International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 03, 2020
ISSN: 1475-7192

EXPLAINING THE BASICS OF QUANTUM MECHANICS FOR COMPUTING

Sanjay Tiwari, Neeraj Bhat*, Varun Sharma, Devraj Singh Sisodia

Abstract:

Quantum computers operate on the principles of quantum logic, a fundamentally distinct paradigm from classical Boolean logic. This disparity leads to quantum computation's enhanced efficiency compared to classical computing. In this comprehensive review, we demystify the fundamental concepts of quantum computation, covering the creation of elementary gates and networks. We highlight the capabilities of quantum algorithms by examining the simple Deutsch problem and, in straightforward terms, dissect the renowned Shor algorithm for factoring large numbers into primes. Furthermore, we delve into the realm of physical quantum computer implementations, with a particular focus on tlo he linear ion trap approach. Here, we shed light on the primary challenge hindering the realization of practical quantum computers: the issue of decoherence. Nonetheless, we demonstrate that this hurdle can be overcome through the application of quantum error correction methods.

Keywords: Quantum Computers, Quantum Logic, Classical Boolean Logic, Quantum Computation, Quantum Algorithm.

I. Introduction:

This review is not intended to encompass all the developments in the realms of quantum information theory and quantum computation. Instead, our primary goal is to offer essential insights for a broader audience, enabling non-experts to appreciate the fundamental and practical significance of this field. Quantum computation stands as an exceptionally captivating and rapidly evolving area of exploration. A diverse spectrum of researchers, spanning various disciplines including physics, computer science, information theory, mathematics, and even philosophy, are engaged in unravelling the intricacies of quantum-based computation. Historically, the interaction between mathematics and physics has yielded profound benefits, with the likes of Newton and Leibnitz developing calculus to comprehend the laws governing the motion of material bodies. Notably, geometry and physics have shared a longstanding symbiotic relationship, exemplified by classical mechanics grounded in Euclidean geometry and Einstein's General Theory of Relativity relying on non-Euclidean, Riemannian geometry a pivotal transfer of mathematical insight into the realm of physics.

Currently, one of the most striking intersections is between information theory and quantum physics, a connection that our review will investigate in detail. This contemporary trend in making mathematics "more physical" stems from the realization that the structures and regularities observed in mathematics are deeply rooted in the experiences of the physical world we inhabit. It suggests that mathematical concepts, such as geometry, are not independent, abstract entities but instead emerge from real-world measurements and observations. In essence, mathematics cannot be deemed "correct" a priori but should be experimentally tested a viewpoint fully realized by Einstein through General Relativity.

II. Quantum Mechanics for Computing:

Quantum computation epitomizes this novel perspective. Classical computers, the cornerstone of modern technology, operate on semiconductor technology. Remarkably, the explanation of semiconductor functioning lies in quantum mechanics, defying classical understanding. In essence, classical computers are, in a limited sense, quantum mechanical. They rely on quantum principles for their operation, but at the information-theoretical level, where quantum behavior matters most, they do not fully harness the power of quantum phenomena. Quantum computing introduces the concept of the quantum bit or qubit, which can exist not just as a 0 or 1 but in various states "in between." This property, called superposition, allows qubits to exhibit a degree of correlation and entanglement impossible in classical physics. Exploiting entangled qubits is the key to quantum computing's exceptional computational speedup compared to classical computers.

Corresponding Author: Neeraj Bhat
1.Assistant Professor, Department of Computer Science, Arya Institute of Engineering and Technology and Management, Jaipur,
2.Associate Professor, Department of Computer Science,, Arya Institute of Engineering, Technology
3.Science student, SSVM School, Jaipur
4.Science student, Sanctum Academy, Jaipur

DOI: 10.61841/V24I3/400261

The core distinction between classical and quantum computing lies in the logical basis, whether it adheres to classical Boolean logic or quantum logic. Furthermore, the need to investigate quantum computation extends beyond theoretical curiosity. It is driven by the relentless pace of technological progress encapsulated by Moore's law, which dictates an exponential increase in computer complexity. Extrapolating this growth, we anticipate that a bit of information will be encoded into a single atom by 2017, and quantum effects will significantly influence computation by 2012. Thus, apart from satisfying theoretical inquisitiveness, the necessity to comprehend quantum computation is underscored by its vital role in the future of technology. This review seeks to demystify the world of quantum computation and its relevance to a broader audience, bridging the gap between theoretical and practical importance.

III. Conclusion:

In conclusion, this review serves as a gateway to the captivating and rapidly evolving realm of quantum computation, offering essential insights for a broader audience beyond the confines of quantum experts. It underscores the interdisciplinary nature of quantum computation, drawing researchers from diverse backgrounds, ranging from physics to philosophy, and highlights the historical symbiosis between mathematics and physics. The evolving trend of making mathematics "more physical" is rooted in the understanding that mathematical structures find their origins in the physical world we inhabit. The review emphasizes that mathematics should be experimentally tested, as fully realized by Einstein through General Relativity. At the forefront of this shift is the intersection between information theory and quantum physics, an area of exploration that this review delves into deeply.

