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Media information

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Wolfsburg/Mountain View/Lisbon, November 7, 2017. At the technology conference "Web Summit 2017" (Lisbon), the Volkswagen Group and Google today announced comprehensive research cooperation in the field of quantum computing. In future, the two companies will explore the utilization of quantum computers together. They intend to build up specialist knowledge and to carry out practically oriented research.
► You will find attached further information related to the press release.

Basic principles of quantum computing

Explanation: what is a quantum computer?

The memory of a **conventional (classical) computer** consists of bits, the smallest unit of information, each of which can be in one of two states ("zero" and "one"). Conventional computers reach their limits in attempts to solve highly complex tasks but are regarded as very reliable because of their binary system.

Quantum computers have a fundamentally different design. Their hardware architecture is based on the principles of quantum mechanics. A quantum bit ("qubit") may adopt the states of zero, one, or a mixture of the two states simultaneously (a "superposition") on the basis of the laws of quantum mechanics. The computing power available therefore rises exponentially as a quantum computer can carry out each calculation step with all states at the same time. However, the number of possible states to be considered also makes the calculation operations involved considerably more complex. In addition, a quantum computer is a highly sensitive system which may be

disturbed by any external influence. This may even include changes in the earth's magnetic field. Working with quantum computers therefore calls for specialist expertise and methodological competence. Volkswagen Group IT is continually building up these skills.

Quantum computers are not superior to classical computers for all problems. However, quantum computers enable the use of algorithms to solve some complex problems exponentially faster than possible with any known algorithm on classical computers. In some cases, a solution will only be possible with quantum computers.

What quantum computing processes are available?

There are two quantum computing processes which are suitable for different types of tasks.

An **annealing system** (annealing quantum computer) is designed for the solution of optimization problems. In simplified terms, an optimization problem considers the question of how a resource such as time, money or energy can be used in the optimum way in a specific scenario. An annealing system finds the "sufficiently optimum solution" or the "minimum". Volkswagen Group IT announced its first successful research project on a quantum computer in March 2017, traffic optimization for 10,000 taxis in the Chinese capital Beijing. For this project, an annealing system of Canadian company D-Wave Systems was used.

A **universal quantum computer** (universal gate quantum computer) is suitable for a variety of experimental tasks. In the future, specialists from Volkswagen Group IT will carry out practically oriented research on a Google universal computer and explore the potential of this quantum computer in several different areas. The research areas concerned include:

- The further development of traffic optimization: The Volkswagen specialists are building on the research project which they have already successfully completed and now want to consider additional variables, in addition to reducing travelling times. These include urban traffic guidance systems, available electric charging stations or vacant parking spaces.
- The simulation and optimization of materials: The specialists aim to simulate and optimize the structure of materials. The company expects this approach to provide new information for vehicle construction and battery research, especially for the development of high-performance batteries for electric vehicles.
- Machine learning: The specialists want to work on new processes in machine learning. Machine learning is a key technology for the development of advanced AI systems.

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Information on the development areas of Volkswagen Group IT

Further development of traffic flow optimization

The Volkswagen specialists are building on their first successful research project on a quantum computer, which concerned traffic optimization for 10,000 taxis in the Chinese capital Beijing. They want to pursue the special knowledge they have acquired in depth on the Google universal quantum computer and to develop experimental algorithms which will consider further parameters in addition to reduced travel times.

The Volkswagen specialists are concerned not only with solutions for individual road users but also with the control possibilities of urban traffic planning.

Florian Neukart, Principal Scientist in the CODE Lab of Volkswagen Group IT in San Francisco: "Smart algorithm-based traffic guidance can provide meaningful support for cities and drivers."

In this context, quantum algorithms could be used for a variety of purposes. The Volkswagen specialists are concerned not only with solutions for individual road users (vehicles) but also with the control possibilities of urban traffic planning.

It is conceivable that, in addition to reducing travelling times and avoiding congestion, vehicles could also be assigned to available electric charging stations or vacant parking spaces. More general factors such as urban traffic guidance systems, public transport or weather conditions could also be taken into consideration.

