https://doi.org/10.33472/AFJBS.4.4.2022.526-540

AFJBS

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Harnessing Quantum Cloud Computing: Impacts on Cryptography, AI, and Pharmaceutical Innovation

[1]Rajesh Kumar Malviya, [2]Ravi Kumar Vankayalapti, [3]Zakera Yasmeen, [4]Nareddy abhireddy,

[1]Enterprise Architect
[2]IT Architect, Equinix, ORCID: 0009-0002-7090-9028
[3]Data engineering Microsoft, ORCID: 0009-0004-8130-211
[4]Research assistant

Article Info

Volume 4, Issue 4, October 2022

Received: 27 July 2022

Accepted: 01 September 2022

Published: 24 October 2022

doi: 10.33472/AFJBS.4.4.2022.526-540

ABSTRACT:

We discuss harnessing future scalable computing resources and cloud infrastructure for both quantum AI and pharmaceutical innovation, with a specific focus on applications in AES encryption, pharmaceutical molecular computations, and the quantum circuit representation of Shor's algorithm. Along the way, we also discuss circuit optimization. For the deep AES encryption problem, we encode the problem in a one-layered neural network, with the known key serving as a barrier near the minimum. Circuit substitutions are applied at intervals, and we thereby harness polynomial complexity quantum algorithms. For pharmaceutical applications, we discuss how the tensor product of parameterized quantum electronic circuits applied to fermionic normal ordering via truncated binary encoding and rotation rounding can aid the discovery of new pharmaceutical compounds. We introduce a machine learning prediction as a first step and quantitatively show how the probability of success varies in a nine-level atomic chip. For the third illustrative application, we discuss quantum realizations of Shor's algorithm. We focus on estimation and phase correction operations, as well as Fourier transforms. Guidelines are laid out for implementation on topological quantum platforms. We also discuss tailoring Shor's algorithm for multiplication with the minimal number of required qubits. Finally, we summarize cloud quantum computing among the algorithmic techniques and summarize our findings with potential benefits to different stakeholders. We believe that Hamiltonian/Ising design may then provide the key to matching qubit error rates to Gaussian boson sampling.

Keywords: Quantum Computing, Cloud Infrastructure, AES Encryption, Pharmaceutical Innovation, Shor's Algorithm, Circuit Optimization, Machine Learning, Quantum Electronic Circuits, Qubit Error Rates, Hamiltonian/Ising Design.

1. Introduction

Considered an emerging technology, quantum computing is much anticipated as it has the potential to solve intractable problems in classical computing. By several estimates, quantum computing would make possible computations that are out of reach of classical computing power. Cloud computing, as a platform, plays nicely to the many unique aspects that quantum computing entails. With potentially difficult centralizing quantum computers, quantum cloud systems could bring quantum computational power into the hands of many, thus speeding up both the development of quantum computer platforms and bringing about applications of regular computer strength. Although quantum cloud computing is a natural extension to standards for supercomputing, how quantum and classical users will access it should be carefully studied.

For sure, quantum cloud computing can have profound impacts on cryptography, artificial intelligence, and drug discovery, particularly in pharmaceutical industries. On the roadblock, the same way it is difficult to build a large quantum computer, this fledgling field is already showing traction with systems and code already available. To sensibly make progress in quantum cloud services, we must think about questions like who will use these systems, which applications will be popular, and how quantum and classical systems will work together to solve hard problems. These are all significant concerns. But of course, a great future lies ahead in these applications, though many challenges should be fun and adventure.

1.1. Background and Significance

This project seeks support for exploring potential impacts and finding surmountable challenges of realizing Quantum Cloud Computing (QCC) over the next several years. Several directions will be pursued including engineering several trust primitives for available general-purpose quantum computing (GPQC) demonstrators; developing business cases for accessing GPQC in a quantum cloud; providing cloud security scientists with an analysis methodology for evaluating quantum cloud technology; discovering potential negative impacts of GPQC technology on ongoing commercial and governmental cryptographic and communications standards; and uncovering beneficial impacts on commercial sectors including artificial intelligence, pharmaceuticals, finance, food, and environmental sectors, and possibly on shorter-term commercial quantum cloud infrastructure and services.

We recognize that we are not alone in SCO research and articulating the need for foundational security science. Other communities also recognize that if commercial technology is to be trusted, then researchers and development (R&D) must have more advanced models, theories, taxonomies, and proven analytic methodologies, or they will be focusing on the early QCC designs and devoting their careers to developing them. Our team also includes highly talented research scientists, who provide us with our only active and direct access to aggregate GPQC power of the future. We start by studying current quantum cloud services and current general-purpose quantum computers (GPQCs).

