Innovation Insight for Quantum Computing for the Automotive Industry

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Initiatives: Manufacturing Digital Transformation and Innovation

Quantum computing is becoming more available to organizations, which can create a breakthrough by solving many complex problems previously considered too time-consuming. Automotive and mobility CIOs must consider this technology as a way to build a major competitive advantage.

Additional Perspectives

- Summary Translation: Innovation Insight for Quantum Computing for the Automotive Industry
  (25 June 2021)

Overview

Key Findings

- Quantum computing (QC) will be able to solve optimization problems faster than conventional processors, opening the door to tackle areas that were previously considered impractical. These include, for instance, holistic traffic flow optimization or optimization of materials at the molecular level.
- Several companies have started to offer QC as a service (QCaaS) to external parties. The solution offers access to superior computational power with comparatively lower investment.
- QC's early stage as a research tool means it can often be marginalized in technology budgets and perceived as something too futuristic.

Recommendations

CIOs focused on the digital transformation and innovation of the mobility industry should:

- Determine a list of use cases that QC could solve better than traditional computational methods in order to formulate a sound business case, working together with stakeholders across the value chain. This will be the backbone of the long-term QC plan you will take to the board.
- Set up QC governance and an internal innovation team, backed by a major executive sponsor to make sure this project can sustain long-term strategic importance.
- Build external partnerships according to the project´s needs, be it with QCaaS providers or other relevant entities to tackle the use cases selected.

Strategic Planning Assumption

By 2025, several automotive OEMs will bring into production at least one QC use case.

Introduction

The disruptive impact of real QC is more than a decade away (see Quantum Computing Planning for Technology General Managers), but investments and innovation in QC are being driven by the potential business value advantage of intermediate annealing technologies, such as quantum annealing or digital annealing.

Gartner inquiries on the topic of QC have increased by more than 50% since 2018 (see Strategy Guide to Navigating the Quantum Computing Hype). More concretely, automotive is one of the key sectors with the most to gain from advancements in QC (see Top 10 Strategic Technology Trends for 2019: Quantum Computing). A commercially available, affordable and reliable QC product or service can allow breakthroughs in several areas, such as vehicle development and manufacturing. As described in this research, several automotive companies are already actively exploring QC with the purpose of incorporating it into their regular processes and operations.

Description

QC is a type of nonclassical computing that operates on the quantum state of subatomic particles (for example, electrons, photos or ions) that represent information as elements denoted as quantum bits (qubits).

On the other hand, digital annealing is a floating point accelerator, structured specifically for optimization problems. Digital annealers offer very high precision compared with a quantum annealer, but cannot advance at the same rate. Digital annealing is not QC, but its superior computing power in relation to conventional processors allows companies to consider a broader range of more-ambitious annealing problems in preparation for a broader future deployment of QC.

