International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Quantum Computing Improves Efficiency and Productivity in Financial Institutions

[1]Jabin Geevarghese George, [2]Manoj Kumar Vandanapu

Submitted: 07/02/2024 **Revised**: 15/03/2024 **Accepted**: 21/03/2024

Abstract: Various ways in which quantum computing may transform the financial industry are also explored in this research, and this includes its potential to deal with the problems that we are currently faced with and the opportunities that it may bring. The research starts with a general survey of the existing situation in the area of quantum computing technology which contains lowering of costs and increase in effectiveness. It proposes how quantum computing can vastly change the current performance of banking regarding fraud detection, improvements in risk management measures, and better optimization of various financial process. Additionally, the report reviews the barriers and possible risks that exist in the banking industry implementing quantum computing techniques and, thus, offers crucial points for the successful mitigation of these risks. This study's outcomes are expected to provide banks with helpful information on how they can exploit the capacities of quantum chips to reinforce their data security strategies and assert themselves against their competitors. The research results present the findings that are practical for the strategic application of quantum computing in the banking sector, identifying an opportunity for the transformative effects of the technology to start changing the expensive and inefficient banking processes and giving rise to a safe and efficient financial environment.

Keywords: *Quantum Computing in Finance, Banking Innovation, Financial Risk Management, Quantum Algorithms in Finance, Process Optimization*

1. Introduction

The banking and financial sector is on the edge of an unprecedented technological revolution which is a big opportunity at the same time a big challenge for its future. The most progressive technology in our era- Quantum computing, based on purely quantum concepts, has the potential to dramatically alter outdated banking processes and resolve tough financials issues. With qubits processing the data instead of classical algorithms which require 0s or 1s, quantum computing introduces a new and more powerful paradigm. In particular, due to a phenomenon particular to quantum physics, the basic units of quantum computing can occur in this fashion, in multiple states at the same time through superposition [2].cIt is a gift of this system that the processing ability scales not only

in size but speed as well, which classical computers either could not or they never could dream having done. Quantum computation has a direst and foundational in banking transformation that can be used in many different ways. Mitigating and optimizing safety as risk management and ever-growing portfolios represents major concern could be doable through it. This is the kind of management solutions that the banks can never miss on due to the plethora of the advantages it undertakes.

[1]*Financial Technology Transformation Expert, TCS, New Jersey USA, 07002, jabing28@gmail.com*
[2]*Corporate Finance and Transformations Expert, , Aurora IL, 60502, email: manoj.dhs@gmail.com*

Quantum computing opens to doors to a promise of the disruption of cryptography where the security of information encrypted by traditional methods could be severely put in doubt unless quantum-resistant encryption techniques that are hard to crack are developed immediately [3]. Financial institutions, indeed, are well-oriented on the security algorithms for saving customers private data and safe transacting. Quantum computers will have the ability to break nowadays cryptographic techniques which utilize the nowadays challenge for the cracking of huge prime numbers. Even though quantum encryption provides most secure communication ways such as quantum key distribution, their practical security still remain an open technological problem which is less investigated empirically by hackers aside from theory.

Through exploiting the quantum computing opportunities, the finance institutions thus can guarantee nailing the most irreproachable of the clients' confidential data.

Although quantum annealing may at present appear as highly complex, it could in the near future have a significant impact on streamlining financial transactions in conventional banking. Once banks encounter huge amounts of data and complicated computations they start dealing with the equations that usually they wouldn't. As such, banks tend to solve complex problems, which eventually improve risk assessment, portfolio management, and decision-making.

However, commercial application of quantum computing is a bit far away for the time being, as it is reasonable to suppose that there will be major technological barriers to be overcome until then, but its obvious potential, to change the practice of the core banking sector and even redefine some functions, is highly awaited.

With the developments in the respective banks, the bases are being constructed now for innovation and efficiency in banking during the time the technology is investigated and adopted. This research paper delves into the following set of research questions:This research paper delves into the following set of research questions:

RQ1: What crucial stepping stones got <quantum computing system> to be everywhere it is now, and how do they affect its current place in modern world?

RQ2: By means of quantum computing, how can optimization be attained in financial activities of the banking sector, and which processes will highly benefit from this?

RQ3: Why does quantum computing not take a major part in banking processes and which challenges stand in the way to its full-scale implementation?

RQ4: What are the key security concerns and the role of quantum computing for the banks through the strategic incorporation of quantum technology; and what is the goal?