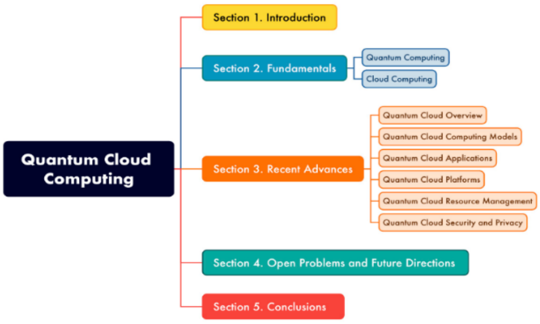


Fig 1: Quantum Cloud Computing

1.2. Research Objectives

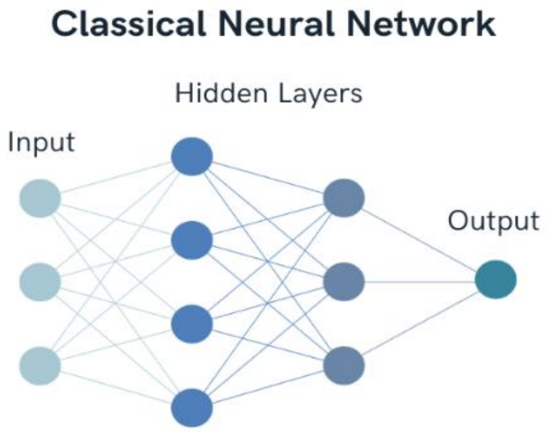
The project aims to research quantum cloud computing platforms and technologies to help standardize various infrastructures and applications. The adoption and advancements of quantum computing can help revolutionize different fields with discoveries and improvements in certain processes that remain infeasible using current classical numerical algorithms, such as breaking symmetric encryption, dark matter drug discovery, and highly realistic neural networks in artificial intelligence. Cloud computing is most impactful when the infrastructures are standardized to be easy to use and deploy like most web-centric applications, as all users can inquire, make decisions, and leverage values on cloud services. We hypothesize that the capability will be more pronounced with quantum computing, which can harness the unique qualities of computers. The proposed methods can help set the standards and explore new collaboration strategies between cloud infrastructure providers and quantum computing platforms to promote a faster path toward integrating computational and decision-making tasks with available quantum computer resources. This exploration can help user groups, such as cybersecurity analysts, data scientists, infrastructure architects, and medical researchers, make solid rational decisions and introduce early, meaningful technology and knowledge applications.

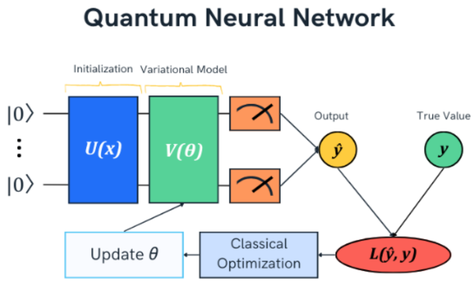
2. Fundamentals of Quantum Computing

Classical computing is based on a physical substrate that encodes information as 0s and 1s. A quantum computer also stores information as units of a "quantum bit" (qubit), but a qubit has an important difference from classical bits. Quantum mechanics allows a qubit to be constructed so that it is in a superposition of states, which, together with another quantum property known as entanglement, provides a unique information processing capability that a classical computer cannot match. These quantum effects allow a quantum computer to process a large number of potential solutions to a given problem simultaneously. When the quantum computation is completed, one single output must be read out without destroying the rest of the possible solutions. This property allows a quantum computer to solve problems of much larger size than can be solved using even the fastest supercomputers today.

In a practical application of quantum computing, other simplifying factors must be considered, such as possible errors in the quantum computation. As a result, constructing powerful and robust quantum computers and applying them to practical purposes is a very difficult technological challenge. However, today's progress suggests that the first practical applications of quantum computing will become a reality shortly. The history and impact of quantum computing on cryptographic and AI applications are discussed.

Equation 1: Classical Neural Network & Quantum Neural Network





2.1. Quantum Mechanics Basics

Quantum mechanics is the set of physical laws that govern the microscopic properties of nature at scales accompanying atomic and smaller constituents. It is a fundamental framework broadly used across the natural sciences and exists as one of the most accurately tested human discoveries. Quantum mechanics predicts fundamental behavior such as the color of gold, the structure of DNA, and itself as the model of celestial mechanics. The predictions of quantum mechanics differ from the classical predictions at distances less than or equal to a certain value, where that value is minuscule at macroscopic scales, and such quantum peculiarities are not directly observed outside the microscopic scale. On the other hand, there is a multitude of robust effects that rely on these microscopic predictions. These effects form the foundation of a huge set of macroscopic technologies, ranging from the color palette of light-emitting diodes in a display to the marvelous degree of sensitivity in the detectors of a large particle collider.

Because quantum mechanics is the model of reality that the laws of physics dictate, its behavior must also govern the operation of any theoretical or hypothetical information processing device. In this work, we investigate the second type of digital quantum computer, commonly known as a Quantum Cloud Computer. At the most basic level, a cloud is a reference to a remote point in a communications network. For communications purposes, cloud computing is distributed implementations of application software, a kind of distributed computer that accumulates contributions from a large number of sites to create an exascale amateur computer. More prosaically, a cloud computer running a quantum algorithm takes as its input a set of classical bits, and at the end of the computation, the output of the algorithm is read out by measuring the state of some quantum system.

2.2. Quantum Computing Principles

The most important property of quantum mechanics is the superposition principle. It allows storing and manipulating many states, as present in the computer's bits, simultaneously. This leads to parallelism and an extremely fast aspect. Quantum mechanics also provides a non-local type of correlation between states, which is called entanglement. The qubits can therefore store a lot of applications in a short number of qubits, i.e., quantum states. Several qubits can also be connected by a quantum entangled state to store a lot of information in a short number of coupled qubits. In quantum mechanics, measurement induces a collapse of the system's wave function, losing the superposition state. Some properties are then observed by measuring them, while others are not because several states cannot coexist at the same time. This becomes an issue when designing and programming a quantum computer, particularly in finding the right algorithm that allows switching states and dimensions of the qubit. Superposition and entanglement are the two unique properties explicitly present in a quantum computer. They are binary and cannot be retrieved or duplicated on a classical computer. A large number of systems or processes have been proposed to model a qubit and manipulate it. Some physical structures used to store an artificial qubit are the superconducting transmon, the single-electron, the quantum dot, the nitrogen-vacancy center, the trapped ion in a Paul trap using the electronic level or the vibronic mode, the color center of a diamond crystal, and to a lesser extent, the topological qubit. All these qubit models have advantages and drawbacks, and the concept of a quantum multilevel system in general is universal, allowing for the connection of qubits, processing information, and performing circuits.

