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INDUSTRIAL QUANTUM COMPUTING

ALGORITHMS, BLOCKCHAINS, INDUSTRY 4.0

Edited by Umesh Kumar Lilhore, Surjeet Dalal, Vishal Dutt and Magdalena Radulescu

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Chapter 8
Applications of quantum computing in financial planning and financial control

Abstract: Quantum computing is an emerging area of computer science that combines computing, physics and mathematics to solve the real-time problems of industry, economy and operations. It is a multidisciplinary approach that applies computing technologies in the various operations of the economy to achieve comprehensive quality management. Financial planning and control is an integral part of financial management that is very crucial for any enterprise whether it is profit oriented or not. Financial management started using computing technologies in analysis and decision-making. Financial management has to deal with large amounts of data which is easily done with the help of Quantum computing methodology. Companies can also use quantum computing to empower customers to experience better financial services. It takes consumer behaviours as inputs in order to predict the needs in real-time and near future. Major financial institutions and companies such as JP Morgan Chase, HSBC, Goldman Sachs, etc. started using quantum computing for their financial operations and decisions. In future, almost all industries will have the real-time application of quantum computing in their operations at a micro or macro level.

Keywords: Quantum Computing, Financial Planning and Control, Quantum Users, Artificial Intelligence

8.1 Introduction

Quantum computing has the potential to revolutionize various aspects of the financial industry, bringing new capabilities that can have a significant impact on financial modelling, optimization, and security. However, it is important to note that practical and scalable quantum computers are still in the beginning stages of research and development which requires time. The industry is actively conducting research and experiments with quantum algorithms and applications, but it may take some time before

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widespread adoption occurs. Financial institutions will need to stay updated on quantum developments, evaluate the practical applications for their specific needs, and adjust their strategies accordingly.

8.1.1 Finance

Finance is one of the traditional disciplines. It concentrates on effective and efficient management of money, liquid assets and fixed assets. It is different from the discipline of Economics. Economics just deals with the theory of production, distribution and consumption of goods and services in an economy. Financial Economics emerged to fill the gap between two fields viz. Economics and Finance. Finance can be further divided into personal finance, corporate finance and public finance. Based on the scope of financial activities, the size of finance is determined, within financial systems [1].

In financial system, assets are purchased, sold, invested and traded like financial instruments, in various forms such as shares, currencies, bonds, loans and so on. Those assets are also deposited, invested elsewhere, wherever required and insured for maximizing their value and minimizing potential losses from risks and hazards. Anyhow, it is crucial to consider that risks are bundled in any financial activity or organization [1].

Because of the widened scope of finance, it has many subfields. Assets management, money handling, risk management, and investment management are to optimize value and reduce uncertainty. Financial analysis involves examining the scope, stability and profit-making of activities or entities [1]. In certain circumstances, finance theories can be validated using scientific methods and can be demonstrated in the experimental finance area. Finance also gets interlinked with other disciplines such as mathematical finance, financial law, financial economics, financial engineering, and financial technology. These fields contribute themselves as the fundamentals for business and accounting practices in the world.

8.1.2 Financial management

Financial management emerged as a separate discipline to oversee, regulate, safeguard and document the financial assets of an organization. Businesses usually make use of accountants or finance departments to handle their financial matters, consisting of banking activities, borrowing process, liabilities management, investments management and various funding arrangements. Financial management is the core operational aspect of business as well as non-business which focuses on enhancing profit making, expenses management and effective handling of cash and credit transactions. These key elements are commonly summarized under the core objective of financial management, i.e. maximizing the firm's value for its stockholders.

8.1.3 Financial planning

Financial planning deals with a thorough design for
- Evaluating the financial status of an individual or an organization,
- Establishing financial objectives, and
- Devising tactics to accomplish those desired objectives.

It is also a continuous process that considers different aspects of personal or organizational finance. It guarantees efficient and effective resource management and the attainment of financial goals optimally [7].

8.1.4 Financial control

Financial control shares a crucial place in financial management. It involves in
- Overseeing finance,
- Analysing activities, and
- Regulating an organization's financial operations
- Ensuring alignment of activities with its objectives.

The main objective of financial control is to safeguard assets and resources, ensure precision and accuracy in financial reporting, and facilitate appropriate decision-making in business [7].