2. Background

Quantum mechanics, a discipline of science on which the behaviour of the matter and energy of the tiniest components depend is at the core of quantum computing. Quantum bits, also referred as qubits, can be represented as the combination of 0 and 1 states. Different from that in classical bits, qubits can exist superposition of 0 and 1 states simultaneously. Whilst carrying their processing, quantum computers show that property as superior for such tasks which cannot be calculated within a short period with classical computers [5].

Here, we will use Dirac notation to express a qubit in a superposition of states [6]; "see equation 1:Here, we will use Dirac notation to express a qubit in a superposition of states [6]; see equation 1:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \tag{1}$$

Were

- $|\psi\rangle$ are the qubit's foundational states.
- α and β are complex values that, respectively, reflect the probability amplitudes of the qubit being in state $|0\rangle$ or $|1\rangle$ respectively.
- $|0\rangle$ and $|1\rangle$ are the basis states of the qubit.

The squared magnitudes of the amplitudes represent the odds of measuring the qubit in either state 0 or level 1:

The probabilities are given by equation 2:

$$P(0) = |\alpha|^2, \quad P(1) = |\beta|^2 \tag{2}$$

Furthermore, in order to meet the normalizing criteria,

1) Quantum Gates and Operations: From qubit manipulation to quantum computation, quantum gates constitute the fundamental components of quantum circuits [7]. A basic gate that produces superposition is the Hadamard gate (H). The Hadamard gate is represented mathematically by the matrix in equation 3 [8]":

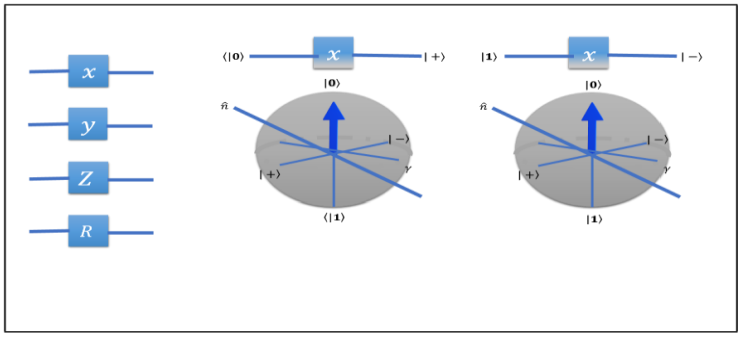

Fig 1: Quantum Gates

$$H = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{3}$$

Applying Hadamard gate to the qubit in the state played would affect the state.

***2) Quantum Entanglement*:** One main feature in quantum computer science is quantum entanglement. Examine the following two-qubit system in an entangled state, which is a Bell state [9], see equation 4: The Scopus database served as our principal tool in attaining all the literature. In the same way, papers that have not been published are excluded from the replicated study. Although figure 3 illustrates a distribution of the publications from this database in this database, there is no available information about the other two databases for

this analysis. The following 6 databases are being offered Scoops, ACM, IEEE, Springer, ProQuest, and T&FS.

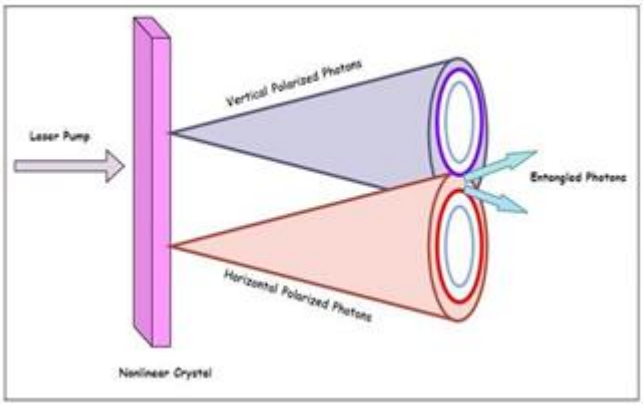

Fig 2: Quantum Entanglement Illusion

3. Methodology

We employed the subsequent search query: "Quantum Computing" AND “Banking Industry" AND (Comp Sci" OR " Engi-neering") AND (re" AND (English). With over 100 papers about the topic searched after a period from January 2018 to September of 2023 appearing. The image indicates the periods of the articles in the media.