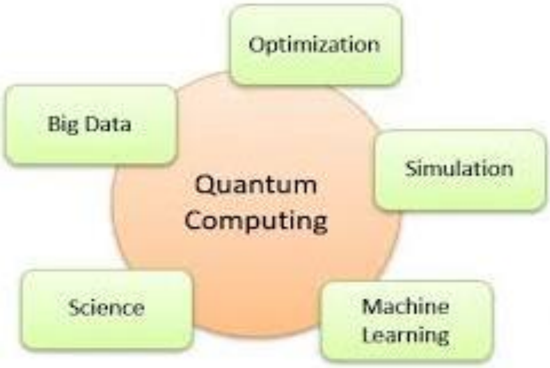


Fig 2: Quantum Computing

3. Quantum Cloud Computing

Quantum cloud computing is the fusion of two emerging concepts: quantum computing and cloud computing. As of today, advances in quantum computing are made public either in scientific publications, patents, or products. Due to the complexity of the technology, as well as high entry costs and a long time to market, quantum computing is expected to operate on a B2B cloud business model where quantum gate time is sold on a per-use basis as 'quantum computer cycles.' The current climate of secrecy surrounding quantum technology also results in underutilized quantum machines. Quantum cloud marketplaces add another layer on top of quantum computers by bringing consumers in contact with the owners of quantum machines, business models, and third parties that provide software and services. Companies and academia will find quantum cloud marketplaces invaluable for finding help with their complex and mission-critical problems.

Many software stacks have been developed for programming quantum computers, from low-level procedures to entire development environments. The latter allows for writing code at a high level of abstraction suitable for quantum algorithms and is equipped with both a rich library of primitives and automatic tools for memory and time optimization. It is reasonable to expect that the expectations of both experienced and new developers about future quantum systems will resemble today's cloud paradigms, characterized by features like elasticity, high performance, and virtualized pay-per-use. On the quantum cloud, the developers' needs will include insight into traditional aspects, as well as the capacity to deploy the most advanced quantum algorithms in a reliable and cost-efficient way.

3.1. Definition and Overview

Quantum cloud computing involves using a cloud computer to make calculations designed for quantum computers, also known as universal quantum simulators. Like conventional cloud computing services, quantum cloud computing provides scalable and on-demand resources and a pay-per-usage model. However, workloads on quantum cloud computers involve quantum-bit circuits, and these calculations are executed by a quantum chip, not conventional processors. Quantum chip manufacturers also use quantum cloud computers to verify the operations and system performance of the quantum chips. Users can send quantum-bit circuits to the quantum computer using a classical computing processor. They can also define and execute dynamic, or adaptive, quantum-bit circuits that enable classical computers to adapt to the needs of quantum cloud computers in real-time. This feature optimizes productivity by substituting classical and quantum resources, thus avoiding wasting quantum resources. The current development and practical use of quantum cloud computing on quantum computers form a powerful supercomputer composed of classical and quantum systems.

Quantum computers are still only at the research and development stage. The most successful AI fields, such as deep learning, use general-purpose architectures and dynamically allocated memory. When existing R&D technologies could no longer meet the increasing amount of data and parameters with more computing power, quantum cloud computers could compensate for their natural deficiency and achieve deep learning. The fault tolerance and matching of error-correction optical chips for quantum general-purpose quantum computing machines seems to be a distant dream. The current research trend in quantum computer development still uses gate-model programs. The point of practical interest is in developing an eager gate model algorithm and designing the most suitable quantum cloud computers that can execute these calculations rapidly. Combining error-correction gate-model calculations with quantum cloud computing has also attracted much attention.

3.2. Advantages and Challenges

Now that we have examined some external influences on the adoption of QCC, we can examine some QCC-specific advantages and challenges. QCC is not limited to simulating quantum systems; there are other classes of problems where a QCC approach is expected to perform better compared to a traditional cloud model. Quantum optimization allows QCC to swiftly find the absolute value of large combinatorial optimization problems, while the quantum search algorithm promises better performance for NP-hard decision problems. This may suit other areas of non-quantum computing without the need to use the power provided by digiscoping.

We have already touched upon some application areas of QCC, such as drug discovery and optimization of machines and logistics. Computationally efficient quantum image processing can also be achieved by manipulating the qubits. Technological advancements incorporating spin qubits and integration with semiconductor technology promise not only smaller QCC than the current superconducting solutions but also to directly benefit from the high level of integration, parallelism, and data storage of current classical computers. Spin qubits are predicted to be faster, cheaper, and more robust over a wider temperature range than superconducting qubits. On the other hand, there is also potential in bottom-up hardware adaptations designed particularly for quantum computing that mine a clever quantum approach.

