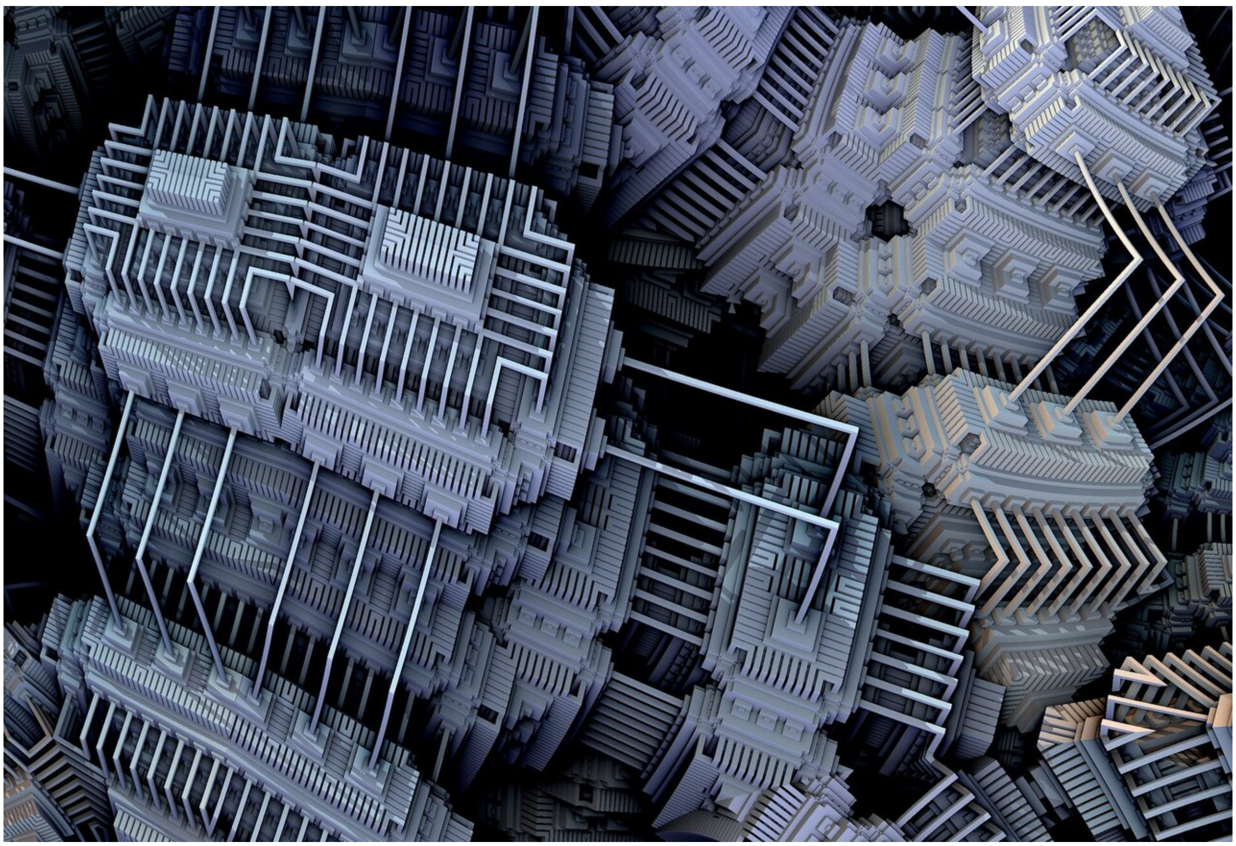
Computer scientists set benchmarks to optimize quantum computer performance

August 14 2020



Credit: CC0 Public Domain

Two UCLA computer scientists have shown that existing compilers, which tell quantum computers how to use their circuits to execute quantum programs, inhibit the computers' ability to achieve optimal performance. Specifically, their research has revealed that improving quantum compilation design could help achieve computation speeds up to 45 times faster than currently demonstrated.

The computer scientists created a family of benchmark quantum circuits with known optimal depths or sizes. In computer design, the smaller the circuit depth, the faster a computation can be completed. Smaller circuits also imply more computation can be packed into the existing quantum computer. Quantum computer designers could use these benchmarks to improve design tools that could then find the best circuit design.

"We believe in the 'measure, then improve' methodology," said lead researcher Jason Cong, a Distinguished Chancellor's Professor of Computer Science at UCLA Samueli School of Engineering. "Now that we have revealed the large optimality gap, we are on the way to develop better quantum compilation tools, and we hope the entire quantum research community will as well."

Cong and graduate student Daniel (Bochen) Tan tested their benchmarks in four of the most used quantum compilation tools. A study detailing their research was published in *IEEE Transactions on Computers*, a peer-reviewed journal.

Tan and Cong have made the benchmarks, named QUEKO, open source and available on the software repository GitHub.

Quantum computers utilize quantum mechanics to perform a great deal of computations simultaneously, which has the potential to make them exponentially faster and more powerful than today's best supercomputers. But many issues need to be addressed before these devices can move out of the research lab.

For example, due to the sensitive nature of how quantum circuits work, tiny environmental changes, such as small temperature fluctuations, can interfere with quantum computation. When that happens, the quantum circuits are called decoherent—which is to say they have lost the information once encoded in them.

"If we can consistently halve the circuit depth by better layout synthesis, we effectively double the time it takes for a quantum device to become decoherent," Cong said.

"This compilation research could effectively extend that time, and it would be the equivalent to a huge advancement in experimental physics and electrical engineering," Cong added. "So we expect these benchmarks to motivate both academia and the industry to develop better layout synthesis tools, which in turn will help drive advances in quantum computing."

Cong and his colleagues led a similar effort in the early 2000s to optimize integrated circuit design in classical computers. That research effectively pushed two generations of advances in computer processing speeds, using only optimized layout design, which shortened the distance between the transistors that comprise the circuit. This cost-efficient improvement was achieved without any other major investments in technological advances, such as physically shrinking the circuits themselves.

"Quantum processors in existence today are extremely limited by environmental interference, which puts severe restrictions on the length of computations that can be performed," said Mark Gyure, executive director of the UCLA Center for Quantum Science and Engineering, who was not involved in this study. "That's why the recent research results from Professor Cong's group are so important because they have shown that most implementations of quantum circuits to date are likely extremely inefficient and more optimally compiled circuits could enable much longer algorithms to be executed. This could result in today's processors solving much more interesting problems than previously thought. That's an extremely important advance for the field and incredibly exciting."

More information: Bochen Tan et al, Optimality Study of Existing Quantum Computing Layout Synthesis Tools, *IEEE Transactions on Computers* (2020). DOI: 10.1109/TC.2020.3009140

Provided by University of California, Los Angeles