We utilized the subsequent eligibility criteria for each paper:We utilized the subsequent eligibility criteria for each paper:

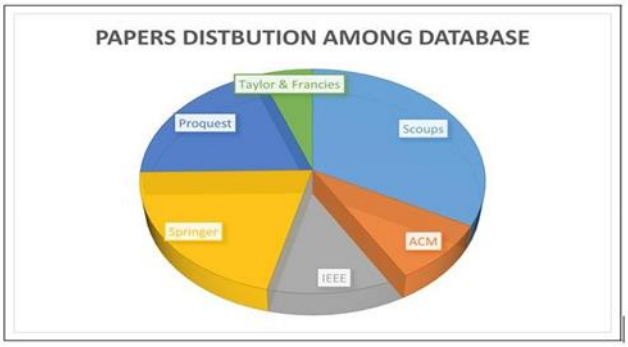

Figure 3: Distribution of Papers across Databases

The topic we also cover about quantum computing in financial services. The critical part of my information management plan is that all articles are taken from journals, conferences or reputable online sources

A careful observation of the search would reveal that papers without referees were not included.

Initially we focused on the main details, we listed the facts such as the paper’s title, year of publication, the authors list and the publisher.

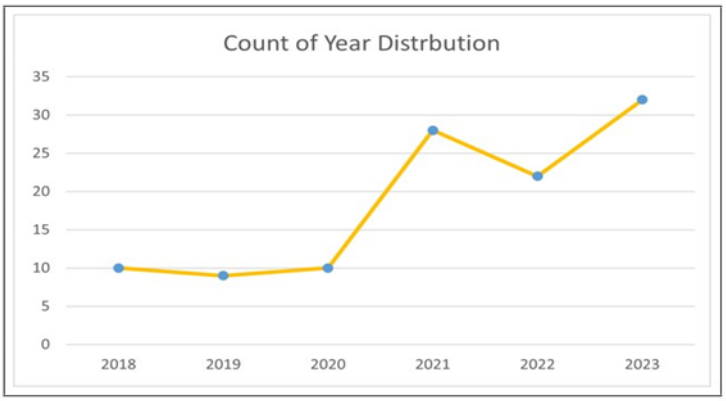

Fig 4: Distribution of Papers across Databases

4. Results And Discussion

We also added other details to the method side of the systematic review process, including description of procedures and yes/no answers to the question of whether there was an emphasis. In our first effort, for this meta-analysis we got 123 conference and journal articles. The 86 articles related to quantum computing in banking industry reveal the remaining irrelevant papers and unrelates studies after completing the process of exclusion. Figure5 illustrate approach in search of volunteer.

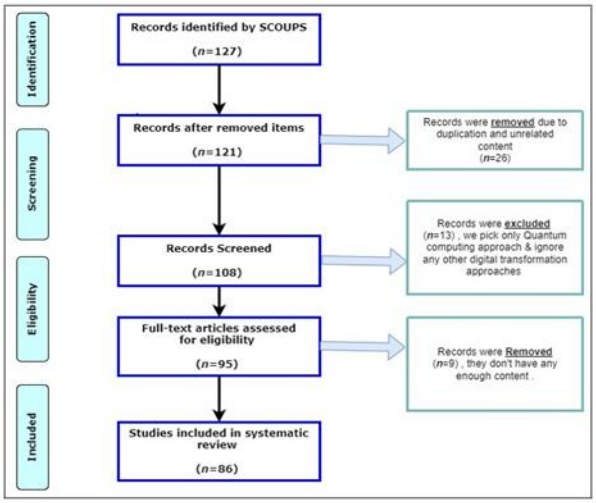

Fig 5: Progression of Information across the Stages of a Systematic Review A. Comparison Computing

Table 1: Comparison Between Traditional and Quantum Computing

Feature	**Traditional Computing**	**Quantum Computing**
Basic Unit	Bits (0 or 1)	Qubits (0, 1, or superposition of both)
Processing Principle	Binary logic (classical gates)	Quantum gates and superposition
Information Representation	Boolean algebra	Quantum superposition and entanglement
Parallelism	Limited by classical parallelism	Exploits quantum parallelism
Speed	Limited by classical processing speed	Potentially much faster for certain tasks
Complexity	Exponential with problem size	Polynomial for certain problems
Memory	Classical bits (0 or 1)	Quantum bits (Qubits)
Entanglement	Not applicable	Key feature, entangled qubits share info
Error Correction	Uses classical error correction codes	Quantum error correction algorithms
Energy Efficiency	Limited by classical physics	Potential for greater energy efficiency

Applications	General-purpose computing tasks	Optimization problems, cryptography, etc.
Decoherence	Rarely an issue	Major challenge in quantum systems
Fraud Detection	Relies on classical algorithms and data analysis for pattern recognition and anomaly detection	Has potential for enhanced pattern recognition and optimization in fraud detection due to quantum parallelism
Risk Management	Analyzes risk using classical statistical models and algorithms	Quantum algorithms could provide more efficient solutions for certain risk management problems, such as portfolio optimization or option pricing

The Information Developing during the Instances of a Systematic Review B. The Likeness-of-algorithms. When the mechanisms of quantum computing and the conventional one is compared, you can see a series of their major differences, which are the starting point of all differences.