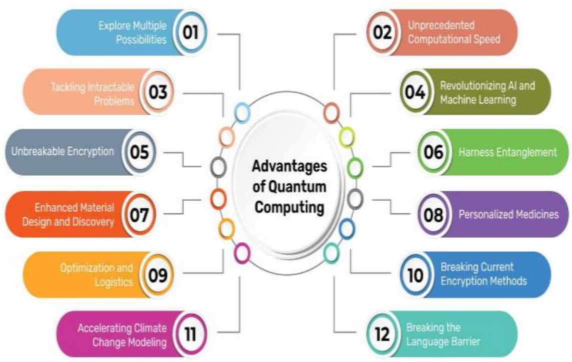


Fig 3: Advantages of Quantum Computing

4. Impacts on Cryptography

We pay particular attention to some of the impacts quantum cloud computing can be anticipated to have in the area of cryptography. This area is worth examining because any practical realization of a quantum computer could have the potential to defeat the public key encryption methods in widespread use. The wide variety of essential applications this technology underpins spur us to ask how the disruptive destruction of this billion-dollar sector may affect modern life. In contrast, the potential impact on other emerging applications tends to be rather overlooked. This may be because advances and innovation in data storage, processing efficiency, and machine learning make more headline news generally, and hence tend to stimulate users to consider the beneficial impacts of quantum computing on their specific applications.

It is a matter worthy of note that organizations that have the most to lose from the resultant encryption crisis, such as banks, internet vendors, cloud service providers, and government agencies, have so far shown relatively little interest in the particular potential of quantum cloud computing. Their response may be partly due to an expectation that an encryption crisis would provoke swift developments in the field of quantum key distribution, offering the prospect of safety through quantum. This has some grounds for being a reasonable assumption. Market and technology developments that are conducive to the security and efficiency of quantum communication already underpin an advanced network fabric of telecommunications. Indeed, for high-end data security, there are already in place commercial services based on quantum cryptography.

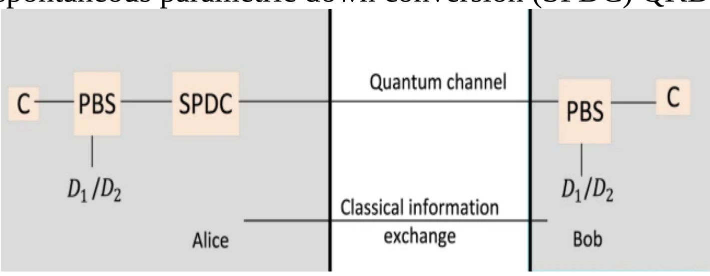
4.1. Current Cryptographic Systems

4.1. Current Cryptographic Systems

I will start my presentation with a summary of some current cryptographic systems and their relation to machine learning in chapter 4.2. Ideally, we would like to maintain our current security protocols in the quantum setting. To transition to post-quantum cryptography, lattice-based cryptography will be used to safeguard against any potential quantum attacks. Asymmetric key encryption, or public key cryptography, is often described using several concepts including key generation, encryption, and decryption. Public key cryptography is defined by mathematics. Despite the promises made by factor-based systems, classical computing power proved that large innovative prime number lengths were insufficient to guarantee encryption levels capable of withstanding a simple attack on time.

A better, more costly approach is to consider symmetric key encryption. For any message that we want to keep secret from anyone who doesn't intercept it, we must develop and distribute a secret key first. The message can then be encrypted. We can then send the encrypted message to a receiver, who can decrypt the message using only the secret key. The goal of the identification protocol is to determine that the entity with a particular key is the key. Approaches like authentication and key exchange are often used in secure data transmission. Because only two parties have exchanged the position with which they have been linked, this protocol is particularly invaluable. Despite its current use, symmetric key cryptography can be vulnerable to a significant threat from a potential quantum machine. Currently, symmetric encryption is considered safe if one is prepared to explore only a small portion of the keyword space since traditional computers can conduct severe current-depth exploration attacks.

Equation 2: A schematic diagram for the Fibonacci- and Lucas- valued entanglement spontaneous parametric down conversion (SPDC) QKD.



4.2. Quantum Cryptography

Quantum cryptography can provide strictly private communications, guaranteed by the laws of nature. It combines the security of physical systems governed by fundamental laws of quantum mechanics and some digital message exchange techniques. In a quantum key distribution protocol, two users can produce identical shared random information that can be used to generate a secret key that is both never transmitted and impervious to algorithmic complexity attacks. Despite the exponential computational costs associated with factoring large numbers, fast classical computer decryption, and even superior quantum computer agility, brute force attacks on today's public/private encryption exchanges remain the only known means for breaking widely utilized cryptosystems. Quantum Key Distribution enables communication security that is guaranteed by the physical laws and, except for a limited amount of information to reduce errors, does not require trusting the computational assumptions that form the basis for today's cryptographic security.

Quantum cryptography is made possible by quantum physics and has several attractive properties that will revolutionize network security. Through the powerful laws of quantum physics, we can configure quantum cryptographic systems in such a way that physical eavesdropping on the exchange of secret information can be excluded, even in principle. Furthermore, public channels can be wholly sufficient for the acting parties to check each other's data and certify that no third party has information about the data. On the downside, quantum cryptography is expensive in terms of resources, both in terms of hardware and in terms of information outlays. This account allows the construction of quantum key exchange systems without attacking.

Another potential benefit from quantum effects is the development of quantum codes. Well-known encryption and error correction methods preserve data integrity and confidentiality, as long as the average error rate fits certain conditions and the process is preceded by a random number exchange. However, the average error rate is physically relevant, as the error rate conditions data alteration vulnerability. Quantum codes were initially foreseen to perpetuate quantum processing and communication in error-prone environments. Current quantum error correction code designs are extensions of stabilizer codes. Such quantum devices can in practice provide limited benefits concerning the secure quantum key exchange and could perhaps be attributed if they are physically possible given the technology advancements.