8.2 Quantum computing

Quantum computing emerged as an interdisciplinary domain. It includes computer science, physics, and mathematics together. It balances the principles of quantum mechanics to effectively and efficiently handle complicated problems in a faster manner than traditional computer machines. The domain of quantum computing consists of both research in hardware and practical application development. Quantum computers draw from quantum mechanical phenomena such as superposition and quantum involvement to solve specific problems faster than day's computers. The enhanced speed of machines brings out the possibilities for various applications, including machine learning, optimization techniques and simulation of physical systems in the modern digital world. In the upcoming years, quantum computing will certainly revolutionize finance through the application of portfolio optimization. It may also enable the forcing of systems, solving critical problems that are currently beyond the abilities of the supercomputers having superpowers available in the market right now [3].

8.2.1 Fundamentals of quantum computing

Quantum computing works based on the foundational principles of quantum technology and technics. To understand those principles and techniques, three concepts such as superposition, entanglement and decoherence are required.

Superposition
Superposition means that, like the waves in classical physics, multiple quantum states can be joined to create another valid quantum state. Oppositely, any quantum state can also be demonstrated as a combination of two or more different states. This superposition of qubits enables quantum computers to balance parallelism, by allowing them to perform enormous operations at the same time [7].

Entanglement
Quantum entanglement happens when two systems become interconnected observing, one system gives immediate information about the other system, irrespective of the distance between them. Quantum processors can also draw inferences from one particle by measuring another particle. For example, they can predict the situations if one qubit is in an upward spin, obviously the other will always be in a downward spin and vice versa. This principle strengthens quantum computers to solve complicated real-time problems more efficiently and effortlessly.

Decoherence
Decoherence refers to the dissolution of the quantum states within a qubit. External factors, such as radiation, can create the collapse of the qubit's quantum state. A significant designing obstacle in quantum computing happens in developing mechanisms that can delay decoherence, like constructing specialized structures or patterns to shield or protect the qubits from external influences such as radiation, glitches, etc.

8.2.2 Role of quantum computing in finance

Comprehending Quantum Computing
Traditional computers make use of bits as the fundamental unit of data, which can only be either 0 or 1. Contradict to it, quantum computers deploy quantum bits or qubits. These qubits come with the ability to occupy in multiple states simultaneously, because of the philosophies of superposition and entanglement. This outstanding characteristic enables quantum machines to process vast amounts of data at incomparable speeds [2].

Transforming Risk Analysis
Financial markets are complicated and complex in nature. They are also influenced by numerous factors. Quantum computers are capable of analyzing the factors contin-

uously, by providing a more detailed but precise risk profile assessment. It can prove to be essential for a wide range of real-time applications, including stock market investment trends and insurance underwriting processes [2].

Enhanced Fraud Detection
Financial fraud has become a big challenge, with hackers and fraudsters employing increasingly cheating techniques. Quantum computers can carefully inspect the numerous datasets in real-time, by identifying abnormal data and potential indicators of fraud which may go unnoticed by traditional machines [2].

Sophisticated Financial Modelling
The financial operations heavily believe in models, whether they predict economic upturns and downturns or detail the possible impact of geo-political happenings. Quantum computing comes with the ability to tackle the complexities and factors of the models, by offering appropriate predictions and ideas that were previously unavailable.

Appropriate Portfolio Optimization
Designing an exemplary portfolio is a shaky balance of risk and reward for investors usually. Quantum computers can scrutinize and analyze thousands of potential portfolio combinations within the time of seconds, by ensuring optimal allocation of assets accordingly.

Real-time Decision Making
In the faster world of finance, Decisions are often required to be taken fast but accurate. Quantum computing can innovate real-time data analysis, by ensuring that the parties like traders, investors and financial institutions have the fullest access to the most up-to-date information about finance [2].

Challenges and Considerations
Since the possibilities of quantum computing are widened, there are obstacles to overcome too naturally. Quantum computers are still in their elementary stages of research, development, deployment and testing process. The integration of finance and quantum computing needs a thorough and careful consideration of data security, privacy, infrastructure adaptability and a substantial investment of time and resources.

The Ethical Implications
Great power usually comes with great responsibility. The capabilities of quantum computing bring important ethical questions, in particular, the concern regarding data privacy and security, market manipulation activities and the need for a fair playing field in the financial industry operations [7].

Quantum computing keeps the promise of redefining the edges of financial analysis and decision-making. As this technology continues to develop itself, its integration

will be crucial for financial institutions seeking to stay ahead of the curve. Utilizing quantum computing is not just about harnessing computational power and techniques; it is mainly about envisioning and shaping the future of the financial industry and its operations.