Similarly, Boolean algebra provides a common ground for traditional computing, which is exemplified by clocks and clocks [10].

Nevertheless, the considerations of the superposition of qubits and entanglement constitutes a foundational bedrock of quantum computing, giving rise to such quantum processes as error correction and parallel computational modelling [11].

However, the cases of using quantum computing in the field of fraud detection and risk management may be important for the banking sector, this characteristic is among the most importantly advantage for the banking sector.

By doing so, this simultaneously utilizes powerful quantum parallelism that allows for faster processing of certain problems along with polynomial complexity for some of them. Quantum computing can profoundly reform the Financial sector in different areas – asset management, investment optimization, finance quantitate finance, among others – offering a new level of specificity to complex problems solving and optimization tasks. The efforts of such research and development that use quantum

computing's particular strengths will have to continue in the constant changing financial industry so that they are able to be treated as the potentials. As the emergence of quantum computing progresses, the complex banking operations is bound to undergo a radical transformation, giving a novel framework to deal with multi-faceted approaches to problem-solving and optimization tasks. However, the research process and further development of this unique capacity of quantum computation will be a task that is likely to coincide with the implementation of new technology. For concise a summary of the major points, look to comparison table v.

4.1. Optimizing Portfolio Management and Risk Assessment

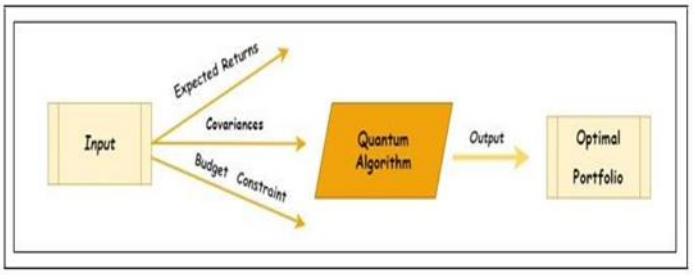

Fig 6: Optimizing Portfolio Management

The quantum computer's ability to process huge volumes of information at the same time as well as the ability to perform complex calculations could significantly improve the performance of banks in their administration of investment profiles, which can be achieved through a much higher analytical edge [14]. The Quantum

algorithms can help to speed up the analysis of multiple variables, for example, market trends, asset correlations, and risk factors, thus optimizing the investment strategies [15]. Additionally, the banks will be able to assess risk better with the help of quantum computing. Traditional risk assessment models are based on over-simplified presumptions and estimates that may lead to the low accuracy and miscalculation [17]. What is more, while classical computing is unable to handle the complexity of real-world issues and provides inaccurate risk assessment, quantum computing can handle these issues properly and provide more accurate risk assessment. By means of quantum computing's capabilities, banks could seek to simulate a variety of markets and, simultaneously, trace how their assortments will be affected in real time, thus making it possible to take action in a timely manner when needed [18]. The progressive approach offers a proactive risk management that enables the banks to be knowledge-based and thereby making informed decisions and mitigating the potential losses. The quantum computing technology can be really useful in conducting the stress testing in a way that determines the financial institutions' ability to withstand shocks, which is an absolutely critical issue. Through the use of stress-testing techniques, banks can recognize weaknesses in their risk management framework and put in place appropriate measures to ensure that their portfolios can withstand extreme market conditions [20]. In brief, quantum computing can be used to perform very complex but very quick calculations that are impossible to do in the time required with the classical computer. This will help banks to make the portfolio management and risk assessment processes smoother and more accurate. Given the fact that banks are able to take advantage of these innovations they can improve their investment strategies, run precise risk appraisals and make sure that their banks are stable in the growing financial complexity. The future of banking which is based on the unlocking of quantum computing will be the real future banking.