5. Impacts on AI

Recent studies have theorized and attempted preliminary expert systems to infer interventions in quantum contexts, run reinforcement learning, and apply quantum computing applications beyond solving hard multivariable optimization tasks. A quantum computational network combining physical quantum memory, quantum processing, and a multi-layer neural network capable of deep learning with ultimate analytics speed was developed and is currently being commercially refined for availability as an AI accelerator. At a large scale, the co-designed programming interface should allow seamless integration with leading AI software stacks to, in particular, enable hitherto unimaginable acceleration of common recurrent, generative adversarial, cryptographic neural networks. The hardware developments in the co-design are also being assisted by the expectations and competitive comparisons associated with quantum computing, which should induce benchmarks, architectures, and new features to quantum AI accelerators.

Such reactive measures could easily give way to progressive phases of the technology, reshaping deep learning applications completely. Indeed, when entanglement or discord are created between real and virtual quantum states, newer AI models will emerge and forecasting accuracy should also be radically boosted. Due to such projections, recipients of high-end digital computing leapfrogs in the so-called blossoming fourth industrial revolution during the final quarter of this decade should possibly not exclusively belong to the very few in the traditional G8 or privileged races. Quantum cloud computing could democratize transformative AI components with direct experience in quantum technology and make local digital proliferation beneficial to more people around the world by providing renaissance opportunities through quantum computational advances.

5.1. Quantum Machine Learning

The advances in quantum computing can potentially decrease the energy consumed during training. The compression of the resource problem could relieve these energy constraints and help to establish fast debugging, allowing for more iterations during learning and accelerating machine learning development. A second line of development focuses on the use of quantum computing to design and implement algorithms that mimic or excel in logical functions that are naturally addressed with quantum systems. Following the mathematical structure of quantum mechanics, quantum computing is specialized in eigenvalue problems that can benefit large-scale digital computation. It can speed up problems of complexity associated with the interplay of many-body quantum coherence. Furthermore, quantum computing is optimal for simulating the dynamics of isolated quantum systems, expressed in differential equations developed in the mathematical formulation of quantum computing. The dynamic evolution of quantum systems is hard to capture by a classical computer; hence, quantum computing is essential. Applications to quantum systems range from quantum material science to simulating quantum field theories in high-energy physics and quantum chemistry simulations.

The development of quantum computing technologies and software applications is still in its infancy, with diverse problems in fundamental physics, related sensory and data collection, methodologies to translate findings into usable algorithms, and hardware still being unstudied. Yet the toolkits of quantum computers are already seen in the mathematically rich problems inherent in entanglement, manipulating high-dimensional control circuits, and scalable linear optical operations that yield the appealing promise of quantum computing to revolutionize machine learning and artificial intelligence, which surfaced as early experiments in its feasibility. The surge in hybrid classical-quantum algorithms for optimization problems, driven by the significant efforts to develop a quantum advantage on NISQ devices, is the groundwork upon which quantum-enhanced machine learning is now being born. The benefit that standard learning processes would gain is, for instance, an exponential speedup in the processing times, increasing its viability for big data inferred with a reduced grid search space.

5.2. Quantum Neural Networks

Implementing quantum machine learning (QML), including quantum neural networks (QNNs) and quantum-enhanced support vector machines, has been attracting growing interest in the quantum community. Following the first theoretical concept in 2017 of a quantum Boltzmann machine using superconducting circuit quantum electrodynamics, various quantum neural network architectures have also been proposed based on concepts from traditional machine learning, deep learning algorithms, quantum state preparation, quantum algorithms, quantum approximate optimization algorithm, and tensor network state evolution to facilitate training and classification. There is a wide variety of QNNs trained by different quantum or hybrid quantum-classical learning methods. Existing QNN proposals can be generally grouped into three classes: 1) modification of traditional quantum algorithms; 2) classical-to-quantum back-propagation; and 3) inheriting classical neural network structures.

The modifications on traditional quantum algorithms focus on the upgrade from traditional quantum algorithms to QNNs by increasing the scalability, capacity, and improved efficiency of quantum algorithms for training classical machine learning models such as support vector classifiers. The QNN training algorithm generally exploits a small-sized quantum device to train another large quantum data; hence, it may be realized via hybrid quantum-classical methods, with quantum processors enhancing the performance of the traditional stochastic gradient descent method for quantum machine learning. Using hybrid architectures to train QNNs via reinforcement learning, including the policy gradient, deep Q-learning, and evolutionary strategy, may offer promising benefits. In the middle, quantum circuit learning assumes a circuit ansatz structure of the trained model and uses the quantum device to find unitary operations such that when the input quantum state evolves through the quantum circuit, it generates the output close to those from the model to be trained.

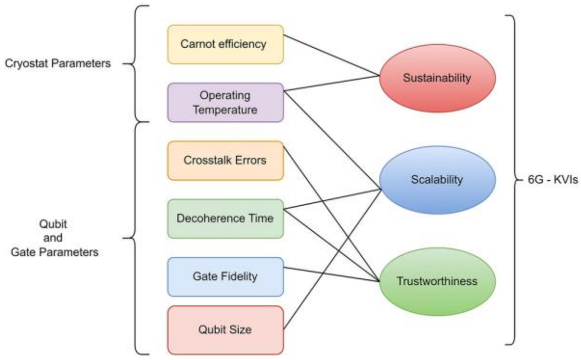


Fig 4: In-Network Quantum Computing

6. Impacts on Pharmaceutical Innovation

In pharmaceutical innovation, classical computing has been used to understand the mechanisms of molecular interaction within the complex environment of a cellular system. With the somewhat recent emergence of AI, the pharmaceutical application of AI was used to leverage the combined knowledge of all human drug discovery to help discover new drugs more quickly and cheaply. This is of value because the time it takes to translate a molecular idea into a precision medicine solution, such as a new drug, can take on the order of twenty years, costing over $2 billion, and only having about a 12% success rate from preclinical to market. Quantum computing has the incredible potential to speed up the drug discovery pipeline, especially when drug discovery is inherently derived from a molecular principle and the application of quantum mechanical ideas can drastically speed up the modeling process of how the drug affects an organism. The ability to model these impacts and biological processes of pharmaceutical innovation more realistically using quantum computers can be used to enhance drug discovery and design, produce more robust forecasting predictions, and ultimately, generate a higher success rate of precision treatments from molecule to market. The impacts on pharmaceutical innovation can be categorically broken down by its ability to model and the speed to solution for any given molecule with a specified quantum cloud computer.

