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The Future Possibility of Consumer-Grade Quantum Computers

Peter Dolan
Missouri University of Science and Technology

An effort by computer scientists is being made to reinvent the computer, creating a quantum computer that works by using quantum mechanics to run computations (Gershenfeld and Chuang 1998). A quantum computer would theoretically be much faster than any computer currently in existence, which would be useful for solving incredibly complex problems (Almudever et al. 2017). Classical computers take months or years to solve these problems due to their complexity. Certain problems could take longer, becoming unfeasible to solve on a classical computer because it would take too long to be usable. Quantum computers solving the same problems can finish in much less time, even solving problems that are out of reach of classical computers.

Currently, quantum computers are found almost exclusively in laboratories and research institutions. There are quantum computers for sale, though they require significant resources to run properly, such as multi-million dollar funding, large spaces to house the computer, essential liquid helium cooling systems, a controlled vacuum, and large amounts of electromagnetic shielding (Gartenberg 2017). The cost and resources are far beyond the scope of the average consumer, which means these quantum computers are not likely to be found in family living rooms anytime soon. However, the field of computing has been in a very similar situation before. Classical computers did not become commonplace for years after the first ones were built. Quantum computers are following a similar development pattern, as they are currently restricted to laboratories. Large corporations and institutions are providing funding and research to develop state-of-the-art quantum computers. However, there is no consensus or even estimate available regarding how soon average consumers would be able to harness the power of a quantum computer, let alone what they would use it for. The purpose of this study is to provide a realistic estimate of the timeframe in which general access to quantum computing could become a reality.

Quantum versus Classical Computing

Current computers, often called classical computers, use transistors to perform calculations. The more transistors available, the more calculations can be completed in a given span of time. To achieve these increased speeds, transistors have been made smaller to satisfy increasing computational requirements. In recent years, transistors have become so small that to shrink them any further would create faulty transistors due to quantum tunneling because electrons would bypass transistor gates that are sometimes meant to stop the electrons. This, by extension, would create faulty computers (Yang 2016). If computers are to continue getting faster, then an alternative method of computing must be employed.

Quantum computers are a completely different approach to designing computers. As L. K. Grover (1999) notes in his article on the subject, quantum computers leverage quantum physics to carry out similar kinds of calculations as transistor-based computers. One key characteristic of quantum physics is the uncertain nature of quantum particles and their capability to occupy multiple states at the same time, a phenomenon known as superposition (Dworzecka 2011). As they currently function, computers occupy one state at a time, but a quantum computer's qubit-- the analogue of the classical computer bit--can occupy multiple states simultaneously. In effect, the computer can carry out millions of calculations simultaneously, as opposed to classical computers that must carry out each of those calculations in series. It then resolves the superposition of all of the qubits to arrive at a singular solution to the given problem (Grover 1999, 26-30).

Research Methods

To understand how far in the future the first consumer-grade quantum computers are, I investigated the recent developments in quantum computers in news articles and press releases by major firms. I also looked within Scopus, ProQuest, the ACM Digital Library, and ABI/INFORM for current journal articles. The search terms "quantum computers," "cloud quantum computers," and "consumer quantum computers" were used to find applicable research. I also considered the possibility that a cloud-based interface will be used with central computers carrying out any necessary computations instead of personal quantum computers. Based on information found about upcoming projects in these areas, the average consumer may be able to use a quantum computer by 2030 through the cloud.

Industry Breakthroughs

It is important to understand what recent developments and breakthroughs have been made to gauge where the field of quantum computing currently stands. Quantum computing architecture relies on entanglement. Quantum entanglement occurs when two particles interact with each other in such a way that any action on one will affect both particles (Bub 2001). Within a quantum computer, it is possible to dynamically entangle the qubits with each other to create a myriad of states not possible in a classical computer. This capability is important since the qubits start by occupying all states simultaneously within a given system. One qubit is then forced to occupy the only possible state it can exist in for the system. This then causes a chain reaction of qubits coalescing from all states down to the only state physically possible for the system, thereby giving the solution for some problem.

One recent advancement, made at the University of New South Wales Sydney (UNSW), was the creation of a new type of qubit called the flip-flop qubit (Da Silva 2017). This new qubit uses electrodes to influence the qubits rather than magnetic signals. The electrical signals from the electrodes can reliably influence each other over longer distances than the magnetic waves. One of the most developed forms of quantum computing uses superconductors to contain the qubits. However, these are room-scale machines that would need to be larger to be truly useful. Using the flip-flop qubit, the UNSW researchers believe that millions of these qubits can be placed within a square millimeter, making it sufficient to run most useful quantum algorithms without being too large or too expensive (Da Silva 2017).

Google has claimed that by the end of 2017 it will produce and test a 49-qubit computer that will hold $5.6295 * 10^{14}$ (or 2^{49}) numbers simultaneously (Emerging Technology from the arXiv 2017). They are attempting to create a proof of concept to demonstrate that the error rate of additional qubits does not increase exponentially, but instead much more slowly. More qubits mean more computational power, but also more errors as each qubit begins to interfere with other qubits (Technology Review 2017). The engineers of this computer believe that their architecture can reduce the rate of errors while also allowing for a grid layout.