4.2. Innovating the Way Fraud Detection and Prevention Happen

Fraud detection and prevention in the banking industry, like any other sector, could be completely transformed by quantum computing. In the traditional methods, fraudulent actions are mostly detected and controlled by means of data-mining algorithms and statistics [21]. In spite of this, however, these algorithms can be optimized considerably due to the high processing speed that quantum computers afford. The ability of quantum computer to handle very large amounts of data at once is one of the most important benefits of quantum computing in fight against fraud [22]. The analysis of large data sets can be very difficult for traditional computers, and it also provides space for fraudsters to introduce sophisticated fraud schemes [23]. On the other side of the spectrum, quantum computers are capable of processing multiple data points at the same time which in return makes fraud detection faster and more accurate. In addition to that, quantum computing can take encryption to a higher level by providing better techniques for keeping clients' private data safe. Quantum algorithms may be the next generation hacking methods using which traditional cryptographic systems can be broken. Banks can ensure the safety of the consumer data by implementing quantum computing technology that allows the development of stronger encryption algorithms which are not attackable by quantum computers [24]. Also, the ability to detect anomalies is a key aspect of fraud that quantum computing can support as well. Banking institutions can be more precise and more accurate in identifying fraudulent transactions since quantum algorithms are better at finding patterns and inconsistencies in data. This is the way that it can assist in the identification of fraudulent activities, such as identity theft, money laundering, and unauthorized access to accounts. This is an important thing to be aware that quantum computing in financial sector at the moment is still in its early stages and it is being developed and implemented. Banks undertake the research and development investments to explore potential applications of quantum computing for the purposes of fraud detection and prevention. Banks will continue to be on the front line of this technology innovation by forming partnerships with quantum technology companies and co-operating with the experts from the industry [26]. In fact, the banking industry could be the most gainful from the futuristic revolution quantum computing could make in fraud detection and prevention. The ability of banks to successfully combat fraud at a higher level and make their customers' financial safety is greatly enhanced by quantum algorithms and computational abilities [27].

4.3. Streamlining complex financial calculations

From simplifying complex financial calculations to transforming the banking sector, this is one way how quantum computing could revolutionize the banking sector. These institutions of traditional financial systems are often at a disadvantage when it comes to fast and complex computing processes or huge data processing [28]. Although, banks have to face the challenge of ever-increasing number of transactions and complexity of financial calculations, the emergence of quantum computing allows banks to use a their enormous processing power to perform these kinds of intricate financial computations at a speed and accuracy which is unimaginable. Risk analysis is among the key areas where quantum computing is expected to make a great impact [20]. Banks use sophisticated risk models in their

operations that necessitate a comprehensive data analysis and a considerate approach to a range of factors. Benefitting from their power to process large data sets fast as well as their ability to perform complex calculations, banks are able to assess risks with more precision and respond to them promptly.

In addition to that, quantum computing is likely to lead to the development of more effective portfolio optimization techniques. The process of finding the optimal asset allocation that allows for the highest returns with the lowest risks is one of a complex nature that necessitate the use of mathematical computations in managing investment portfolios. Inadequate portfolio allocation is as a result of traditional computer systems that cannot do the job of managing the large number of alternative combinations. While banks will now be able to deal with multiple circumstances at higher speed, investment outcomes will be more successful, and portfolios can be optimized more successfully as well. Quantum Computing is also a way to improve the speed of fraud detection in financial calculations. The war with fraudsters always have new tactics to fight with in the banks. Banks will be able to scan through big numbers of transactional data in real-time and more precisely identify suspicious trends or abnormalities using quantum computing in the refinement stage of fraud detection algorithms. This can help in avoiding fraud and the guards of properties of clients. Another financial computation, for example computation required for pricing derivatives, refining credit risk assessment, and optimizing trading strategies, can also be improved with the help of quantum computing [31]. The monumental processing power of the quantum computers makes possible for the banks to perform these computations at a level of complexity and effectiveness that was not viable before. To ensure the full benefits of this breakthrough technology, the banking sector has to embrace quantum computing as it continues to advance. A bank may be able to optimize portfolio, detect fraud more accurately, manage risk adequately, and offer better results for its clients by automating complex financial calculations [32].