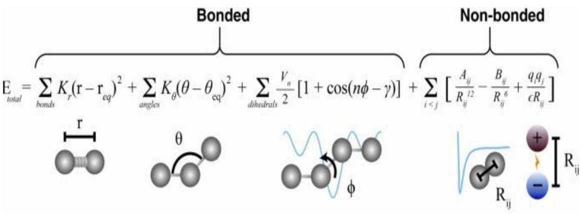
By being able to model the biological interactions of the drugged molecule more effectively, pharmaceutical innovation can benefit by understanding new ways to utilize enhanced quantum effects to create more intelligent designs that may have fewer side effects for a more robust target, relevance, safety, and efficacy on a patient-to-patient basis. We posit a method by which quantum mechanical models for the pharma industry can be used to create detailed mechanisms of action that the compound is taking in the physiological system. It is logical to model the targeting behavior of the drugged molecule using quantum mechanical models because the biological process is simply that - a quantum mechanical model initiated by a drug molecule designed to target a biological receptor. With a quantum cloud computer, we can use more advanced methods to solve the Schrödinger equation which enables exponentially larger biochemical machinery to be modeled to therefore have better forecasted populations of patient individual responses resulting in a narrower range of responses in a patient population.

6.1. Drug Discovery and Development

One of the key emerging commercial applications of quantum cloud computing is the use of variational hybrid algorithms to model molecules and chemical reactions. Quantum circuit-specific building blocks are designed to perform certain quantum operations. Combining both classical and quantum machines provides an efficient method to simulate quantum systems. This is a priority for quantum devices given the complex interactions in small molecules, which lie beyond the capability of digital computers, even the largest and fastest supercomputers.

Recent advances in digital computing, together with current and proposed modes of bench-top near-term and useful fault-tolerant error-corrected quantum devices, have been, in part, driven by practical applications in drug discovery and development, which are currently hampered by quantum computations required for accurate simulations of both small and large molecules. Drug discovery is currently limited by the capabilities of advances in supercomputing hardware and software that permit quantum simulations to become fast enough to perform useful molecular simulations. Concerning the question of the number of qubits and their fidelity, it has been shown that 100 error-corrected logical qubits with 99% fidelity, approximately 100,000 surface code qubits, approximately 100 ms gate time, and approximately 1000-cycle ancilla cycles would be sufficient to solve a high-dimensional dissociation of H2 energy surface. The key challenge of pharmaceutical innovation has been addressed via NISQ technologies and established leaders in supercomputing with the recently completed supercomputer. The use of highly accurate Lanczos methods reveals the ground state properties of molecules exhibiting bond dissociation at equilibrium separation, which is important in the accurate prediction of reactions comprising multiple molecules.

Equation 3: Molecular Dynamics Simulations and Drug Discovery



6.2. Personalized Medicine

To many, developing drugs seems to be a very exclusive thing—either you're a big pharma company or you are not. The need to spend a colossal sum of R&D money to launch a new drug into the market excludes the public from this power. What can small companies or even academic researchers do in this respect? The answer is a lot of things. In this era of AI, innovation is less about drug discovery and more about drug development and prescription. With cloud computing, the power can be leveled to everyone who cares. In classical computer architecture, when we want to do something hard if we care, we can figure it out.

Personalized medicine will benefit from quantum cloud computing in two ways: on the drug development side, quantum cloud computing tools can dramatically hasten the process of drug design and development. On drug prescription, quantum machine learning and artificial intelligence can predict drug sensitivity to patient genotype and disease state, and provide insights into targeted therapies. Data supports that quantum-like computation can significantly advance personal medicine goals and revolutionize drug and disease treatment. We are at the right time at a crossroads with a unique opportunity to rapidly and exponentially advance healthcare sectors on multiple fronts.

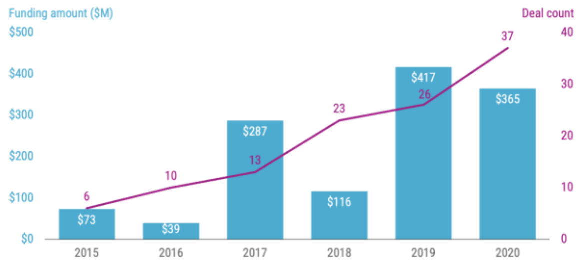


Fig 5: Quantum Computing Deals are on the Rise
Disclosed Deals & Equity Funding ($M), 2015 – 2020

