Quantum Computing and AI – a compelling combination

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2024 is shaping up to be a breakthrough year for quantum computing. We're on the brink of seeing the emergence of a symbiotic relationship between quantum and Artificial Intelligence (AI). This has enormous potential to drive advancements in both fields, pushing the boundaries of what's possible.

Since we're finally reaching the limits of Moore's Law, we need alternative approaches to advancing computing performance. Putting quantum computing together with AI is opening some exciting possibilities. It works both ways. We can make increasing use of AI to detect and compensate for anomalies in quantum computing – the factor currently holding back its rapid advancement – and on the other hand, leverage quantum computing to extend the development of AI.
It's only a matter of time until we can harness the vast computational capabilities of quantum systems – which will drive breakthroughs in areas such as drug discovery and revolutionize the financial markets through the ability to crunch complex algorithms in the blink of an eye. But some experts say it may be another 10 years before we reach this point.

Despite having a possibility of being many times faster than conventional silicon-based computing, the technology is still error prone. Qubits used for quantum computing must be stable enough to produce meaningful, accurate results. If they are unstable, then results are unreliable. Although we are making progress in getting and keeping quantum systems in a stable state, advances are still not fast enough.

Of course, getting a quantum computer up and running is a bit more complicated than a conventional computer. Qubits are controlled and measured using microwaves in superconducting qubit technology. They are inherently delicate and susceptible to noise from their surroundings – which means they are affected by factors including thermal noise, electromagnetic interference and material imperfections. Even simple operations or measurements can introduce errors. That means quantum calculations must always be cross-checked on High-Performance Computing systems – a fact that significantly undermines the usefulness of current quantum computers. Despite being the world's most potent conventional computers, HPC systems are many times slower in some calculations than quantum.

To fine-tune qubits today, we optimize the shapes of microwave pulses by hand – but we're limited in scale as, realistically, it's simply impossible for a human to conduct such optimization for several tens of qubits simultaneously. Here is where AI comes in. It can learn how to optimize the microwave pulses to better control multiple qubits simultaneously, reducing quantum errors. On top of that, AI can be used to identify which qubits should preferentially be used for specific quantum calculations. On the flip side, more powerful quantum computing calculations will enable the development of faster, more advanced AI systems. And you don't need to be a quantum expert to realize why the combination is so exciting.

In 2024, we may also see the development of optimized task allocation. Here, we will refine AI-driven computational brokers to assess computational tasks and determine whether they're better suited for a quantum computer, a classical computer, or a hybrid combination. That's because there are still many tasks where a High-Performance Computer (HPC) is faster than a quantum computer – for example, in straightforward mathematical functions like multiplication and addition.
As we utilize AI algorithms to optimize the way we manipulate qubits, it could lead to more stable quantum operations: a critical breakthrough that will allow us to rapidly increase the number of reliable qubits in quantum systems beyond the 100 qubits we've reached today.

Fujitsu is working with the Japanese research institute RIKEN on a joint mission to increase the use of quantum technology to 1,000 qubits by boosting both hardware and software capabilities.
This approach combines DMET (Density Matrix Embedding Theory) – which gives a theoretical framework for handling finite fragments in the presence of a surrounding molecular or bulk environment, even when there is large correlation between

them – and VQE (Variational Quantum Eigensolver), an algorithm designed to solve optimization problems using near-term quantum devices, sometimes referred to as Noisy Intermediate-Scale Quantum (NISQ) devices.

Looking into the future, we envision the seamless integration of AI, quantum computers and HPC in a hybrid platform, which ensures smooth transitioning between quantum and classical computations as needed.
And because of this, we are excited to go into 2024, a breakthrough year for quantum computing.

To learn more about Fujitsu's developments in quantum computing, visit our website.

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Dr. Shintaro Sato was also a group leader at the National Institute of Advanced Industrial Science and Technology from 2010 to 2014 working on "green nanoelectronics" funded by the Japan Society for the Promotion of Science through the First Program. He also had a concurrent position at Semiconductor Leading-Edge Technologies, Inc. from 2006 to 2010. He joined Fujitsu in 2001. He was also a staff engineer at Ushio Inc., Japan from 1990 to 1997. He obtained his MS in Science and Engineering (Physics) from the University of Tsukuba in 1990. He obtained his Ph.D. in Mechanical Engineering from the University of Minnesota, USA in 2001. His research areas include quantum computing, nanoelectronics, and nanomaterials.