The idea is that cities could route traffic effectively around major events or construction work in the city area, preventing congestion. On this project, the Volkswagen specialists are at the beginning of their development work.

Florian Neukart, Principal Scientist in the CODE Lab of Volkswagen Group IT in San Francisco, says: "At Volkswagen, we are forging ahead with practically oriented research in the field of quantum computing with a view to learning how to use the potential of the Google universal quantum computer successfully for varied and demanding tasks. Smart algorithm-based traffic guidance can provide meaningful support for cities and drivers. We are looking forward to this work."

Material simulation for high-performance electric vehicle batteries and new materials

Using the Google universal quantum computer, the Volkswagen specialists want to develop algorithms for simulating and optimizing the structures of materials. The first practically oriented research project will concern the development of an algorithm for simulating the chemical structure of high-performance electric vehicle batteries.

Specialists from Volkswagen want to simulate the chemical structure of high-performance electric vehicle batteries. It also is conceivable that such algorithms can simulate metal structures and new materials.

Ulrich Eichhorn, Head of Research and Development of the Volkswagen Group: „The Volkswagen Group has set itself the target of becoming market leader in e-mobility. Our battery competence will be a key success factor in this context. Together with Group IT, we have adopted innovative approaches."

It is conceivable that such an algorithm could optimize battery variants for a variety of different applications by indicating appropriate chemical structures. Such requirements could include maximum weight reduction with increased power density or alternative chemical compositions for the cells. Within the Volkswagen Group, IT is cooperating closely with Research and Development to ensure that all the knowledge gained is used directly in the Group's battery research. The specialists also see other possibilities in the development of algorithms and applications on the Google quantum computer to simulate and optimize metal structures in vehicle construction or new materials.

Ulrich Eichhorn, Head of Research and Development of the Volkswagen Group, says: "The Volkswagen Group has set itself the target of becoming market leader in e-mobility. Our battery competence will be a key success factor in this context. We are pooling our battery competence at the Salzgitter Center of Excellence. Together with Group IT, we have adopted innovative approaches. These may provide knowledge which will give us the edge in competition."

Florian Neukart says: "With material simulation for vehicle batteries on a quantum computer, we are launching a unique project in the industry. For the Volkswagen team, this is a major step from basic investigations to practically oriented research."

New machine learning and processes

The specialists from Volkswagen want to tap the potential of the Google quantum computer system to work on artificial intelligence by exploring new machine learning processes.

Machine learning is important for autonomous driving. The specialists from Volkswagen want to tap the potential of the quantum computer system to explore new machine learning processes.

Christian Seidel, Lead Quantum Computer Scientist in the Volkswagen Group IT Data Lab in Munich: „A key factor in machine learning is data analysis and processing. We are exploring the potential of Google's universal quantum computer for this purpose."

In simplified terms, machine learning means the capability of a program (or system) to link data, analyze relationships and make predictions on this basis. A system acquires information in several steps or on several levels and compares the new information with what it has already learnt. This way, systems become highly reliable and efficient in detecting patterns and laws. Machine learning is seen as a key technology for the development of advanced AI (artificial intelligence) systems. For example, these are a prerequisite for autonomous driving.

Volkswagen expects the experimental work with the Google quantum computer to lead to new possibilities for the further development of learning systems. By exploring quantum based algorithms, the specialists want to further enhance the detection of patterns. A learning system would then therefore have a very large volume of data available – this would provide the "experience" needed by the system for making decisions.

Christian Seidel, Lead Quantum Computer Scientist in the Volkswagen Group IT Data Lab in Munich, says: "The data lab is the Volkswagen Group's machine learning and artificial intelligence competence center. Here, we are developing possibilities of using learning systems in a wide variety of different corporate processes. A key factor is data analysis and processing. We are exploring the potential of Google's universal quantum computer for this purpose."

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Note for editorial teams:

This text and pictures are available at: www.volkswagen-media-services.com

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