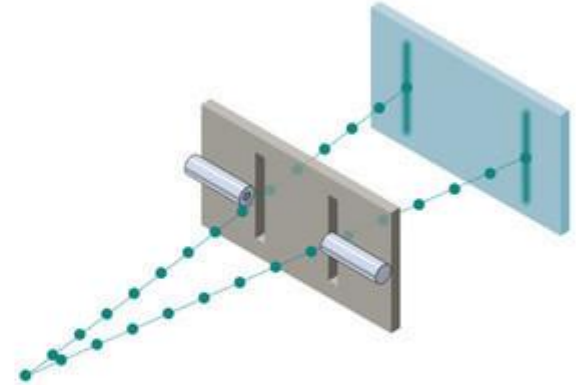
We can measure only one state and the other information is lost.

A central mystery

The classic double slit experiment seems to suggest quantum objects such as electrons are sometimes **particles**, sometimes **waves** – and we decide which guise they take



A stream of single electrons is fired at two slits and measured on a screen behind. An interference pattern forms, as if each electron were a **wave** that passed through both slits at once



Measure the electrons first at the slits, however, and you see individual **particles** passing through one slit or the other – and the interference pattern on the screen disappears

New Scientist

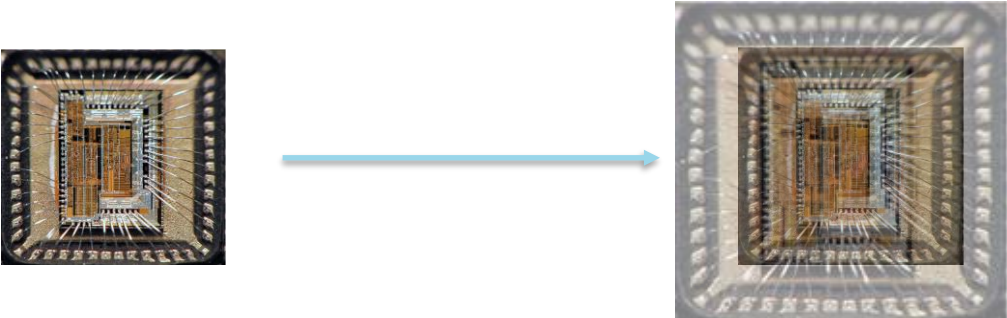
Collapse: Has quantum theory's greatest mystery been solved?

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In order to multiply the processing power of a CPU, you need to double the wires inside the CPU.



In order to multiply the processing power of a QPU, you just need one more qubit!



Deutsch – Jozsa Algorithm

- Not a practical algorithm, but a good demonstration of exponential speed up over classical computers.

Problem statement:

“You are given an unknown function $f(x)$. With the least number of operations, find if this function is balanced or constant”

$$f(0) = 0$$

$$f(1) = 0$$

constant

$$f(0) = 1$$

$$f(1) = 1$$

constant

$$f(0) = 1$$

$$f(1) = 0$$

balanced

$$f(0) = 0$$

$$f(1) = 1$$

balanced

We just need to check if $f(0) = f(1)$ on one qubit

Deutsch – Jozsa Algorithm

Mach-Zehnder realization

