Quantum Computing and Advancements of Computing Technology at a Quantum Level

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1. Introduction

Companies such as IBM and various Universities have been showing progress in the formation of quantum machines, but mass production is still a way off. One University has discovered initializing the qubits in silicon may give the users more control over the processes and overcome some of the roadblocks currently halting progress [3]. Clear progress is being made, and quantum computing is no longer a distant dream in the field of technology. In this paper, I will 1. Explain quantum computing and its advantages/disadvantages, 2. Evaluate examples of advancements in the development, 3. Discuss quantum computing's relevance in business and science.

2. Background

Classic computers interpret data using binary bits to process information in one of two states, 0 or 1, using transistors. Quantum computing holds the idea of super positioning the bits, so they are in a state of 0 and 1 at the same time to greatly enhance computational speed and data processing. These bits, qubits, allow a quantum computer to factor extremely large numbers, search large and unsorted data sets, simulate quantum systems, which may allow scientists to study results on a molecular or atomic level, and more that a classic computer struggles to do [1]. Quantum theory is a highly important piece of the construction for many current scientific research and theories. So, combining quantum theory with computing will accelerate technology exponentially.

3. Quantum Computing and Advantages/Disadvantages

Everything that exists can be viewed based on advantages and disadvantages, and even this viewpoint is difficult to base opinion around as these advantages/disadvantages may change depending on what someone or some group is looking for specifically. In general, quantum computers have a few advantages and disadvantages that may be universally accepted to pinpoint a niche for this machine.

Right away one of the largest disadvantages in quantum computing is the cost. IBM has been developing a quantum computer dubbed the IBM Q, and has an expected price of $15 million [6]. The cost is derived from the work put into research and development, as well as construction, processing, and rebuilding of the structure which is not even available yet. Countering this downside, an advantage found in quantum computing is the fact it can compute things exponentially faster than any classic computer [9]. Efficiently, quantum computers are believed to be able to sort extremely large sets of unsorted data, simulate quantum and atomic systems quickly and effectively, and factor numbers normal computers cannot work with. This ability makes quantum computers effective business and scientific investments as they can alleviate wasted time and provide investors with efficient, next level computational ability.

Another disadvantage to quantum computing is the maintenance needed to maintain the machines optimal level of abilities. Recently, it was found that silicon-based qubits may alleviate some of the problems with entanglement and separation. With the qubits, they super positioning leaves them extremely fragile and it has been hard to experiment with them as when a computation test has been completed, upon trying to review results or investigate the qubit being, they break out of the super positioned state and essentially revert to a classic computer. Basing the qubits in a silicon material has proven to be effective at maintaining the super positioned state to allow researchers to view results of computations and the processes but this finding is still new and should be tested further [3]. Another advantage of quantum computers is found within the disadvantages of it. Having this technology unavailable and still being tested makes it a hot topic and a large business area for future productions. This opens new fields of science and connects them with computers for a collaborative effort as researchers race to complete a true quantum computer [14].

4. Advancements in Quantum Computing

As quantum computing is such a trending topic in the tech world, there are clear advancements made in its research and development. One area has found that certain fibers may speed up computations and absorb qubits more efficiently, allowing them to remained super positioned [5]. Advanced algorithms have been experimented with and were found to be more effective than previous attempted equations to abuse the effectiveness of quantum systems [10]. Ethically, the development of quantum computers is a sound case as it can propel business and science into new eras of progress. As increasing advancements are found in the field, new researchers should also investigate security of these systems. If quantum computers turn out to be as effective as the research has been showing, then they will become a prime target for hackers and terrorism. Not only would this open a new area of development for this system, but it would broaden the field of cybersecurity and has the potential of supplying more employment to those who take a liking to futuristic ideas such as this.

Entropy in quantum systems has also been researched and is being solved in recent times. This is a development where the atoms become stuck and begin to create problems for the systems. Using lasers to adjust polarities, researchers have found that trapping the atoms on a grid and arranging them to not begin entropy is effective at solving that issue and the large complaint about their noise [2]. It has been speculated that these computers can find their way onto the market within the next 10 years, which would suggest that researchers are beginning to draw conclusions and solve issues, pushing ever forward to the futures of computing.

