INDUSTRIAL APPLICATIONS OF QUANTUM COMPUTING

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1 Introduction

In 1994, mathematician Peter Shor introduced a quantum-computing algorithm that could reduce the time it takes to find the prime factors of large numbers from billions of years using a conventional transistor-based computer to a few days using a quantum computer. This was an enormous breakthrough, because prime factorization is the foundation for much of our present encryption and information security infrastructure. Seven years later, IBM scientists successfully demonstrated the algorithm on a quantum machine—albeit a very small one—for the first time, proving that quantum computers could be built and that Shor's algorithm could be implemented. Quantum computing will enable businesses to better optimize investment strategies, improve encryption, discover products, and much more. Tremendous levels of investment, private-sector competition, and mathematical and scientific talent are currently being devoted to quantum research. This is the type of environment that so often in the past has produced breakthrough advances in technology. And make no mistake: The quantum-computing breakthrough will be a big one. It will bring two huge, simultaneous, and sudden changes to the modern business world: The first is an end to our current infrastructure for ensuring digital privacy and security over public networks, leaving companies that have not upgraded their infrastructure wide-open to devastating attacks. The second change is much more positive; it's an explosion of algorithmic power that will let us do things with computers that are impossible today and that hold the promise to reshape our world.

2 ExxonMobil

ExxonMobil was the first energy company to join IBM's Quantum Network in 2019, and has expressed a keen interest in using the technology to explore various applications, ranging from the simulation of new materials to solving optimization problems.
Quantum computers take a new approach to addressing this sort of complexity, with the potential to find solutions that classical supercomputer alone cannot

handle. Industry leaders like Exxon are getting involved now to explore how blending classical and quantum computing techniques might solve big, complex, pressing global challengesTeams at IBM Research and ExxonMobil Corporate Strategy Research have collaborated to model maritime inventory routing on quantum devices, analyzing the strengths and trade-offs of different strategies for vehicle and inventory routing, and laying the foundation for constructing practical solutions for their operations. Quantum variational algorithms are already being studied for optimization problems in finance and chemistry. ExxonMobil sought to understand the extent to which maritime routing problems could also be addressed using existing quantum variational algorithms, and to determine which strategies are needed to account for complex real-world constraints, including capacity limitations and time windows, which dictate the arrival and departure of shipments.Teams at IBM Research and ExxonMobil Corporate Strategy Research have collaborated to model maritime inventory routing on quantum devices, analyzing the strengths and trade-offs of different strategies for vehicle and inventory routing, and laying the foundation for constructing practical solutions for their operations.
ExxonMobil relies on IBM to design and relentlessly improve the quantum hardware and software. And ExxonMobil researchers work alongside IBM experts to develop and test new generations of algorithms.IBM and ExxonMobil's teams started with widely-used mathematical representations of the problem, which account for factors such as the routes traveled, the potential movements between port locations and the order in which each location is visited on a particular route. There are many existing ways to formulate the equation, one of which is called the quadratic unconstrained binary optimization (QUBO) technique, and which is often used in classical computer science.

3 JP Morgan

JPMorgan Chase Co. is one of the largest financial institutions in the world and is also exploring the use of quantum computing for a variety of purposes.

One major area of interest for JPMorgan is in the field of financial modeling and risk analysis, where quantum computing has the potential to significantly speed up and improve the accuracy of simulations used to understand and predict financial markets. JP Morgan is exploring the use of quantum computing for various financial applications. The bank is researching the use of quantum computing to improve the efficiency and accuracy of financial modeling and risk analysis. They also looking at ways to apply quantum computing to enhance their portfolio optimization and asset pricing. Additionally, JP Morgan is researching the use of quantum computing to improve the security of their systems and protect against fraud. The bank is also exploring the use of quantum machine learning to enhance its fraud detection capabilities. This can include analyzing large datasets, such as customer transactions, to identify unusual patterns or behaviors that may indicate fraud.

By using quantum computing, the company could run simulations that are currently too time-consuming or difficult for classical computers, which would help them to improve their predictions and make better investment decisions.