2. Conclusion

A standard PC is almost enough to discuss research use cases and commercial projects. A Cloud-based platform with appropriate software libraries should be the interface. Ordinary programmers should be able to understand, and executives benefit, from the interaction. A quantum application on this developing kind of cloud is, mainly, a tool in the hands of experts. But today and tomorrow, expected rapid development will have wide social and economic impacts. These platforms in the domains of cryptography, artificial intelligence, and quantum simulations play very different roles. However at this moment of the supposed "quantum supremacy," we can't yet predict how and how much they are relevant. After all, problems that have for standard algorithms exponential complexity related to system size, and which can't even be approximated to reasonable degrees of precision because of, for instance, local minima, are just a tiny subset of all the math and physics problems that could benefit from quantum digitalization. Even relatively simple problems are useful to discuss.
A noisy, intermediate-scale quantum device is characterized by several limits concerning the dream of a universal quantum computer containing a huge number of qubits with perfect control electronics on which error-correcting codes can be applied. Today's research and commercial realization of quantum technologies can be described as a race to attain quantum advantage over standard computing platforms. It is about time to discuss a wider set of problems that a limited-size quantum processor can do. The mentioned properties underlying quantum advantage for systems of interacting quantum particles are not necessary for a quantum processing polymath to exploit a NISQ computer. For that purpose, one should focus on problems that are hard either because the numerical accuracy of standard methods is impaired, or because the resources required swamp the budgets at disposal. Focusing on tasks where a quantum computer can be pertinent in today's world of AI, specifically where quantum advantage would be evident, is also interesting for the longer term. It is a way to better understand the benefits of large-scale quantum computing. Positions about the impact of quantum computing on IT security have accentuated this aspect of quantum advantage.

7.1. Summary of Findings

To capture the essence of the report, it is important for the summary of findings to be as simple and all-encompassing as possible. The following are some essential factors of the complete use case: - Custom quantum circuit beyond the capabilities of classical simulation - The speedup granted by quantum advantage on specific optimization problems - Quantum key distribution to achieve a provably secure means of communication - Risk assessment of quantum communications - Performant and highly scalable quantum computing capacity - Artificial intelligence version compiled for quantum computing - Solution of high-value optimization and hardware validation - Calculation of ground-state energy for a molecular system model across drug studies - Infrastructure with quantum cloud and classical computer - Collaboration on the network with other companies. With a growth scale and sustainability trends unique to quantum computing science, quantum cloud computing allows us to realize these massive capabilities as they relate to classical computing. At the heart of the enterprise would be a quantum processor that enables advanced features of interest that do not require specific knowledge of quantum physics at the user end.

7.2. Future Research Directions

This section provides a guidepost into current granular pathways for future research in harnessing advances of quantum cloud computing within business domains that materialize the missions of the field of quantum cloud computing itself. Rather than summarize research agendas reported frequently within academic journals, we focus uniquely on business domains spanning cryptography, conversational AI, and pharmaceutical AI.

7.2.1. Cryptography In the historical tech governance of both government and business, intelligence centers have consistently tilted towards the field of encryption to establish economic and defense-unifying primitives. Research is needed to model the pragmatic outcomes of quantum-specified cryptographic agility in different sectors of the global economy. The ROI at risk due to lack of cybersecurity research establishes an actionable implication in establishing data security architectures within standard integrative technologies employed in business operations in the context of leveraging a quantum internet.

7.2.2. Conversational AI Quantum cloud computing will contribute to superintelligence in more than one way under real-world constraints collectively held by hyperscale cloud data governance, financial governance, and technological design governance. For instance, quantum-inspired cloud computing could be an attractive approach compared to traditional simulation-based development techniques for digitally transmissive pharmaceutical manufacturing and health services data due to these theory constraints. Cloud quantum computing may offer superintelligence jumpstarts with dramatic factors over traditional AI training under demand-side financial constraints on today's leading AI development platforms.

7.2.3. Pharmaceutical AI For enterprises and authorities looking to compare quantum volume and domain of problem areas relevant to the terascale cloud quantum market moving forward, a critical issue is understanding the overlap between basic problems, problems where special implementation benefits may abound from quantum machine learning and commercially relevant domain problems that should attract interest and collaboration from classical collaborators. A response about a basic type of problem would need a trusted application for FDA approval or following principles by the aspiration as a viable enterprise array of use, much like cloud quantum attempts to be.

8. References

1. Avacharmal, R. (2022). ADVANCES IN UNSUPERVISED LEARNING TECHN IQUES FOR ANOMALY DETECTION AND FRAUD IDENTIFICATION IN FINANCIAL TRANSACTIONS. NeuroQuantology, 20(5), 5570.
2. Aravind, R., Shah, C. V., & Surabhi, M. D. (2022). Machine Learning Applications in Predictive Maintenancefor Vehicles: Case Studies. International Journal of Engineering and Computer Science, 11(11), 25628–25640.https://doi.org/10.1853 5/ijecs/v11i11.4707
3. Mahida, A. (2022). Comprehensive Review on Optimizing Resource Allocation in Cloud Computing for Cost Efficiency. Journal of Artificial Intelligence & Cloud Computing. SRC/JAICC-249. DOI: doi. org/10.47363/JAICC/2022 (1), 232, 2-4.
4. Mandala, V., Premkumar, C. D., Nivitha, K., & Kumar, R. S. (2022). Machine Learning Techniques and Big Data Tools in Design and Manufacturing. In Big Data Analytics in Smart Manufacturing (pp. 149-169). Chapman and Hall/CRC.