5. Relevance of Quantum Computing

Classical computers have been around for a while and have served a great purpose in the advancement of society, but as new problems arise, as does a new way to solve them. Quantum computing is extremely relevant in the world today as the problems needing to be solved are becoming more taxing and difficult for modern machines to handle. In fields of science, new advancements of quantum computing can allow scientists to study at atomic levels and record vast amounts of data for more precise conclusions [1]. Though dreaming, computational abilities such as this can possibly lead to newfound ways to cure incurable diseases, or at least learn new ways to aid in prevention. With things like cancer being a raging topic in the medical world, a quantum computer can assist researchers in their search of a cure through its potentially unmatched speed, accuracy, and indefinability [8]. Progress for these machines is speeding up as it is realized the potential these machines hold. Scientists already do a lot when it comes to coming up with questions then answering them, but with the power quantum computing holds, their results can be infinitely more precise and reliable.

Aside from the science world, quantum computing can become an important asset for businesses and corporations, especially those that handle large amounts of data. One of the main features of quantum computing technology is to search extremely large, unsorted sets of data as well as factor and handle numbers classic computers struggle to work with [1]. Even though it would be a large investment, quantum computing can find its niche in business. If a company invested in this technology, they would be theoretically saving time and boosting efficiency in the future [15]. Right now, businesses are benefiting from the research and development of quantum technology. Companies have been formed around the basis of developing this tech, and other companies, such as IBM, have been leading the advancements. Business centered around technology is often profitable and popular, and with the new ideas and research associated with quantum computing, it opens a whole new market and customer base that can be catered too.

6. Conclusion

This paper has looks at the research and development of current quantum computers in 3 sections:

1. Quantum Computing’s advantages and disadvantages
2. Current progress and recent advancements
3. Relevance

In terms of advantages and disadvantages, price is currently the most outstanding feature of this technology. With a estimated asking price of $15 million, these machines are a large investment and must be thought about carefully. Yet as time passes, with more advancements in the field being made, the price of these machines will drop, and it will become more ethical to buy. Progress is being made in the field with new development such as the findings with silicon and controlling entanglement with lasers on a grid but there are still a few kinks to work out in the technology and implementation. Given 10-15 more years, quantum computing could be on the market and available for professional, or even consumer, purchase. Quantum mechanics is a tough subject and very relevant in terms of research. Having the power to view results at atomic levels can propel scientific research and boost legitimacy of conclusions drawn in related fields. Along with benefitting science, quantum technology will become an asset for future businesses as it theoretically has the capacity to sort through innumerable amounts of data and compute with numbers unreasonable with current hardware. In the field of computers, quantum mechanics will open whole new opportunities and markets for computing. It is the future, and it is not so distant.

Sources

Source 1: Prince, J. (2014). Quantum computing: An introduction. *Journal of Electronic Resources in Medical Libraries, 11*(3), 155-158. doi:10.1080/15424065.2014.939462

Classic computers interpret data into binary bits to process the information and can only do so in one of two states, 0 or 1, using transistors, which function as a "switch". Quantum Computing pursues the idea of "superposition", being both 1 and 0 at once, through the use of qubits (fundamental particles such as photons/electrons). Quantum Computing would excel at factoring extremely large numbers into prime numbers; searching large, unsorted data sets; simulating quantum systems, allowing scientists to study results on molecular and atomic levels, aiding in the drug development process. Quantum Computing is important because the number of transistors per square inch of integrated circuits will double every 18 months (Moore's Law), so there will come the time when the transistors will be so small that quantum physics must become part of the functionality of the computer to continue developing computational efficiency. In Quantum Computing, qubits are a necessary component, but also a roadblock. Looking at what is happening or the result of a computation that uses the qubits causes them to decohere (collapse), out of the superposition state and into a 1 or 0 state, essentially causing them to become a "normal" computer. This article is relevant to my research because I would like to answer the question of what quantum computing is (since I have no idea), and to theorize what could be possible after it is achieved. This introductory article has given me a basic look into how Quantum Computing is supposed to work and the ideas behind it. It also gave good examples of qubits, superpositions, and simulated annealing (probabilities of accepting solutions). I feel this article, although short, got to the point and was very informative, giving me a good basic understanding of Quantum Computing which I can now use to my advantage when finding other sources and theorizing what can come after Quantum Computing.