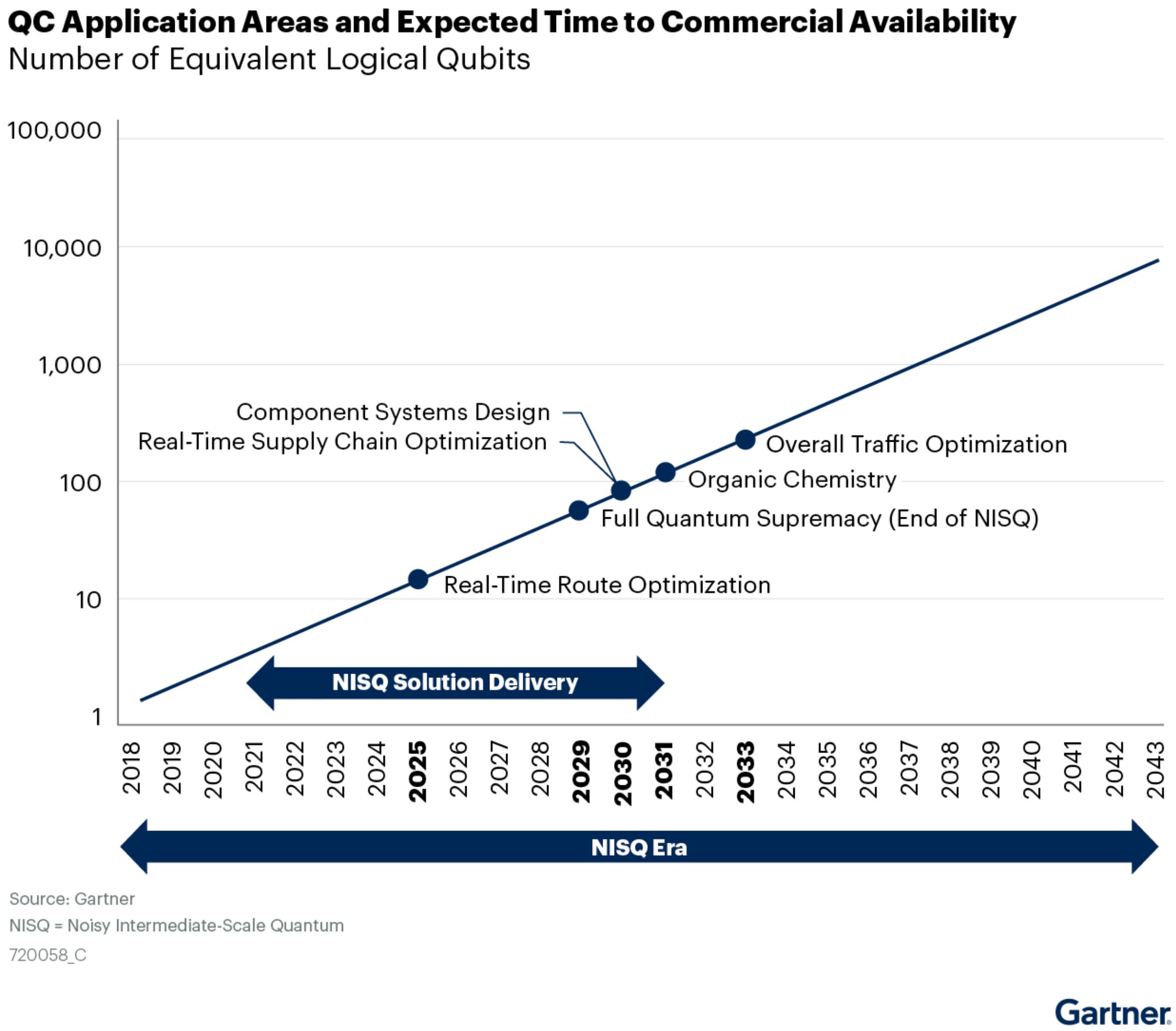
Classical computers use bits that are binary, meaning they are either zero or one. In a quantum computer, a qubit is the fundamental bit and can seem to be both zero and one until it's read (see Top 10 Strategic Technology Trends for 2019: Quantum Computing). Qubits can be linked with other qubits, a property known as entanglement. [1] Quantum algorithms manipulate linked qubits in their undetermined, entangled state. The qubits resolve to a solution when read. [2]

QC is not a replacement for classical computing, because most problems do not need quantum capabilities (see Strategy Guide to Navigating the Quantum Computing Hype). But QC can deliver disruptive advantages for a select set of problems. It has no similarities with classical computing, and is more akin to analog computing, where circuits are designed to solve problems. Nearly all layers of the QC stack — from enabling technologies, programming models and infrastructures to algorithms — are radically different from their classical counterparts.

Benefits and Uses

QC will be applicable to several automotive and mobility use cases as the technology itself evolves. Gartner's research estimates that real-time applications could be put into production in five years for situations where calculation speed is crucial. The same should be applicable to full optimization problems within a 10-year time frame. Figure 1 shows the time for commercial availability of each specific use case.

Figure 1. QC Application Areas and Expected Time to Commercial Availability



Several automotive companies have already piloted a number of QC applications with the purpose of building know-how on the technology. However, none of these are yet commercially available applications.

Traffic management and route optimization. Present-day traffic management systems and associated connected navigation systems struggle to build a precise and holistic model of the urban traffic ecosystem, hence falling short in predicting several factors. For instance, when informed of a jam, navigation systems will direct vehicles to the same alternative route, creating new traffic holdups. In 2017, DENSO and Toyota Tsusho conducted what they claim was the world's first usage of QC on a road traffic Internet of Things (IoT) platform. [3] The test aimed to improve the applicability of QC in transportation through real-time monitoring of 130,000 taxis and trucks in Thailand. The purpose was to build further optimization in route guidance and traffic flow.

Research and development. The development of a vehicle and its components entails a number of complex processes where greater computing power can bring optimization to multiple areas, such as structural analysis [4] and computational fluid dynamics. [5] This will be possible not just on an individual component basis, but also on a system basis, where more-advanced simulation can more quickly improve each component based on its interaction with other system parts.

Materials science. QC will be able to more quickly model existing materials to the molecular level, [6] enabling a much better prediction of their mechanical properties or chemical properties. Similarly, QC will also be able to accelerate the creation of more and better metamaterials (synthetic materials with properties superior to those of natural materials). [7]

These possibilities can enable breakthroughs at several levels of vehicle performance, like crash protection, weight reduction and resistance to wear and tear. However, due to the sector's major push in electrification, battery chemistry has been so far one of the main use cases overall. Daimler and IBM claim the use of QC has enabled a breakthrough on the road to a next-generation lithium-sulfur (Li-S) battery that would be more powerful, last longer and cost less than today's lithium-ion batteries. [8] Volkswagen (VW) also is working with QC and believes it can help make electric vehicle batteries up to 40% more powerful using a QC system. [9]

Supply chain and manufacturing. These complex processes are also being researched as potential regular QC applications. For instance, VW has been researching the technology for production line optimization. [10] BMW Group is investigating the application of QIC for a more efficient orchestration and coordination of robots. [11] As IoT spreads across the factory floor and the supply chain, this will also allow the development of more-accurate digital twins.