8.2.3 Quantum computing in financial planning

Quantum computing has the power to radically change various sectors of the world and government, including finance. Although quantum computers are still in the early stages of development, deployment and testing; Researchers and financial institutions utilize their potential applications in financial planning also [3]. Here are how quantum computing can influence the financial planning:

Optimization Problems

Quantum computers performs well in solving optimization problems, which are important in financial planning. For example, portfolio optimization involves in finding the optimal collection of investments to maximize returns on investment by minimizing risk elements. Quantum algorithms have the ability to process large amount of data and deliver more efficient real-time solutions compared to early days' algorithms.

Machine Learning and Data Analysis

Machine Learning and Data Analytics emerged as separate domains. The potential effect of quantum computing on financial planning is significantly considerable. Since the technology continues to advance day-to-day, it is crucial for researchers and financial institutions to implement its applications and adapt to the changing landscape of finance [7].

Cryptography and Security

Quantum computing has inherences and scope for cryptography. Since quantum computers advances daily, they could potentially split widely used cryptographic algorithms, such as RSA and ECC. It poses a challenge to securing financial transactions and sensitive data of the clients. Consequently, the finance industry may have to move to quantum-resistant cryptographic techniques.

Risk Management

Quantum computing has the scope to innovate risk management models by enabling more comprehensive techniques. By processing large amount of data and complex computations at an accelerated level, quantum computers can importantly enhance the accuracy, speed, and risk assessments in financial planning [7].

Option Pricing and Derivatives
Derivatives are important in international financing. Quantum computing could enhance the pricing of complex financial derivatives and options instruments. Those instruments often involve complex mathematical models and quantum programmed algorithms could potentially offer faster and more accurate pricing computations.

Blockchain and Smart Contracts
The effect of quantum computing increases to the security of blockchain networks and smart contracts. As blockchain technology depends on cryptographic algorithms, it may be vulnerable to quantum attacks. Financial experts who apply the blockchain technology in finance must take the establishment of quantum-resistant cryptographic solutions into account, to ensure the integrity, privacy and security of the quantum systems.

8.2.4 Quantum computing in financial control

Quantum computing offers the possibility to changeover in the financial control area of a business. It familiarizes new opportunities and efficiencies to impact various aspects of control processes in the finance domain. For example, quantum computers can analyze broad datasets. It works much faster than traditional computers, by enhancing analysis of data for risk profile management, detection of fraud & vulnerability; and detection of abnormality & suspects in financial control [3].

Advanced Data Analysis	Quantum computing offers the possibilities to changeover in financial control area of a business. It familiarizes new opportunities and efficiencies to impact various aspects of control processes in finance domain. For example, quantum computers can analyze broad datasets. Actually it works much faster than traditional computers, by enhancing analysis of data for risk profile management, detection of fraud & vulnerability; and detection of abnormality & suspects in financial control.
Optimization of Control Processes	Quantum computing performs well by bringing solutions for optimization problems which are important to financial control processes. It focuses on complicated areas like allocation of resource, budgeting tools and systematic and unsystematic risk management. Quantum algorithms are basically capable of providing more feasible and real time remedies to complex optimization challenges and further improving financial control mechanism [7].

(continued)

Enhanced Encryption and Cyber security	The capableness of quantum computing also shows a warning signal to cyber-security architecture. Quantum computers have the ability to divide and subdivide the widely used cryptographic algorithms that may compromise and deviate the security of sensitive financial information of clients. This concern is addressed by implementing quantum-preventive encryption methods to ensure the continued security of financial information in the financial control systems [7].
Portfolio Risk Management	Quantum computing significantly improvise the strategies of Portfolio optimization and risk management strategies. Challenges of dealing with complex portfolios and conducting risk assessments often affect Financial institutions. By employing quantum algorithms in finance, more precise and faster calculations can be attained, leading to optimized portfolios and sound management of risks associated with available financial instruments.
Fraud Detection and Prevention	The remarkable high speed processing at which quantum computing can process and analyze data can be balanced properly for real-time fraud detection and prevention of malicious attacks. Quantum algorithms can be utilized by financial control systems to identify patterns and abnormally suspicious accesses that indicate fraudulent activities [7].
Simulation of Financial Scenarios	Quantum computers have the potential to speed up the simulation of financial scenarios. Stress testing and scenario analysis are important components of financial control mechanism, as they assess the stubbornness of financial systems. Quantum computing can accelerate the simulations, by providing timely and accurate feedbacks into potentially possible financial risks.

8.3 Future of quantum computing in financial management

The future of quantum computing in financial management will showcase great potential but also present challenges and uncertainties in the financial sector. Since quantum technologies progress now, various developments and trends will shape the landscape of quantum computing in financial management and its applications [6].