Source 2: G. (2018, September 11). An old physics demon could be the future of quantum computing. Retrieved September 13, 2018, from https://thenextweb.com/science/2018/09/11/an-old-physics-demon-could-be-the-future-of-quantum-computing/

Due to a thought experiment called Maxwell's Demon, some scientists believe the idea can help resolve one of the biggest issues with quantum computing: Entropy in the qubits and noise. Instead of a demon, a team at Penn State uses lasers to trap and arrange atoms across a 5x5x5 grid. Scientists can control the atoms by adjusting the polarity in the traps. They then are "super-cooled", which contains the entropy system, thus working around the noise problem in the qubits. Not only is there a fix-in-progress for the qubits and their noise, but a startup company, Strangeworks, has unveiled a 128-qubit computer, which is said to be a hybrid between quantum computing and classical computing with cloud access for developers.

This news article is relevant to my research because it depicts what is happening in the world of quantum computing right now. It talked about a problem quantum computing was facing and how a team at Penn State has tried to solve it. Not only did it mention the common problem with quantum computing, but it also brought up a startup company that claims to have unveiled a new 128-qubit computer that is both a quantum computer and a classical system. These recent discoveries and advances in the field depicted in the news article make it relevant to my research.

Source 3: Maragkou, M. (2015). Quantum Computing: Silicon qubits. Retrieved September 18, 2018,

from http://web.b.ebscohost.com.saintleo.idm.oclc.org/ehost/pdfviewer/pdfviewer?vid=1&sid=4366e846-d4a6-4c0b-bf43-3a82fc9419c2@sessionmgr104

A large challenge that quantum computing faces is trying to merge quantum physics with electronic systems. Universities have been experimenting with silicon and the control it gives a user with the creation and destruction of quantum wave packets (simultaneous states of information). Now that silicon can be used for ultrafast switching times in the setup, the next step would be to implement the dynamics into a logic gate on-chip, for use in quantum computing that demand speeds currently unachievable by classic computers.

This article is relevant to my research because it addresses a fix for problems found in quantum computing. The silicon platform and the experiments done by the Universities involved have progressed the engineering behind quantum computing and has brought the idea one step closer to reality.

Source 4: Blencowe, M. (2010). Quantum RAM: hybrid quantum systems have been suggested as a potential route to building a quantum computer. The latest research shows that they offer a robust solution to developing a form of random access memory for such a machine. *Nature*, *468*(7320), 44+. Retrieved from http://link.galegroup.com.saintleo.idm.oclc.org/apps/doc/A241629504/MSIC?u=sain11218&sid=MSIC&xid=b667754f

Instead of looking into how a CPU and other components would work for a quantum computer, this article looks at research done for Quantum RAM. They look at a hybrid of quantum computing using superconducting qubits and spin qubits. The superconducting qubits are well suited for performing fast logic gate operations. The spin qubits act as memory elements to store and retrieve data. In this hybrid scheme, the data bus is best formed by long thing strips of aluminum to form resonators for the qubits to travel.

This article is relevant to my research because it is specific on a part of quantum computing instead of the topic as a whole, which were most of my resources so far. The fact this resource focuses on Quantum RAM will allow me to go further in depth with the workings of Quantum Computing and how it can be applied in the real world.

Source 5: References

Horiuchi, N. (2013). Quantum memory: Hollow-core fibre. *Nature Photonics*, *7*(8), 584–585. https://doi-org.saintleo.idm.oclc.org/10.1038/nphoton.2013.203

Displays info on Hollow Core Fibers using "caesium atoms" and "kagome fibers" which are being researched to create Quantum Memory. These fibers and components are useful as they enhance the absorption of qubits and speed up the computing. These are in high demand as they can store broadband pulses when light-induced to achieve highly optical depth for resonance absorption at room temperature.