4.4. The Task of Addressing the Certain Limitedness of Intertwining the QC into the Banking Area

Quantum computers have many virtues that ultimately will benefit banking but there are technical issues that should be resolved before the general implementation. But, the problem with quantum technology that can be called for a moment - is one of the most important obstacles. On the contrary, these computers cannot execute intricate financial calculations or tremendous data processing at present because their early stage of development has not enabled them to do so yet. As one of the quantum computing obstacles, the indispensable expensive infrastructure is another problem. Quantum computing is technologically very innovative idea for most of the financial institutions some even small ones that do not have a big budget for development and operation of the quantum computing system. One more reason the limitation of qualified employees who have the experienced to handle quantum technology arises as a problem should be included when discussing why the quantum technologies are not securing their place in banking industry. Sometimes, quantum computing also causes concerns with privacy and security aspects [29]. There is the necessity that today's cryptographic methods will be built upon new powerful algorithms that can beat the quantum computing machines. This is because those machines have a power to brake ordinary encryption algorithms. As bank records tend to be held on the cloud and the ever-increasing quantum computing will be at play, providing a high level of protection for the sensitive financial data will be of great urgency. Finally, I would like to think that the other crucial point to mention is that this technology targets the problems of global security and privacy [37]. In the fight against quantum computers, which have the capacity to crack prevailing encryption algorithms, new techniques in cryptography resisting the strength of quantum computers are needed. It won't be enough to maintain the security of data and to protect sensitive financial information while the transition to quantum computing is in progress [38]. The banking sector acknowledges the groundbreaking potential of quantum computing when compared to its current state, which still has its inherent limitations and challenges. In the times to come, quantum computing could be the currency used for banking practices, wiser data analytics, safer risk management, as well as faster and more accurate decision making.

The present schemes are targeted at overcoming these barriers in order to ensure the success of the programme or campaign. Financial institutions have to pay particular attention to develop the technology and come up with reliable strategies that will enable them to integrate the evolving technologies to their financial business as the technology matures and become available to all the people [40]. The financial industry will ultimately become a pioneer of improved and economical technology only when the full quantum computing potential is achieved.

4.5. The future outlook of Quantum Computing and its impacts on banking sector are among the most important aspects of its application.

For quantam computers, it is just not in the net but for many exports, products too. This new technology has a

potential to radicalize and change the conventional process of data analysis, encryption, and optimization because to its extreme speed in computation [41]. The technology of quantum computing has the capacity to bring about an increase in the risk management, an improvement in the security of information and high-speed information processing of the banking industry. It is essential to give birth to the algorithms for quantum-resistant encryption which will guard the financing data against quantum flaws that may eventually get through typical system of encryption [42]. Not to mention that quantum computing enables banks to process huge data volumes in real-time, which results in ability to make qualitative analysis predictions at the milliseconds. These therefore play a great role in the not only curtailment of fraud cases but also in the spotting of customer behavior trends and strategic investment plans. Talking of quantum computing, there's no doubt that its impact on banking is not the only one; the technology is also beneficial in other fields such as artificial intelligence, weather forecasting, medical treatment development and supply chain optimization [44]. Using quantum computers, researchers can conduct virtual experiments on complicated molecular structures and consequently find new drugs for human or develop materials in the affirmative. Quantum computers are significantly different in their computational nature that the applications are as intriguing as they are. Quantum computing with its applicable across a wide range of industries new windows be created for research and development and maybe ways the world will deal with complex issues to be changed. The companies have to do this technology advancement if they want to be prosperous in future and not lag behind in the industry.

5. Conclusion

The perspective of the bankers' quantum computing effects has been not only interesting but also suggested for the future community through the investigation. The substantial possible revolution in the banking industry occurs by the huge developing the technology called quantum computing as technological advancements keep moving on. The forecasting ability of quantum computing is amply seen, as applications ranging from the information processing to the mathematical finance and cyber security strengthened can be imagined. With the advent of a rapidly changing business environment, financial institutions are urged to build a mechanism of adaptation to the neural-network-based solutions that quantum computing creates. For a full exploitation of the benefits that quantum computers may offer, banks must always stay current on related development. Quantum computing coupled with banking will determine the direction in which financial operations are headed proving beneficial for the institutions wishing to be innovative and early adopters. The anticipation and excitement that arises from the grassroot element of quantum computing in a banking landscape is also intensified. Not a doubt, the frontier consequences and consequential impact of quantum computing on the financial sector will definitely be experienced in the future. We approach an age of banking that is like a new sunrise and which will combine new elements not seen before: effectiveness and originality.

References

[1] R. Orús, S. Mugel, and E. Lizaso, "Quantum computing for finance: Overview and prospects," Reviews in Physics, vol. 4, p. 100028, 2019.

[2] S. Bravyi, D. Gosset, and R. König, "Quantum advantage with shallow circuits," Science, vol. 362, no. 6412, pp. 308–311, 2018.

[3] M. A. Nielsen and I. L. Chuang, "Quantum computation and quantum information," Phys. Today, vol. 54, no. 2, p. 60, 2001.

[4] D. J. Egger, C. Gambella, J. Marecek, S. McFaddin, M. Mevissen, R. Raymond, A. Simonetto, S. Woerner, and E. Yndurain, "Quantum computing for finance: State-of-the-art and future prospects," IEEE Transactions on Quantum Engineering, vol. 1, pp. 1–24, 2020.