5. Perumal, A. P., Deshmukh, H., Chintale, P., Desaboyina, G., & Najana, M. Implementing zero trust architecture in financial services cloud environments in Microsoft azure security framework.
6. Kommisetty, P. D. N. K. (2022). Leading the Future: Big Data Solutions, Cloud Migration, and AI-Driven Decision-Making in Modern Enterprises. Educational Administration: Theory and Practice, 28(03), 352-364.
7. Bansal, A. Advanced Approaches to Estimating and Utilizing Customer Lifetime Value in Business Strategy.
8. Korada, L., & Somepalli, S. (2022). Leveraging 5G Technology and Drones for Proactive Maintenance in the Power Transmission Industry: Enhancing Safety, Continuity, and Cost Savings. In Journal of Engineering and Applied Sciences Technology (pp. 1–5). Scientific Research and Community Ltd. https://doi.org/10.47363/jeast/2022(4)260
9. Avacharmal, R., & Pamulaparthyvenkata, S. (2022). Enhancing Algorithmic Efficacy: A Comprehensive Exploration of Machine Learning Model Lifecycle Management from Inception to Operationalization. Distributed Learning and Broad Applications in Scientific Research, 8, 29-45.
10. Shah, C., Sabbella, V. R. R., & Buvvaji, H. V. (2022). From Deterministic to Data-Driven: AI and Machine Learning for Next-Generation Production Line Optimization. Journal of Artificial Intelligence and Big Data, 21-31.
11. Mahida, A. Predictive Incident Management Using Machine Learning.
12. Mandala, V., & Surabhi, S. N. R. D. (2021). Leveraging AI and ML for Enhanced Efficiency and Innovation in Manufacturing: A Comparative Analysis.
13. Perumal, A. P., & Chintale, P. Improving operational efficiency and productivity through the fusion of DevOps and SRE practices in multi-cloud operations.
14. Bansal, A. (2022). Establishing a Framework for a Successful Center of Excellence in Advanced Analytics. ESP Journal of Engineering & Technology Advancements (ESP-JETA), 2(3), 76-84.
15. Korada, L. (2022). Low Code/No Code Application Development - Opportunity and Challenges for Enterprises. In International Journal on Recent and Innovation Trends in Computing and Communication (Vol. 10, Issue 11, pp. 209–218). Auricle Technologies, Pvt., Ltd. https://doi.org/10.17762/ijritcc.v10i11.11038
16. Avacharmal, R. (2021). Leveraging Supervised Machine Learning Algorithms for Enhanced Anomaly Detection in Anti-Money Laundering (AML) Transaction Monitoring Systems: A Comparative Analysis of Performance and Explainability. African Journal of Artificial Intelligence and Sustainable Development, 1(2), 68-85.
17. Vehicle Control Systems: Integrating Edge AI and ML for Enhanced Safety and Performance. (2022).International Journal of Scientific Research and Management (IJSRM), 10(04), 871-886.https://doi.org/10.18535/ijsrm/v10i4.ec10
18. Mahida, A. (2022). A Comprehensive Review on Ethical Considerations in Cloud Computing-Privacy Data Sovereignty, and Compliance. Journal of Artificial Intelligence & Cloud Computing. SRC/JAICC-248. DOI: doi. org/10.47363/JAICC/2022 (1), 231, 2-4.
19. Chintale, P. (2020). Designing a secure self-onboarding system for internet customers using Google cloud SaaS framework. IJAR, 6(5), 482-487.
20. Bansal, A. (2022). REVOLUTIONIZING REVENUE: THE POWER OF AUTOMATED PROMO ENGINES. INTERNATIONAL JOURNAL OF ELECTRONICS AND COMMUNICATION ENGINEERING AND TECHNOLOGY (IJECET), 13(3), 30-37.
21. Laxminarayana Korada, Vijay Kartik Sikha, & Satyaveda Somepalli. (2022). Importance of Cloud Governance Framework for Robust Digital Transformation and IT Management

at Scale. Journal of Scientific and Engineering Research. https://doi.org/10.5281/ZENODO.13348757
22. Dilip Kumar Vaka. (2019). Cloud-Driven Excellence: A Comprehensive Evaluation of SAP S/4HANA ERP. Journal of Scientific and Engineering Research. https://doi.org/10.5281/ZENODO.11219959
23. Mahida, A. A Review on Continuous Integration and Continuous Deployment (CI/CD) for Machine Learning.
24. Chintale, P. SCALABLE AND COST-EFFECTIVE SELF-ONBOARDING SOLUTIONS FOR HOME INTERNET USERS UTILIZING GOOGLE CLOUD'S SAAS FRAMEWORK.
25. Bansal, A. (2021). OPTIMIZING WITHDRAWAL RISK ASSESSMENT FOR GUARANTEED MINIMUM WITHDRAWAL BENEFITS IN INSURANCE USING ARTIFICIAL INTELLIGENCE TECHNIQUES. INTERNATIONAL JOURNAL OF INFORMATION TECHNOLOGY AND MANAGEMENT INFORMATION SYSTEMS (IJITMIS), 12(1), 97-107.
26. Laxminarayana Korada. (2022). Optimizing Multicloud Data Integration for AI-Powered Healthcare Research. Journal of Scientific and Engineering Research. https://doi.org/10.5281/ZENODO.13474840
27. Mahida, A. A Comprehensive Review on Generative Models for Anomaly Detection in Financial Data.
28. Bansal, A. (2021). INTRODUCTION AND APPLICATION OF CHANGE POINT ANALYSIS IN ANALYTICS SPACE. INTERNATIONAL JOURNAL OF DATA SCIENCE RESEARCH AND DEVELOPMENT (IJDSRD), 1(2), 9-16.
29. Korada, L. (2021). Unlocking Urban Futures: The Role Of Big Data Analytics And AI In Urban Planning–A Systematic Literature Review And Bibliometric Insight. Migration Letters, 18(6), 775-795.