Portfolio Optimization and Risk Management

Quantum computing is carried out to have a significant impact on portfolio optimization and risk management in financial management. Quantum algorithms shall provide more efficient and real-time solutions to complicated optimization problems, by allowing financial institutions to effectively and effortlessly manage diversified portfolios and assessing risks of the market with greater precision.

Cryptographic Evolution
The evolution of quantum computing showcases a risk to current cryptographic standards, which may be vulnerable to quantum attacks. Furthermore, there may be a shift towards implementing quantum-repellent cryptographic methods in financial systems to safeguard the security, privacy and integrity of transactions and sensitive data [6].

Quantum Machine Learning
Quantum machine learning algorithms could be used for predictive analytics, credit scoring calculations and fraud detection. Quantum computers can process and analyze large-size data in ways that traditional computers cannot perform, leading to more comprehensive and accurate financial models.

Simulation of Financial Models
Quantum computers are expected to perform outstandingly in replicating complex financial models. This ability can be employed for scenario analysis, stress testing techniques and essentially forecasting the movement of various economic factors in financial markets [8].

Blockchain and Cryptocurrencies
The impact of quantum computing on blockchain technology and cryptocurrency is subject to progressive and ongoing research. While quantum computers could showcase a risk to current cryptographic methods, they could also be deployed to increase the security and measurability of blockchain networks [6].

Regulatory Compliance
– Quantum computing has the prospect of streamlining regulatory compliance procedures by speeding up the analysis of large data needed for compliance reporting. Financial institutions could gain from more appropriate, effective and real-time compliance management and reporting.

Partnerships and Collaboration
Financial institutions are anticipated to establish partnerships with quantum computing organizations or research institutions to investigate and implement quantum solutions for real-time issues. Collaboration will be important for adapting current financial systems to quantum technologies [7].

Education and Skill Development
Quantum computing becomes more essential to financial management so there will be a gradually increasing demand for professionals with expertise in both finance and quantum computing areas. Educational programmes and training initiatives may also take place to bridge the skills gap [6].

Integration Challenges
The integration of quantum computing into current financial systems will have definite challenges. Financial institutions will have to utilize the strategies for gradually integrating quantum technologies with finance, by ensuring compatibility with traditional systems and addressing security issues in real-time.

8.4 Positive and negative sides of quantum computing in finance

Quantum computing has the scope to revolutionize various industries and businesses, bringing about significantly tremendous changes in society. The development of quantum computers is a technological race in which both governments and private companies actively participate, by investing billions of dollars to make it a reality for the world. Advanced machines can solve intricate problems at a faster and more precise rate than yesteryear computers, leading to ground-breaking inventions and innovations across different sectors [8].

But, considering that quantum computers are also as signal of threat to the encryption algorithms currently used for digital security and privacy, is also important. It brings concerns about the impact of quantum computing on the security of daily interactions for businesses and individuals practically. One specific area where quantum computing has great potential is in the field of finance, where it can well-balance its computational ability to solve more complicated problems and enhance finance optimization and prediction capabilities of trends. It also exhibits that traditional cryptographic systems ensure secured transactions, which shall become a potential vulnerability to quantum computing technology.

i. ***Positive Side***
The scope for quantum finance is invaluable in real-world applications. Quantum computers can redesign the financial industry products and services, and even it can predict future financial trends and crashes systematically. Finance should benefit from quantum computing and it will be one of the first sectors to envision its advantages. Banks and financial institutions currently rely upon complex and hectic calculations to understand and forecast market trends. Quantum computers could sort out even more complicated issues in a fraction of a second, compared to traditional computers [4].

In the area of stock market operations, quantum computers will assist in calculations that were previously too numerous and random to analyze. Moreover, when it comes to credit loans and portfolio calculations, quantum computers provide the promise of enhanced precision in credit assessments and scoring, which leads to

more informed lending decisions. Additionally, the increased accuracy and authenticity of quantum computers can be used to detect fraud, potentially saving banks amounting to millions of dollars [4].

Quantum computers can bring new amendments to the financial services industry in various areas. The areas include trading optimization process, clear risk profiling and risk classification, targeting trends, predictions of trends and securities, product suggestions to clients, systematic portfolio management, credit scoring and credit worthiness assessment, fraud detection and fraud prevention, handling the anti-money laundering and forecasting financial crises near future [5]. Practically, quantum computing is unable to predict the entire financial trends with 100% accuracy. Nevertheless, they offer numerous advantages over traditional computers, enhancing portfolio assets management, risk profile management, asset pricing techniques and more.