Regardless of how well Google's computer works, they must contend with the fact that IBM has created a simulation of a 56-qubit computer (Pednault et al. 2017). In doing so, IBM has shown that a quantum computer with more than 49 qubits can be simulated on a classical computer. This is important because IBM has essentially increased the threshold of quantum supremacy, the point where quantum computers can solve computational problems that no classical computer in the world could even simulate (Preskill 2017, 1-2). They achieved this using a technique that simulates each qubit using tensors, which are multi-dimensional arrays (Pednault et al. 2017, 2). Until IBM created their 56-qubit simulation, it was considered impossible to run a simulation of a quantum computer with more than 50 qubits due to size limitations. This simulation runs a billion times slower than a 56-qubit quantum computer would theoretically be capable of, acting to push the boundaries of quantum supremacy rather than attempting to outperform a quantum computer. Even if Google is successful in creating their quantum computer, it would still fall short of the requirements of many proposed quantum algorithms. Some of the most useful quantum algorithms require millions of qubits to work (Da Silva 2017). While Google's quantum computer would be an extraordinary engineering feat, it only possesses 49 qubits which would not satisfy this requirement at all. It would, potentially, take years to create a quantum computer with the required number of qubits. This does not even consider the task of scaling down that technology to be affordable to average consumers. If they hoped to own a quantum computer anytime soon, they might be out of luck.

Quantum Computers on the Cloud

Quantum computing is an especially difficult dream to realize since the fundamental aspect of this new form of computing is manipulating quantum physics at the atomic level and gathering useful data from it. Most likely, it will take decades before consumers would be able to purchase their own quantum computer, assuming they would ever be able to. One of the fundamental strengths of quantum computers is that adding more qubits to a processor increases the computational capability exponentially. However, the increased qubit count also increases the possibility of errors, mostly from quantum noise within the system (*MIT Technology Review* 2017). Should the error probability increase too rapidly, further scaling of quantum computers may not be possible. A computer system that is fast but has a high chance of being inaccurate is not ideal. Until this problem is resolved, personal quantum computers are going to remain a dream to aspire to, rather than a true possibility.

However, the first *access* to quantum computers is not so far away at all. In fact, one could experiment with a publicly available quantum computer right now. In 2016, IBM launched a project called IBM Q, which allows anyone to use a quantum processor being managed by IBM to run algorithms and experiment over the internet (IBM 2017). However, IBM Q is made for experimentation by programmers and scientists and would not be useful to the general public. No widely available software relies on IBM Q to run, and such a dependence may hamper the software in the event that IBM Q is shut down in the future. The purpose of IBM Q is to give programmers and scientists exposure to how a quantum computer would work and not for commercially available software. This knowledge will be useful once quantum computers are deployed in the private sector.

The private sector may be getting access to quantum computers in the next ten years. According to sources from Bloomberg Technology, Google is laying out a business plan to offer commercial cloud computing on their own quantum computer (Bergen 2017). In the words of Q. F. Hassan (2011), cloud computing is "to outsource IT activities to one or more third parties that have rich pools of resources to meet organization needs easily and efficiently. These needs may include hardware components, networking, storage, and software systems and applications." This allows software developers to use additional computing power available over the internet to complete various tasks. Developers could leverage quantum computers on the cloud to process more complicated problems and then feed results back to the individual user. Rather than using large arrays of classical computers to process terabytes of data, such a setup would mean data could offload onto a single quantum computer. That system would process that data more quickly than current cloud computing systems. Based on advances in the field, business plans from Google, and some conjecture on my part, such availability to quantum computing could occur within ten years, being available to businesses by 2027. This technology could potentially see wider use by common applications--such as social networks and search engines--by 2030.

Discussion

Since electronic devices are embedded in modern society in many forms, the fastest route to quantum computing for the masses would be everyday electronics like tablets and laptops interacting with quantum computers through cloud technology. Recent advancements by researchers at UNSW help compartmentalize quantum computers, but their methods are still subject to many of the same limitations as most current systems, such as magnetic shielding and cooling to near absolute zero. They have, however, attempted to resolve the scalability problem of the physical size of quantum computers versus their computational power. Google's 49-qubit computer is attempting to solve a different scalability problem regarding the error rate of adding more qubits to a system. Based on all of this information, no one knows if we will see a personal quantum computer, as all of the technology behind it requires further research. Given the strides quantum computing researchers have made since the first demonstration of a quantum computer--particularly the work of the UNSW researchers--there is still the possibility of one day seeing a personal quantum computer. Once researchers show computers like these are even possible, it will be a matter of compressing the supporting equipment down to size. This will be much easier to accomplish once the first programmable quantum computers are operational. These computers can then be programmed to assist in the design of newer quantum computers, much like how designers of computers today use currently available computers to design new ones.

There is no speculation in this study about why average consumers would use a quantum computer. One may argue that they have no need for the power afforded by a quantum computer. This same thinking blurred the vision of early computer scientists who could not understand everything that computers would eventually become. They simply saw computers as a tool for researchers and little else. And yet, computers have become prevalent in our lives because visionaries used those tools and made them accessible for everyone. We have not yet seen the visionaries who will give quantum computers meaning to the general public, but they are out there. Even without them, quantum computers will spark revolutions in every major field as new advancements in medicine, chemistry, and physics break down the boundaries of what is currently possible. Therefore, more research into quantum computing must be made so we may all one day have our own quantum computer.

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