[5] N. Vidhya, V. Seethalakshmi, and S. Suganyadevi, "Non-silicon computing with quantum superposition entanglement using qubits," in Quantum Computing: A Shift from Bits to Qubits. Springer, 2023, pp. 131– 150.

[6] C. M. Dawson, H. L. Haselgrove, A. P. Hines, D. Mortimer, M. A. Nielsen, and T. J. Osborne, "Quantum computing and polynomial equations over the finite field z_2," arXiv preprint quant-ph/0408129, 2004.

[7] X.-D. Cai, C. Weedbrook, Z.-E. Su, M.-C. Chen, M. Gu, M.-J. Zhu, L. Li, N.-L. Liu, C.-Y. Lu, and J.-W. Pan, "Experimental quantum computing to solve systems of linear equations," Physical review letters, vol. 110, no. 23, p. 230501, 2013.

[8] J. Strumpfer and K. Schulten, "Open quantum dynamics calculations with the hierarchy equations of motion on parallel computers," Journal of chemical theory and computation, vol. 8, no. 8, pp. 2808–2816, 2012.

[9] S. Hallgren and U. Vollmer, "Quantum computing," in post-quantum cryptography. Springer, 2008, pp. 15– 34.

[10] E. National Academies of Sciences, Medicine et al., "Quantum computing: progress and prospects," 2019.

[11] S. S. Gill, A. Kumar, H. Singh, M. Singh, K. Kaur, M. Usman, and R. Buyya, "Quantum computing: A taxonomy, systematic review and future directions," Software: Practice and Experience, vol. 52, no. 1, pp. 66–114, 2022.

[12] O. Covers and M. Doeland, "How the financial sector can anticipate the threats of quantum computing to keep payments safe and secure,"