Another area where quantum computing could be useful for JPMorgan is in the field of machine learning and artificial intelligence, which are increasingly being used in the financial industry for tasks such as fraud detection and risk management. Quantum computing has the potential to improve the performance of machine learning algorithms, which can process and analyze large amounts of data much faster than classical computers.

Additionally, JPMorgan also see potential in using quantum computing for portfolio optimization, derivatives pricing, natural language processing and in cryptography as well, which are all are essential for financial institutions for providing enhanced services to their clients.

As with other companies, JPMorgan is still in the early stages of exploring the potential use of quantum computing and it's likely that the full potential of this technology will become more clear over time as it continues to develop and mature

4 Mitsubishi

Mitsubishi Electric Corporation is using quantum computing for research and development in a variety of fields, including optimization of logistics systems, drug discovery, and financial modeling. They are also looking at ways to apply quantum computing to improve the performance of their products and services, such as control systems for power plants and transportation systems. For the chemical industry, turning that theory into a marketable product could create a thriving profit center for decades to come – with applications to everything from mobile devices to cars to unimagined new forms of transportation. That's one reason why Jamie Garcia, Senior Manager of Quantum Algorithms, Applications and Theory at IBM and her team of quantum chemists have been spending a lot of time on video conferences with research colleagues at Mitsubishi Chemical in Japan.

The IBM Quantum team was approached by Qi Gao at Mitsubishi Chemical and Professor Naoki Yamamoto at Keio University to model and study the complex mechanism for lithium superoxide rearrangement, a key chemical step in lithium-oxygen batteries. Their collaboration lays the groundwork for simulating – and eventually, investigating a problem connected to a real-world application on a quantum computer. moments The research triumvirate of Mitsubishi Chemical, Keio University, and IBM Quantum is working to better understand lithium-oxygen's potential as an energy source by using new algorithms that take advantage of quantum computing.

Running a new breed of algorithms, within quantum's completely new hardware environment and software, has already yielded quantitatively correct computational results of complicated chemical reaction in the discharge process of

lithium-oxygen battery. Furthermore, by looking at molecular fundamentals through a new lens, researchers are also trying to mine new insights, and observe phenomena that are not generally accepted as known or expected Another area of research for the company is in logistics, where quantum computing can help optimize complex logistics networks and improve transportation efficiency. This can help to reduce costs and improve delivery times for goods and services.

Mitsubishi Electric also announced its collaboration with 1QBit, a quantum computing software company to develop software for quantum optimization and quantum machine learning.

It's worth noting that currently most companies, including Mitsubishi, are in research phase and there is not a product yet. Also, quantum computing is a new and rapidly evolving field, and the exact ways in which it will be used by companies like Mitsubishi Electric in the future is still unclear. Mitsubishi Electric Corporation is using quantum computing for research and development in a variety of fields, including optimization of logistics systems, drug discovery, and financial modeling. They are also looking at ways to apply quantum computing to improve the performance of their products and services, such as control systems for power plants and transportation systems.

5 Boeing

Boeing is a company that designs and manufactures aircraft, and it has expressed interest in using quantum computing to help with a variety of tasks related to aircraft design and manufacturing.

One example is the optimization of aircraft systems and the aerodynamics of aircraft using quantum computing. The optimization problem that needs to be solved is extremely complex due to the large number of variables involved and the need to consider multiple objectives simultaneously. Quantum computing could help solve such problems by providing more efficient and accurate solutions. Another area of research is in materials and manufacturing, quantum computing can help simulate the behavior of various materials under different conditions, which can help to optimize the design and construction of aircraft parts and systems.

It's worth noting that currently most companies, including Boeing, are in research phase and there is not a product yet. Also, quantum computing is a new and rapidly evolving field, and the exact ways in which it will be used by companies like Boeing in the future is still unclear. Boeing is researching the use of quantum computing for various aerospace and defense applications, including aircraft design and optimization, logistics optimization, and cybersecurity. They are also investigating the use of quantum computing to improve the performance of their simulation and modeling tools. The company is working with partners such as Google to further explore the possibilities of quantum computing in these areas.