However, the current unavailability of quantum computers in most banks and financial institutions prevented the implementation of quantum finance today [4]. Quantum computers are mainly seen in research labs and have not yet become familiar widely in the financial services industry. Nevertheless, as advancements in quantum finance technology continue, it is anticipated that quantum finance will share a more crucial role in transforming the faces of financial modelling, analysis and process of decision-making.

ii. ***Negative Side***

On the negative side, there are some significant security threats and risks associated with quantum computers. The powerful machines can easily intrude on the encryption algorithms that banks currently believe in to safeguard the financial data of clients [4]. Consequently, banks using traditional and outdated public key encryption algorithms could become dangerous to data breaches once a cryptographically repellent quantum computer becomes available. Banks have large amounts of data, they are already essential targets for cyber attackers.

However, financial institutions should make it fast in protecting themselves to prevent attacks in quantum computing, as they could already be doubtful of attacks from quantum computers using a “Seed now, Open later” cybercrime strategy. By this approach, malicious attackers influence systems to collect encrypted data, with a criminal intention of decrypting it when quantum computers become available. So, financial institutions must convert the existing practices into quantum-safe encryption without further postponement.

Financial institutions should hyper-actively enhance their defensive mechanism in financial operations. It touches the horizon beyond mere compliance of procedures. It becomes a critical concern and measures to safeguard data. Organizations should actively take alerted and attentive measures by enlisting the cryptographic assets ideas, prioritizing long-term trust and security; and exploring the integration of technic “post-quantum cryptography” (PQC) algorithms to strengthen themselves against possible quantum threats and malicious attacks [5].

8.5 Limitations of quantum computing

The quantum computing domain showcases a few challenges and pitfalls. It is mainly regarding the complex engineering, architecture techniques and programming systems employed. The destruction of quantum systems makes us vulnerable to errors, noise, faults and loss of quantum coherence on the applications side. The errors can purposively distract and stop the operation of quantum computers. Quantum coherence is crucial for their proper functioning in operations, it should not be misled. Unexpectedly, quantum coherence tends to dissolve rapidly, often before the execution of any substantial program [8].

Hardware Challenges
The requirements of hardware for establishing quantum computing showcase significant challenges and obstacles such as heavy cost and infrastructure. Quantum computers are dependent on complex and costly equipment. Even, the extremely advanced machines are vulnerable to errors, glitches and frauds. In addition, the size of quantum systems needed to run the quantum algorithms is often regarded as larger compared the traditional computers. It highlights the hardware limitations in this field of applications.

Software Challenges
Software requirements also become limitations in Quantum computing. Only a limited count of quantum programming languages are available to develop systems right now. The languages are normally more complex to learn and utilize compared to yesteryear programming languages. This complexity happens from the unique characteristics of quantum mechanics, which demand a distinct approach to programming compared to classical computers.

Decoherence
Decoherence refers to the situation where the weaker quantum states of a quantum system become entangled with the surrounding environment elements, leading to the loss of its original quantum properties. This shows a significant hurdle for quantum computing, as it prevents the duration for which quantum systems can maintain their quantum properties naturally. Subsequently, quantum computers must be precisely designed to operate in controlled technical environments with extremely low heating temperatures and minimal external factors' interference [4].

Connectivity of Qubits
In the domain of quantum computing, the interlinkage of qubits, are the foundational units of quantum information. It is essential for carrying out computations normally. Nevertheless, with the expansion of qubit numbers, the necessary connections also increase suddenly, indicating a significant challenge in storing the coherence of the

system. This issue, referred to as the qubit connectivity problem, stands as an unavoidable obstacle in the path towards scaling up quantum computers while applying them in real-time.

8.6 Conclusion

It should be emphasized that quantum computing is currently in its initial development, deployment and testing phases. The availability of large-sized, practical quantum computers suitable for financial planning purposes is still progressive. Researchers actively engage in addressing hurdles and pitfalls such as error corrections, coherence timing and scalability issues. As quantum technology progresses daily, financial institutions will have to change their systems and algorithms to balance the potential privileges while handling new privacy and security risks introduced by quantum computers. The integration of quantum computing in finance has the potential to innovate and redesign various aspects of the industry [4].

Practically, scalable quantum computers are still in the beginning stages of development, their unique computational capabilities are to be brought about transformative dynamics. While the full realization of quantum computing's potential in finance may take time to get implemented completely, the industry is on the emergence of a considerable transformative shift [4]. Since quantum technologies mature and become more accessible, financial professionals and organizations will have to adapt their strategies, stay informed about developments and embrace the scope and opportunities presented by quantum computing to get connected in the competitive world and evolving landscape of financial technology.

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