This article is relevant because it talks specifically about Quantum Memory, which is another component in computers that is important, and how it can be achieved on a Quantum level.

Source 6: What is quantum computing? (n.d.). Retrieved from https://www.research.ibm.com/ibm-q/learn/what-is-quantum-computing/

Source 7: Biham, E. (2004, June 12). Quantum Computing Without Entanglement. Retrieved November 10, 2018, from https://www-sciencedirect-com.saintleo.idm.oclc.org/science/article/pii/S0304397504001926

Source 8: Jozsa, R., & Linden, N. (2003, August 08). On the role of entanglement in quantum-computational speed-up. Retrieved November 10, 2018, from http://rspa.royalsocietypublishing.org/content/459/2036/2011

Source 9: Jeffery, S., Magniez, F., & Wolf, R. D. (2016, September 08). Optimal Parallel Quantum Query Algorithms. Retrieved November 10, 2018, from https://link.springer.com/article/10.1007/s00453-016-0206-z

Source 10: Wu, W., & Zhang, H. (2017, May 24). Quantum algorithm to solve function inversion with time–space trade-off. Retrieved November 10, 2018, from https://link.springer.com/article/10.1007/s11128-017-1622-y

Source 11: Huang, H., Bao, A. K., & Panigrahi, P. K. (2018, March 07). Demonstration of essentiality of entanglement in a Deutsch-like quantum algorithm. Retrieved November 10, 2018, from https://link.springer.com/article/10.1007/s11433-018-9175-2

Source 12: Langford, N. K., Ramelow, S., Prevedel, R., Munro, W. J., Milburn, G. J., & Zeilinger, A. (2011). Efficient quantum computing using coherent photon conversion. *Nature*, *478*(7369), 360+. Retrieved from http://link.galegroup.com.saintleo.idm.oclc.org/apps/doc/A271405981/MSIC?u=sain11218&sid=MSIC&xid=4dc08c3c

Source 13: Jones, J. (2010, October 25). Quantum computing with NMR. Retrieved November 16, 2018, from https://www-sciencedirect-com.saintleo.idm.oclc.org/science/article/pii/S0079656510001111

Source 14: Deutsch, D. (1985, July 08). Quantum theory, the Church–Turing principle and the universal quantum computer. Retrieved November 16, 2018, from http://rspa.royalsocietypublishing.org/content/400/1818/97

Source 15: Feynman, R. P. (1982). Simulating physics with computers. Retrieved November 16, 2018, from https://link.springer.com/article/10.1007/BF02650179#citeas

Source 16: Cory, D. (1997, March 4). Ensemble quantum computing by NMR spectroscopy. Retrieved November 16, 2018, from https://www-sciencedirect-com.saintleo.idm.oclc.org/science/article/pii/S0167278998000463

Source 17: Steane, A. (2003). Quantum computing: Logic gateway. *Nature*, *422*(6930), 387+. Retrieved from http://link.galegroup.com.saintleo.idm.oclc.org/apps/doc/A187661668/MSIC?u=sain11218&sid=MSIC&xid=3e04bf95

Source 18: Gottesman, D. (2016). Quantum computing: Efficient fault tolerance. *Nature*, *540*(7631), 44+. Retrieved from http://link.galegroup.com.saintleo.idm.oclc.org/apps/doc/A472287124/MSIC?u=sain11218&sid=MSIC&xid=d1dcd1f7

Source 19: Bartlett, S. D. (2014). Powered by magic. *Nature*, *510*(7505), 345-345,347. Retrieved from https://saintleo.idm.oclc.org/login?url=https://search-proquest-com.saintleo.idm.oclc.org/docview/1540965071?accountid=4870

Source 20: Morton, J. J. L., & Elzerman, J. (2014). Quantum computing: Three of diamonds. *Nature Nanotechnology*, *9*(3), 167–169. https://doi-org.saintleo.idm.oclc.org/10.1038/nnano.2014.37