The Molecules That Make Up Quantum Computers

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Gershenfeld, Neil, and Isaac L. Chuang. “Quantum Computing with Molecules.” Scientific American, Inc., June 1998.

Summary:

Quantum computing is the study of theoretical computation systems (quantum computers) that make use of quantum-mechanical phenomena, such as superposition and entanglement, to perform operations on data. Unlike traditional computers, Quantum Computers use Qubits that can exist in the state of 0 and 1 simultaneously unlike tradition bits which are either 0 or 1. Quantum computers are different from binary digital electronic computers based on transistors. Quantum computers can compute calculations at speeds not even achievable by supercomputers, the theory as to how it can be done begins at the physical level. Quantum transistors work off of quantum physics, and act like liquids, unlike regular transistors which “cannot be made slimmer than the width of an atom.” Quantum Computing is different than traditional computing all the way down to the molecule.

Analysis:

Traditional Transistors in regular computers are made up of bits that are either 0 or 1; these transistors can get as small as an atom, but any smaller they are in the quantum realm. To find a way for computers to break past this limit and become faster than the theoretical limit of traditional computers, researchers realized that bits that were able to exist in multiple states at once would be able to compute solutions exponentially faster than their traditional counterparts. They realized that the Quantum Phenomenon known as superposition did just that, it allowed qubits (quantum bits) to exist as either 0,1, or 0 and 1. Superposition working with another quantum phenomenon is known as entanglement would allow the quantum devices to complete calculations at speeds previously considered unattainable. But reading these results would entail another problem, quantum solutions can be affected decoherence which can make them useless. However, with the use of nuclear magnetic resonance, a way to read the results was developed. Quantum computing has the power to boost numerous industries by solving problems and completing calculations exponentially faster.

As researchers began to look for ways to create faster computers they realized that the quantum phenomenon of superposition would effectively allow transistors to exist in multiple states at once which would more likely emulate a liquid’s structure, unlike traditional transistors. This was an interesting approach as it was completely redefining approach to how computers would be designed. Another phenomenon that was being used to aid create functioning types of these computers was entanglement. Entanglement would allow 2 different photons of light to travel in opposite directions but at the moment the 1st photon’s polarization is measured the 2nd photon’s polarization becomes fixed. This phenomenon creates a link between different quantum particles, this connection is used to connect quantum bits. These two phenomena put together makes the principle of quantum computers unbelievably powerful.

When a quantum computer's system makes contact with a stray particle it can cause the whole structure to fall apart, this is known as decoherence. This fragility causes quantum calculation unreadable. However, “some magnetic fields can trap a few charged particles” which then can be cooled to a “pure quantum state” allowing them to be used. This requirement to be cooled to their pure quantum state most likely rationalizes why modern quantum computers’ environments being colder than the vacuum of space. But even after using these magnetic fields, the particles are still fragile and can lose coherence easily. A discovery with nuclear magnetic resonance (NMR) fields demonstrated that they could be used to help address the issue of decoherence. This stabilizes the quantum particles enough to the point where they can be used more easily. “For instance, protons (hydrogen nuclei) placed within a fixed magnetic field of 10 tesla can be induced to change direction by a magnetic field that oscillates at about 400 megahertz—that is, at radio frequencies.” Different particles react differently, but hydrocarbons seem to be the focus of most quantum liquid experiments.

Now that we can use the quantum bits, how do we use and manipulate them? The magnetic fields cause particles to spin and then applying a pulse with the right degree can help differentiate particles to be interpreted. Generally, 180-degree pulses cause particles to spin in the opposite direction. But if a 90-degree pulse is applied it can cause the particle to be distinguishable from the other parts of the molecule. Researchers used “used chloroform (CHCl3)” in order to observe “the interaction between the spins of the hydrogen and carbon nuclei.” which probably aided in distinguishing the change with the different pulses. Applying the pulses seem like the best way to manipulate the quantum particles to begin to understand what they mean.

Now that the particles are distinguishable, how do you interpret the manipulated particles? Quantum bits are simultaneously multiple states at once, traditionally a searching algorithm, traversing a dataset of n elements would have on average ‘n/2’ attempts before finding something, but using Grover's principle with quantum search this can be reduced to √n attempts. This allows for users to access the potential of quantum computers. Grover’s algorithm allows a solution to be found in a singular quantum step vs. multiple individual attempts. This power can be used in numerous fields. It can help with different fields from data analytics to medical research.

However, with the requirements of quantum computers can cause the size of quantum computers to grow very quickly. As the size increases the potential for decoherence increases but using a specifically designed laser it could help reduce “thermal motion of the molecules—but without actually freezing the liquid and ruining its ability to maintain long coherence times.” Once this issue and others are solved and then scaled to a much smaller size than they are at now, quantum computers could be made for regular public use.

Quantum computing encompasses a host of new problems that scientists must figure out, but the results could be well worth it. With the power of Grover’s algorithm data analytics could be done faster allowing for more efficient businesses and organizations. Biomedical research could be accelerated at an exponential rate - saving lives. Now it is just up to us to figure out the best and fastest way to get there as “nature has already completed the hardest part of the process by assembling the basic components."