Quantum talking points in 2025

Quantum predictions for 2025

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Breakthroughs in Quantum Error Correction offers an exciting outlook for 2025

Quantum computing is generating considerable interest, but the technology is still in its infancy. Substantial progress in quantum hardware and software is needed for it to become more realistic and support complex applications like material science simulations, quantum chemistry calculations, drug discovery, and quantum cryptography.

In 2025, we could see breakthroughs both in quantum hardware performance and quantum software, particularly in error correction techniques.

The level of attention given to quantum software is increasing rapidly and is critical to the further development of quantum systems. Qubits in quantum computers are more susceptible to noise and thus error-prone, unlike bits in classical computers, which are relatively stable and robust.

Quantum operations are susceptible to errors arising from three primary sources: **decoherence**, resulting in the loss of qubit coherence; **gate errors**, stemming from imperfections in quantum gates and leading to erroneous qubit manipulations; and **measurement inaccuracies**, caused by imprecise readings of qubit states.

Software plays a crucial role in suppressing these errors. A particularly promising approach is Quantum Error Correction (QEC), which encodes quantum information redundantly across multiple qubits specially entangled with supplementary qubits (ancillas). Several specific operations and ancillas measurements on these qubits allow for the detection and correction of errors without directly measuring the quantum data.

In 2025, I expect advances in Quantum Error Correction Codes (QECCs) to make quantum computing more scalable and resilient. Researchers will likely develop more efficient ways to implement QECCs, such as surface and quantum low-density parity-check (QLDPC) codes. These could become more practical, requiring fewer physical qubits for logical qubit operations.

We see QECCs developing in 2025 and beyond in multiple areas, starting with **more efficient implementation of the surface code**, the most promising QECC due to its relatively low qubit overhead and robustness. Next year, we could see optimizations in the surface code, such as reductions in the number of physical qubits needed to perform logical qubit operations. Innovations here may involve improved lattice structures (how qubits are arranged) and better error-suppression techniques, allowing surface codes to operate more efficiently.

I also expect advancements in **QLDPC codes**. These are an alternative to surface codes with potentially lower qubit overhead. QLDPC codes use sparse check matrices, making them highly scalable and capable of tolerating higher error rates.

Another advance will be a breakthrough in **code concatenation**, which involves layering different QECCs to create a multi-tiered protection system. I hope to see concatenation strategies improve to combine the strengths of different QECCs. For example, a hybrid approach using surface and QLDPC codes could improve fault tolerance while keeping overhead relatively low.

I also expect further progress in the research and development of **high-speed decoders,** another crucial component of QEC schemes. High-speed decoders are algorithms and, increasingly, specialized hardware designed to rapidly perform error correction. High-speed decoders process the ancillas measurements and efficiently determine the most probable original quantum state. The speed of decoding is critical as the longer the process takes, the greater the risk of additional errors accumulating before correction can be applied, potentially rendering the correction ineffective. The speed of decoding directly impacts the overall throughput and scalability of quantum computers, making it a central challenge in the quest for practical quantum computation.

Advances in QEC will have a transformative practical impact on quantum computing. By reducing error rates and allowing longer processing times, quantum systems will be able to handle deeper, more reliable computations, which is crucial for executing complex algorithms.

In fields like drug discovery and materials science, quantum computers can simulate molecular interactions and quantum properties of new materials at an atomic level – tasks that often exceed the computational capabilities of classical computers. With enhanced error correction, quantum computers could yield more precise and actionable insights, accelerating breakthroughs in developing new pharmaceuticals, sustainable materials, and energy solutions.

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He is responsible for research on quantum computing at Fujitsu. At the Quantum Laboratory, he leads research on all the technology layers of quantum computing: quantum devices, platforms, software, and application. Before engaging in quantum computing, he had been working on research and development of post-silicon devices using carbon nanotubes and graphene and obtained several research awards, including the SAP (the Japan Society of Applied Physics) Fellow Award in 2018.