Quantum computing's next step: New algorithm boosts multitasking

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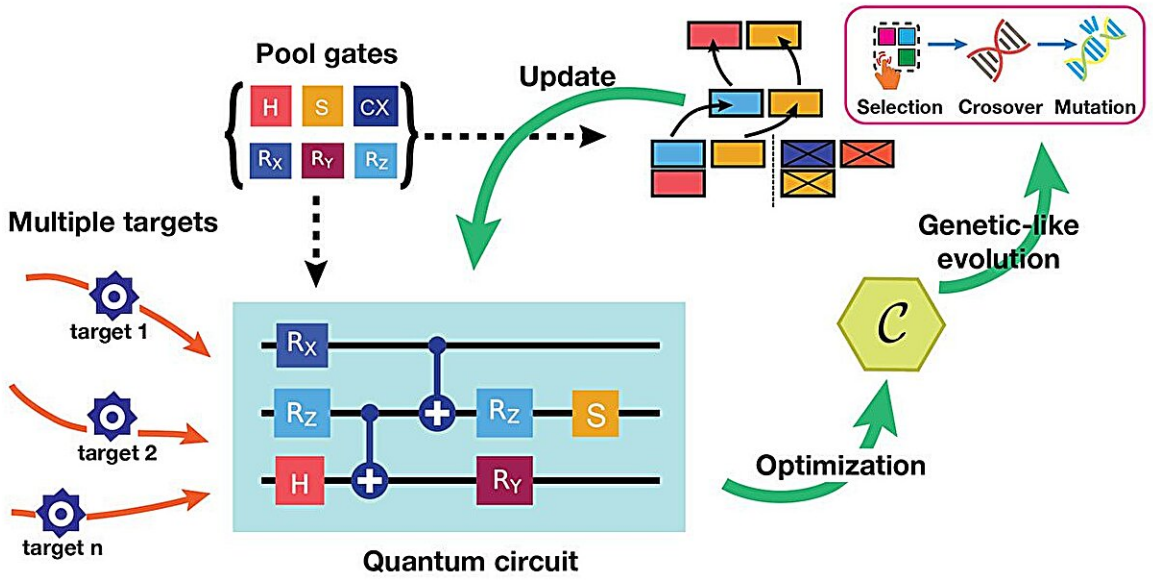

Multi-target quantum compilation protocol. Its core is a quantum circuit designed for quantum computers. The circuit is built from a pool of gates, with the input being a set of target operations. It is then optimized and evolved like a gene through selection, crossover, and mutation. This process continues with each new generation until the circuit reaches an optimal form. Credit: Tohoku University

Quantum computers differ fundamentally from classical ones. Instead of using bits (0s and 1s), they employ "qubits," which can exist in multiple states simultaneously due to quantum phenomena like superposition and

entanglement.

For a quantum computer to simulate dynamic processes or process data, among other essential tasks, it must translate complex input data into "quantum data" that it can understand. This process is known as quantum compilation.

Essentially, quantum compilation "programs" the quantum computer by converting a particular goal into an executable sequence. Just as the GPS app converts your desired destination into a sequence of actionable steps you can follow, quantum compilation translates a high-level goal into a precise sequence of quantum operations that the quantum computer can execute.

Traditionally, quantum compilation algorithms optimize a single target at a time. While effective, there are limitations to this approach. Many complex applications require a quantum computer to multitask. For example, in simulating quantum dynamical processes or preparing quantum states for experiments, researchers may need to manage multiple operations at once to achieve accurate results. In these situations, handling one target at a time becomes inefficient.

To address these challenges, Tohoku University's Dr. Le Bin Ho led a team that developed a multi-target quantum compilation algorithm. They published their new study in the journal *Machine Learning: Science and Technology* on December 5, 2024.

"By enabling a quantum computer to optimize multiple targets at once, this algorithm increases flexibility and maximizes performance," says Le. This leads to improvements in complex-system simulations or tasks that involve multiple variables in quantum machine learning, making it ideal for applications across various scientific disciplines.

In addition to performance improvements, this multi-target algorithm opens the door to new applications previously limited by the single-target approach. For instance, in materials science, researchers could use this algorithm to simultaneously explore multiple properties of a material at the quantum level. In physics, the algorithm may assist in studying systems that evolve or require various interactions to be fully understood.

This development represents a significant advancement in quantum computing. "The multi-target quantum compilation algorithm brings us closer to the day when quantum computers can efficiently handle complex, multi-faceted tasks, providing solutions to problems beyond the reach of classical computers," adds Le.

Looking ahead, Le aims to study how this algorithm can adapt to various types of noise and identify ways to enhance its performance.

More information: Vu Tuan Hai et al, Multi-target quantum compilation algorithm, *Machine Learning: Science and Technology* (2024). DOI: 10.1088/2632-2153/ad9705

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