6 Cleveland clinic

Cleveland Clinic is a medical center that has been researching the use of quantum computing for various applications in healthcare. Specifically Cleveland Clinic has been using D-Wave Quantum computing for improving the treatment of cancer by modeling protein interactions to improve drug design and therapy plans. Additionally, the Cleveland Clinic is looking at ways to use quantum computing to improve the efficiency and accuracy of medical imaging and to better understand the complex biology underlying diseases like Alzheimer's and Parkinson's. They also explore the possibility of using quantum computing in developing personalized medicine approaches.

The organization has been investigating the use of quantum computing to aid in medical research and drug discovery. In particular, they have been looking into the use of quantum computing to help with the simulation of complex biological systems, such as proteins, which are difficult to model using classical computers. By simulating these systems using quantum computers, researchers may be able to gain new insights into the mechanisms of disease and develop new treatments. Additionally, quantum computing has the potential to speed up certain types of machine learning and artificial intelligence (AI) applications, which could be used in a variety of medical applications, such as drug development and personalized medicine.

7 Daimler

Daimler AG, the parent company of Mercedes-Benz, has been researching the use of quantum computing for various applications related to the automotive industry. Daimler has been researching how to apply quantum computing to optimize logistics systems, improve the performance of their products, and help design more energy-efficient vehicles. They have been looking into the ways to apply quantum computing to improve the accuracy and efficiency of their simulations and modeling tools, particularly in the field of engine development, aerodynamics and vehicle safety. Additionally, Daimler is researching the use of quantum computing to improve the security of their systems, specifically the cars on the road and develop the next-gen of autonomous vehicles. One potential application of quantum computing in the automotive industry is in the field of materials science and engineering, where quantum computing could be used to optimize the properties of materials used in car manufacturing, such as metals and polymers. By simulating the behavior of these materials at the atomic and molecular level, quantum computing could help researchers design new materials with better strength, durability, and other properties.

Another potential application of quantum computing in the automotive industry is in the field of logistics and supply chain management, where quantum computing could be used to optimize logistics networks, reduce costs, and improve delivery times. This could be done by using quantum algorithms to solve optimization problems, such as the Traveling Salesman Problem and the Vehicle

Routing Problem.

In addition, Daimler is also exploring the use of quantum computing for developing advanced driver assistance systems, autonomous vehicles and in machine learning to improve overall performance and the power train of its vehicles.

Like Goldman Sachs and other large companies Daimler is also investigating how quantum computing could be used to improve its operations and gain a competitive advantage in the automotive industry. However, it's worth mentioning that quantum computing is still an emerging technology and the full potential of quantum computing in the automotive industry remains to be seen.

8 Goldman Sachs

Goldman Sachs is exploring the use of quantum computing for various financial applications. The bank is researching the use of quantum computing to improve the efficiency and accuracy of financial modeling and risk analysis.Quantum algorithms could do complex financial calculations with blazing speed. Finance was one of the first domains to embrace Big Data, and the drive to innovate continues. Much of the science behind the pricing of financial assets involves simulating large numbers of different statistical possibilities, the forte of quantum computing. They are also looking at ways to apply quantum computing to enhance their portfolio optimization, and help to better understand complex financial systems and improve their trading strategies.In the financial markets, computing speed is a giant advantage. That's why Goldman Sachs has brought on foremost researchers to guide the firm in harnessing the power of quantum computing and applying it to our processes. Additionally, they are exploring the use of quantum machine learning to enhance the ability to identify trends and patterns in large datasets, such as market data, and improve prediction and forecasting capabilities. Another area of interest is the potential for quantum computing to enhance the bank's cybersecurity and fraud detection capabilities. Schemes for efficiently accessing classical data that has been loaded into quantum memory have been proposed, including a particular scheme known as "block-encoding" of the data. To load data using a block-encoding, one uses special purpose data structures, such as a quantum version of a random access memory — QRAM for short. Block-encodings are ubiquitous in quantum algorithms, but they are an often-overlooked source of overhead when assessing the computational resources needed to run the quantum algorithm. Moreover, concrete implementations of block-encodings have not been explored in depth at the level of quantum circuits. Together with Goldman Sachs, the Amazon Quantum Solutions Lab (QSL) and the AWS Center for Quantum Computing (CQC) filled in some of the missing pieces in a new paper titled "Quantum Resources Required to Block-Encode a Matrix of Classical Data".