INDUSTRIAL APPLICATIONS OF QUANTUM COMPUTING

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1 Introduction

Quantum computing is an area of computer science that uses the principles of quantum theory. Quantum theory explains the behavior of energy and material on the atomic and subatomic levels. Quantum computing uses subatomic particles, such as electrons or photons. Quantum bits, or qubits, allow these particles to exist in more than one state (i.e., 1 and 0) at the same time. Classical computers today employ a stream of electrical impulses (1 and 0) in a binary manner to encode information in bits. This restricts their processing ability, compared to quantum computing.
The field of quantum computing emerged in the 1980s. It was discovered that certain computational problems could be tackled more efficiently with quantum algorithms than with their classical counterparts.Quantum computing has the capability to sift through huge numbers of possibilities and extract potential solutions to complex problems and challenges. Where classical computers store information as bits with either 0s or 1s, quantum computers use qubits. Qubits carry information in a quantum state that engages 0 and 1 in a multidimensional way.Such massive computing potential and the projected market size for its use have attracted the attention of some of the most prominent companies. These include IBM, Microsoft, Google, D-Waves Systems, Alibaba, Nokia, Intel, Airbus, HP, Toshiba, Mitsubishi, SK Telecom, NEC, Raytheon, Lockheed Martin, Rigetti, Biogen, Volkswagen, and Amgen.

2 Daimler

Daimler is hard at work with a global research program headquartered in Silicon Valley to explore how it can take computing to the next level. At Mercedes-Benz Research and Development North America (MBRDNA), a team of experts together with their counterparts in Sindelfingen is coordinating the company's efforts to get up to speed with this technology, better understand its potential and current shortcomings and conduct basic research in close collaboration with

industry leaders from the high-tech world and academia.The Quantum Computing Initiative was established within Daimler by 2015 when the company started to explore, evaluate and benchmark this novel technology.
Battery technology is the most promising exploration of quantum computing's potential to date for Daimler. Namely, using a powerful computer to simulate what new battery chemistry is more efficient and long-lived, made with more abundant or less harmful ingredients. The way nature connects or binds two atoms is not dissimilar to how a quantum computer works. So it was an obvious choice to look into how this new computing paradigm can be used as an advantage. In this particular case, a team of scientists at Daimler and IBM looked into whether a quantum machine can compute and accurately simulate the fundamental behavior of lithium battery materials.

3 J P Morgan

JPMorgan Chase is one of the first financial institutions worldwide to invest in quantum computing and to build an internal team of scientists to work on new quantum algorithms and applications to address business use cases in finance, AI, optimization and cryptography. There is a need for standardization across the quantum industry in areas including consistent metrics to quantify hardware fidelity, post-quantum cryptographic algorithms, and quantum secure channel communication protocols. They also believe that there will be a shift from optimizing an entire algorithm to breaking it apart into a hybrid classical/quantum algorithm where quantum will be used only for portions of the computation that are exponential in nature, thereby creating the need for smart compilers that automatically perform this hybrid mapping.
To date, the program has produced new quantum algorithms for use cases such as portfolio optimization, option pricing, risk analysis, and numerous applications in the realm of Machine Learning, ranging from fraud detection to Natural Language Processing. The ultimate goal is to implement quantum solutions for the firm's relevant use cases and embrace an industry-leading position in the chase for quantum advantage and quantum supremacy. The ultimate goal is to implement quantum solutions for the firm's relevant use cases and embrace quantum advantage and quantum supremacy before its competitors. Additionally, JPMorgan Chase, Toshiba and Ciena completed an experiment that demonstrated the full viability of a first-of-its-kind Quantum Key Distribution (QKD) network for metropolitan areas, resistant to Quantum Computing attacks and capable of supporting 800 Gbps data rates for mission-critical applications under real-world environmental conditions. The success of this prototype shows that the firm now has a proven and tested method for preventing quantum attacks, and that it can be used to secure a Blockchain application—something that, up until now, has been unattainable.

4 ExxonMobil

ExxonMobil, the largest publicly traded international oil and gas company, uses technology and innovation to help meet the world‘s growing energy needs. ExxonMobil holds an industry-leading inventory of resources, is one of the largest refiners and marketers of petroleum products, and its chemical company is one of the largest in the world.
ExxonMobil becomes the first energy company to join the IBM Q Network, a worldwide community of Fortune 500 companies, startups, academic institutions and national research labs working to advance quantum computing and explore practical applications for science and business.Advances in quantum computing could provide ExxonMobil with an ability to address computationally challenging problems across a variety of applications, including the potential to optimize a country‘s power grid, and perform more predictive environmental modeling and highly accurate quantum chemistry calculations to enable discovery of new materials for more efficient carbon capture.ExxonMobil‘s partnership with IBM expands the company‘s collaborative efforts with other companies and academic institutions that are focused on developing an array of new energy technologies, improving energy efficiency and reducing greenhouse gas emissions. The company currently works with about 80 universities in the United States, Europe and Asia to explore next-generation energy technologies.

5 Goldman Sachs

Goldman Sachs introduces quantum algorithms developed by its Research and Development Engineering team that could allow the firm to price financial instruments at quantum speeds.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.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. Thier engineers are hard at work developing tools that will help rapidly assess the markets and, at times, alter the way we price some financial instruments. Only time can tell what the future will hold in this space, but current research suggests that the application of quantum computing in financial markets could dramatically change the speed and accuracy of thier business.
The Research and Development team at Goldman Sachs works to develop an edge for clients when it comes to technology in finance. Motivated by the theoretical potential of quantum computing, Goldman Sachs has been studying what it will take to make these theoretical advantages practical, often by taking well-defined benchmark problems in finance and estimating the performance specifications that a quantum computer will need to beat to show advantage. Similarly, the QSL works closely with customers to find the best solutions to their most challenging problems (be they quantum, classical, or hybrid), and

scientists at the AWS CQC are working to push the state-of-the-art in quantum technologies. Goldman Sachs, the QSL, and the CQC joined forces to evaluate different applications of quantum computers to real-world financial problems. Through a series of collaborative research engagements, Goldman Sachs and the quantum computing team at AWS systematically worked to find suitable use-cases for quantum computers, and appropriate quantum solutions. As financial problems often use large amounts of data, we identified that it would be important to specifically study the resources required for data loading.

6 Boeing

The Boeing Company and IBM are working together to explore quantum computing's potential to deliver the advanced computation and communications increasingly at the heart of aerospace innovation. Boeing is taking advantage of IBM's cloud-based Quantum Experience platform to provide researchers with access to quantum computers and other powerful resources that will help determine how best to leverage the technology to solve the aerospace industry's biggest challenges, including materials testing and optimization.

Manufacturers such as Boeing evaluate materials based on their properties to determine how those materials will withstand operating conditions over time. Much time and effort is spent on material selection, qualification and testing. The current materials testing paradigm, however, relies on months-long screening in the laboratory, followed by several years of outdoor exposure or in-service evaluation. Boeing is planning to use quantum computing to help the company perform comprehensive materials evaluations, model a material's reaction to environmental conditions and determine the estimated service life and performance much more efficiently and comprehensively than is possible using classical computers.

Optimization is another important area with potential applications for quantum computing – from logistics routing to factory assembly planning and scheduling optimization. Boeing researchers are experimenting with IBM's quantum computing resources to explore multiple optimization applications.

7 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.
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.

8 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.