Journal of Payments Strategy & Systems, vol. 14, no. 2, pp. 147–156, 2020.
[13] M. Zhang, L. Xie, Z. Zhang, Q. Yu, G. Xi, H. Zhang, F. Liu, Y. Zheng, Y. Zheng, and S. Zhang, "Exploiting different levels of parallelism in the quantum control microarchitecture for superconducting qubits," in MICRO-54: 54th Annual IEEE/ACM International Symposium on Microarchitecture, 2021, pp. 898–911.
[14] M. Marzec, "Portfolio optimization: Applications in quantum computing," Handbook of High-Frequency Trading and Modeling in Finance, pp. 73–106, 2016.
[15] G. Carrascal, P. Hernamperez, G. Botella, and A. del Barrio, "Backtesting quantum computing algorithms for portfolio optimization," IEEE Transactions on Quantum Engineering, 2023.
[16] D. J. Egger, R. G. Gutiérrez, J. C. Mestre, and S. Woerner, "Credit risk analysis using quantum computers," IEEE transactions on computers, vol. 70, no. 12, pp. 2136–2145, 2020.
[17] Kerenidis, A. Prakash, and D. Szilágyi, "Quantum algorithms for portfolio optimization," in Proceedings of the 1st ACM Conference on Advances in Financial Technologies, 2019, pp. 147–155.
[18] Gunjan and S. Bhattacharyya, "A brief review of portfolio optimization techniques," Artificial Intelligence Review, vol. 56, no. 5, pp. 3847– 3886, 2023.
[19] E. Grant, T. S. Humble, and B. Stump, "Benchmarking quantum annealing controls with portfolio optimization," Physical Review Applied, vol. 15, no. 1, p. 014012, 2021. 20) B. Andreas, B. Guillaume, J. Binder, B. Thierry, H. Ehm, T. Ehmer, M. Erdmann, G. Norbert, H. Philipp, M. Hess et al., "Industry quantum computing applications," EPJ Quantum Technology, vol. 8, no. 1, 2021.
[20] O. Kyriienko and E. B. Magnusson, "Unsupervised quantum machine learning for fraud detection," arXiv preprint arXiv:2208.01203, 2022.
[21] Di Pierro and M. Incudini, "Quantum machine learning and fraud detection. protocols. strands, and logic," 2021.
[22] N. Innan, M. A.-Z. Khan, and M. Bennai, "Financial fraud detection: a comparative study of quantum machine learning models," arXiv preprint arXiv:2308.05237, 2023.
[23] M. Grossi, N. Ibrahim, V. Radescu, R. Loredo, K. Voigt, C. Von Altrock, and A. Rudnik, "Mixed quantum– classical method for fraud detection with quantum feature selection," IEEE Transactions on Quantum Engineering, vol. 3, pp. 1–12, 2022.
[24] T. Pourhabibi, K.-L. Ong, B. H. Kam, and Y. L. Boo, "Fraud detection: A systematic literature review of graph-based anomaly detection approaches," Decision Support Systems, vol. 133, p. 113303, 2020.
[25] K. G. Al-Hashedi and P. Magalingam, "Financial fraud detection applying data mining techniques: A comprehensive review from 2009 to 2019," Computer Science Review, vol. 40, p. 100402, 2021.
[26] Ganapathy, "Quantum computing in high frequency trading and fraud detection," Engineering International, vol. 9, no. 2, pp. 61–72, 2021.
[27] V. Murinde, E. Rizopoulos, and M. Zachariadis, "The impact of the fintech revolution on the future of banking: Opportunities and risks," International Review of Financial Analysis, vol. 81, p. 102103, 2022.
[28] J. Deodoro, M. Gorbanyov, M. Malaika, T. S. Sedik, and S. Peiris, "Quantum computing and the financial system: Spooky action at a distance?" IMF Working Papers, vol. 2021, no. 071, 2021.
[29] F. D. Albareti, T. Ankenbrand, D. Bieri, E. Hänggi, D. Lötscher, S. Stettler, and M. Schöngens, "A structured survey of quantum computing for the financial industry," arXiv preprint arXiv:2204.10026, 2022.
[30] Sharma and S. Lenka, "Authentication in online banking systems through quantum cryptography," Int. J. Engineering and Technology, vol. 5, pp. 2696–2700, 2013.
[31] F. Bova, A. Goldfarb, and R. G. Melko, "Commercial applications of quantum computing," EPJ quantum technology, vol. 8, no. 1, p. 2, 2021. 33) N. P. De Leon, K. M. Itoh, D. Kim, K. K. Mehta, T. E. Northup, H. Paik, B. Palmer, N. Samarth, S. Sangtawesin, and D. W. Steuerman, "Materials challenges and opportunities for quantum computing hardware," Science, vol. 372, no. 6539, p. eabb2823, 2021.
[32] Y.-J. Chang, M.-F. Sie, S.-W. Liao, and C.-R. Chang, "The prospects of quantum computing for quantitative finance and beyond," IEEE Nanotechnology Magazine, 2023.
[33] M. Fellous-Asiani, J. H. Chai, R. S. Whitney, A. Auffèves, and H. K. Ng, "Limitations in quantum computing from resource constraints," PRX Quantum, vol. 2, no. 4, p. 040335, 2021.
[34] S. K. Sood et al., "Quantum computing review: A decade of research," IEEE Transactions on Engineering Management, 2023.
[35] H. Bhatt and S. Gautam, "Quantum computing: A new era of computer science," in 2019 6th International Conference on Computing for Sustainable Global Development (INDIACom). IEEE, 2019, pp. 558–561.
[36] Mavroeidis, K. Vishi, M. D. Zych, and A. Jøsang, "The impact of quantum computing on present cryptography," arXiv preprint arXiv:1804.00200, 2018.
[37] M. Njorbuenwu, B. Swar, and P. Zavarsky, "A survey on the impacts of quantum computers on information security," in 2019 2nd International conference on data intelligence and security (ICDIS). IEEE, 2019, pp. 212–218.
[38] Naik, E. Yeniaras, G. Hellstern, G. Prasad, and S. K. L. P. Vishwakarma, "From portfolio optimization to quantum blockchain and security: A systematic review of quantum computing in finance," arXiv preprint arXiv:2307.01155, 2023.

[39] S. Bravyi, O. Dial, J. M. Gambetta, D. Gil, and Z. Nazario, "The future of quantum computing with superconducting qubits," Journal of Applied Physics, vol. 132, no. 16, 2022.

[40] D. Córcoles, A. Kandala, A. Javadi-Abhari, D. T. McClure, A. W. Cross, K. Temme, P. D. Nation, M. Steffen, and J. M. Gambetta, "Challenges and opportunities of near-term quantum computing systems," Proceedings of the IEEE, vol. 108, no. 8, pp. 1338–1352, 2019.

[41] M. Martonosi and M. Roetteler, "Next steps in quantum computing: Computer science's role," arXiv preprint arXiv:1903.10541, 2019.

[42] Rayhan and S. Rayhan, "Quantum computing and ai: A quantum leap in intelligence," 2023.

[43] S. K. Singh, A. E. Azzaoui, M. M. Salim, and J. H. Park, "Quantum communication technology for future ict-review," Journal of Information Processing Systems, vol. 16, no. 6, pp. 1459–1478, 2020.