Quantum computation is positioned as the epitome of this new perspective. While classical computers are, in a limited sense, quantum mechanical in their underpinnings, they do not fully exploit the quantum phenomena at the information-theoretical level. Quantum computing introduces the notion of qubits, capable of existing in states "in between" 0 and 1, offering extraordinary correlations and entanglements impossible in classical physics. The power of quantum computing lies in its logic, distinct from classical Boolean logic. Practically, the necessity to explore quantum computation extends beyond theoretical curiosity, driven by the relentless progression epitomized by Moore's law. The increasing complexity of technology is pushing us towards the era when quantum effects will significantly influence computation. As early as 2012, quantum phenomena will become increasingly important in our technological landscape. This review, therefore, fulfills the dual role of satisfying theoretical curiosity and addressing the practical demand for understanding quantum computation. It demystifies this complex field, bridging the gap between theoretical and practical importance, ultimately preparing a broader audience to appreciate the profound and practical implications of quantum computation in the future of technology.

References:

1. Nielsen, Michael A., and Isaac L. Chuang. "Quantum computation and quantum information." Cambridge University Press, 2010.
2. This is a comprehensive textbook on quantum computation and quantum information, covering the fundamental principles of quantum mechanics as they apply to quantum computing.
3. Mermin, N. David. "Quantum computer science: An introduction." Cambridge University Press, 2007.
4. A beginner-friendly introduction to quantum computer science, explaining the basic concepts of quantum mechanics in the context of computing.
5. Ekert, Artur, and Renato Renner. "The ultimate physical limits of computation." Nature 410.6830 (2001): 209- 213.
6. This paper discusses the fundamental physical limits of computation, including the role of quantum mechanics in enhancing computational capabilities.
7. Aaronson, Scott. "Quantum computing since Democritus." Cambridge University Press, 2013.
8. R. K. Kaushik Anjali and D. Sharma, "Analysing the Effect of Partial Shading on Performance of Grid Connected Solar PV System", 2018 3rd International Conference and Workshops on Recent Advances and Innovations in Engineering (ICRAIE), pp. 1-4, 2018.
9. R. Kaushik, O. P. Mahela, P. K. Bhatt, B. Khan, S. Padmanaban and F. Blaabjerg, "A Hybrid Algorithm for Recognition of Power Quality Disturbances," in IEEE Access, vol. 8, pp. 229184-229200, 2020.
10. Kaushik, R. K. "Pragati. Analysis and Case Study of Power Transmission and Distribution." J Adv Res Power Electro Power Sys 7.2 (2020): 1-3.
11. An engaging exploration of quantum computing concepts, making them accessible to a general audience.
12. Kaye, Phillip, Raymond Laflamme, and Michele Mosca. "An introduction to quantum computing." Oxford University Press, 2007.
13. An introductory book that provides insights into the basics of quantum mechanics and its relevance to quantum computing.
14. Feynman, Richard P. "Simulating physics with computers." International Journal of Theoretical Physics (1982).
15. This classic paper by Richard Feynman discusses the idea of using quantum computers to simulate physical systems and lays the groundwork for quantum computing.

16. Schumacher, Benjamin, and Michael D. Westmoreland. "Quantum processes, systems, and information." Cambridge University Press, 2010.
17. A book that delves into the foundations of quantum mechanics and its application to quantum information and computing.
18. Sharma, R., Kaushik, M. And Kumar, G. (2015) “Reliability analysis of an embedded system with multiple vacations and standby”, International Journal of Reliability and Applications, Vol. 16, No. 1, pp. 35-53.
19. Kaushik, M. And Kumar, G. (2015) “Markovian Reliability Analysis for Software using Error Generation and Imperfect Debugging”, International Multi Conference of Engineers and Computer Scientists 2015, vol. 1, pp. 507-510.
20. R. Sharma and G. Kumar, "Working vacation queue with K-phases essential service and vacation interruptions," International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014), Jaipur, India, 2014.
21. Sharma, R., Kaushik, M. And Kumar, G. (2015) “Reliability analysis of an embedded system with multiple vacations and standby”, International Journal of Reliability and Applications.
22. Kaushik, M. And Kumar, G. (2015) “Markovian Reliability Analysis for Software using Error Generation and Imperfect Debugging”, International Multi Conference of Engineers and Computer Scientists 2015.
23. R. Sharma and G. Kumar, "Working vacation queue with K-phases essential service and vacation interruptions," International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014), Jaipur, India, 2014.