QUANTUM ALGORITHMS INSTITUTE

QUANTUM TECHNOLOGIES 101

How does Quantum Computing work?

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Quantum phenomena such as superposition and entanglement provide powerful new knobs for manipulating qubits beyond the simple 'on/off' switches (bit flips) in binary logic. That's what turbo-charges quantum-powered computing. Multiple qubits interacting together can be placed in a superposition that represents all possible combinations of 0s and 1s and hence all possible solutions to a problem. The catch is that when each qubit is measured, only one outcome of all those possibilities will be observed. So the trick is to develop algorithms that can cleverly manipulate entanglement and superpositions so that the probability of the correct measurement outcome is maximized and the probability of the wrong outcomes minimized.

Can such an algorithm be devised for all computable problems? Yes, because you could always fall back to using only classical bit flips (no superposition or entanglement), which is a subset of all quantum operations, but in that case you get no improvement in performance compared to a classical computer. But for certain problems (the most famous being factoring of large numbers), scientists have worked out clever quantum algorithms that do outperform classical computers by efficiently harnessing superposition and entanglement.

While it is difficult to explain why these algorithms can efficiently solve problems like factoring or optimization without going into the mathematical details, I like to imagine the information encoded in qubits as a fluid probability wave which flows through the computing landscape. A quantum algorithm is a set of operations that shapes the probability wave and guides it to flow towards the correct solution faster than a set of classical bits can discretely jump through the same landscape to the solution. It's not precisely how it works, but I hope you get a sense of the strange and beautiful process of quantum computing.