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Quantum Computing: The Future of AI

Moore's law, the theory proposed by Gordon Moore stating that the number of transistors in a circuit will double every two years, has held true for more than 50 years; [3] however, as the size of transistors approach the size of elemental molecular structures, the upper bound on the number transistors humankind can fit onto one circuit board rapidly approaches. [4] The solution to this problem is the advent of quantum computers. [5] Instead of using the conventional binary data encoding that current computers use, quantum computers use qubits, which use the quantum theory of uncertainty and simultaneous states to make 4 different states possible. [5] The unique properties of qubits allows not only exponential storage and processing power, but also a much more efficient way to analyze chemical reactions. [5] This unparalleled processing power has unlocked completely new realms of possibilities for machine learning and artificial intelligence.

"Job One for Quantum Computers: Boost Artificial Intelligence" by Josef Bsharah visits this crucial idea of the further expansion of quantum computing to artificial intelligence. [1] In a conventional machine learning program, massive matrices are required to store all of the neural network weight data and industry-grade neural networks can sometimes require billions of operations for each training iteration. [1] Quantum computers are able to take advantage of their exponential nature to not only store this data much more efficiently, but also process the data much faster. Firstly, quantum computers storage grows exponentially as the number of parallel qubits grows. 60 parallel qubits is enough to encompass all of the data produced by humanity in a year and 300 parallel qubits is enough to encode all of the data in the known universe. [1] This exponential increase in storage is accompanied by an exponential increase in processing power. Instead of using definite mathematical operations, quantum computers use a completely different method to train qubit matrices that store required data. [1] When quantum computers run an electrical and magnetic field through a qubit matrix, the final arrangement of qubits becomes uncertain because they move relative to how individual qubits interact with each other. Although this seems undesirable, this precise behavior is exactly what makes quantum computers so fast. The system is trained by "just doing what comes naturally." [1] In more specific terms, qubit manipulation is driven by quantum tunneling, which is the natural tendency for quantum systems to seek out the optimal configuration. When qubits are paired up together and allowed to freely interact, they automatically move towards a certain pattern much like a ball will roll downhill when placed on a slope. They will gravitate toward the lowest energy or potential state and automatically choose the optimal route because in cases like these, non-optimal routes actually require excess energy. [1] This characteristic make quantum computers exponentially faster than regular computing. When regular computers try to calculate a neural network, it tries many different combinations and calculates the best route to take toward the optimal solution. Quantum computers doesn't require any of these calculations and automatically moves toward the best solution possible.

Besides processing power, however, Baharah also detailed other more property-based advantages of quantum computing. Quantum computing has an "intrinsic statistical nature" which means that quantum operations naturally operate using probabilities. This statistical nature is perfectly fit for machine learning because machine learning is inherently reliant on statistical data. [1] This also means that quantum computers are noise-tolerant, resisting low probability noise from deterring an otherwise sound model because the larger overall distribution masks irregular cases of noise. [1] This statistical nature means that computation using quantum computers are more easily geared toward machine learning tasks. Moreover, this statistical nature provides a new way to model atomic level interactions. [2] In modern physics, most interactions between particles can only be described using quantum theory and statistical distributions. [2] Quantum computers' statistical nature allows scientists to use a completely new nature provides a new way to model atomic level interactions. [2] In modern physics, most interactions between particles can only be described using quantum theory and statistical distributions. [2] Quantum computers' statistical nature allows scientists to use a completely new way to modeling combinations of elements. [2] Using quantum computing qubits, the interactions between particles can be modeled much more efficiently and accurately, by using qubits themselves as particles. This is shown in an experiment referenced in the article where a team led by USC and Caltech physicists successfully modeled proton collisions using quantum computers. While normal computers required 36 signal variables to be accurate, the quantum computing network only required 16. Not only were less variables required, the actual identification had an accuracy advantage over regular binary computational methods. [1] This particular characteristic of quantum computers has huge implications in the scientific community. One of the largest fields of machine learning today is in bioinformatics and material science where new drugs and materials are developed. Material sciences and medical field research using quantum computing can revolutionize the field, making it much faster to create new drugs to save lives and create new materials that can unlock new realms in technology.

Unfortunately, quantum computing still has some very crucial restrictions that prevent the technology from becoming widespread. Because qubit encoding uses quantum theory as its basis, it is very difficult to input and output readable human data. [1] Scientists haven't found a reliable and efficient way to convert quantum state data into regular binary encoding. According to the article, a single operation manipulates a matrix of 16 numbers but 16 operations are required to input and output the data. Furthermore, just translation isn't the only problem. [1] Transferring data into and out of quantum computers suffers similar difficulties. This also requires encoding data in a quantum state which is a difficulty researchers haven't completely figured out yet. For example, when measurements are taking at random for the state of a machine, there is a chance that the entire quantum state would collapse, wiping out all of the data involved. This phenomenon can potentially wipe out of all of the recorded data on a machine, completely erasing all of the work done up to that point. [1] These and other problem relating to extracting and inputting the data, keep quantum computing from having a huge impact on current technological innovation.

Fortunately, regardless of the problems quantum computing currently faces, the advantages of quantum computers are much too great to be ignored. The processing power of quantum computers is more than enough to accomplish all of the tasks that trouble humanity today. The only restriction from mass utilization is the conversion of data so that we can use the data for ourselves but it will only be a matter of time before researchers overcome this hurdle. Quantum computing will be revolutionize of computing much like the personal computer revolutionized the field decades ago.

Works Cited

1. Bsharah, Josef "Job One for Quantum Computers: Boost Artificial Intelligence."*Quanta Magazine*, www.quantamagazine.org/job-one-for-quantum-computers-boost-artificial-intelligence-20180129/.

2. Gabriel Popkin Sep. 13, 2017 , 1:00 PM, et al. "Quantum Computer Simulates Largest Molecule Yet, Sparking Hope of Future Drug Discoveries." *Science | AAAS*, 13 Sept. 2017, www.sciencemag.org/news/2017/09/quantum-computer-simulates-largest-molecule-yet-sparking-hope-future-drug-discoveries.

3. "After Moore's Law | Technology Quarterly." *The Economist*, The Economist Newspaper, 25 Feb. 2016, www.economist.com/technology-quarterly/2016-03-12/after-moores-law.

4. "100 Years of Moore's Law." *High Tech Forum*, 9 July 2015, hightechforum.org/100-years-of-moores-law/.

5. "What Is Quantum Computing?" *Microsoft Quantum - US (English)*, www.microsoft.com/en-us/quantum/what-is-quantum-computing.

6. https://i.pinimg.com/736x/a4/f5/97/a4f5974f1c5529d9c87c56f5aba00248--artificial-neural-network-deep-learning.jpg

6. https://i.pinimg.com/736x/a4/f5/97/a4f5974f1c5529d9c87c56f5aba00248--artificial-neural-network-deep-learning.jpg

7. http://homework.uoregon.edu/pub/class/155/q1.jpg