Cybersecurity. QIC's large computational power means it can break practically any conventional encryption system. Companies such as Quantum Xchange and ID Quantique already offer quantum encryption solutions that protect systems against the future threat of QC.

Risks

The risks of pure QC are essentially associated with several aspects of usage practicality and the complexity of using a computer in a totally different way to solve a particular problem:

- **Decoherence.** Real quantum computers are somewhat prone to errors due to decoherence, a process where the surrounding environment (like magnetic and electric fields, and heat sources) destabilizes qubits, leading to information loss and diverse results. [12]

- **Modeling.** Even if QIC (digital annealing) can be used to solve highly complex problems, these still demand building a model of a real ecosystem to extract optimization. Many times, such a model is hard to construct or doesn't portray a high degree of faithfulness to the reality it is supposed to represent.

- **Data gathering.** Similarly, a highly detailed model also demands a great deal of data gathering. In some cases, such a level of data may not be available to justify the use of QC.

- **Shortage of QC programming skills.** QC programming languages are different from other existing languages, which entails the need to hire or train specific expertise to enable specific applications.

- **Security.** QC has the potential to crack most of today's encryption systems. This risk will grow with QC adoption.

Recommendations

Prioritize QC Use Cases to Develop a Long-Term Technology Adoption Plan for the Board

Despite its current limitations, QC technology will evolve dramatically in the coming 10 years. This means it should be part of the company's advanced planning strategy to position your organization as a successful early adopter. This entails defining key use cases in line with the following principles:

- Roll out use cases to production according to the evolution of QC technology. For instance, focus on a five-year horizon to deploy real-time applications where speed of calculation is essential. A 10-year time frame is the expected horizon for applications combining speed and complexity.

- In line with QC's capabilities at each point in time, prioritize use cases that entail high-cost processes, but still with not such a high level of optimization. The same can be extrapolated to processes with high revenue-growth potential, like improving vehicle characteristics.

Set Up QC Governance and an Internal Innovation Team

Start by securing a solid governance with a strong executive sponsor, clear innovation processes, collaboration and support of other functional areas of the company. Bring QC expertise to your company that you can develop to take the leadership of a future major QC unit in the long term. Researchers in the area of QC are valuable talent you should pursue. However, to secure and justify these resources as full-time equivalents in the interim period, consider also involving them in other, more-current areas of the business, such as managing the use of digital annealing for solving complex problems in the short term to midterm. This will help establish a bridge to the rollout of QC later on.

Build External Partnerships According to Your Needs

Secure cooperation with a QCaaS provider as a start, to have frequent access to QC without incurring the cost of buying an actual quantum computer. Some of the use cases, like traffic management, may require collaboration with other external entities. This is necessary to guarantee a good level of data collection, interpretation of results and subsequent optimization.

Representative Providers

These are some of the quantum-inspired computing full-stack providers with known work done in automotive and smart mobility:

- Alibaba Group
- D-Wave
- Fujitsu
- Google
- IBM
- Intel
- Microsoft
- Qilimanjaro
- Rigetti Computing

Evidence

[1] Entanglement Made Simple, Quanta Magazine.

[2] Quantum Computation and Quantum Information, Cambridge University Press.

[3] DENSO and Toyota Tsusho to Conduct a Test Applying a Quantum Computer to Analyze IoT Data With a Commercial Application, DENSO.

[4] Material Simulation on D-Wave, Volkswagen Data:Lab Munich.

[5] Quantum Algorithms for Fluid Simulations, IntechOpen.

[6] Quantum Technology & Computing, IBM.

[7] Expanding the Horizon of Automated Metamaterials Discovery via Quantum Annealing, Cornell University.

[8] IBM and Daimler Use Quantum Computer to Develop Next-Gen Batteries, IBM Research Blog.

[9] How VW, Bosch, Ford, Daimler Aim to Gain From Quantum Computing, Automotive News Europe.

[10] Hybrid Algorithm Development for Production Applications, Volkswagen Data:Lab Munich.

[11] Quantum Annealing Based Optimization of Robotic Movement in Manufacturing, BMW Group.

[12] Decoherence Is a Problem for Quantum Computing, But ..., Scientific American.

Recommended by the Authors

Some documents may not be available as part of your current Gartner subscription.

Strategy Guide to Navigating the Quantum Computing Hype

Top 10 Strategic Technology Trends for 2019: Quantum Computing