# Scientists break Google's quantum algorithm

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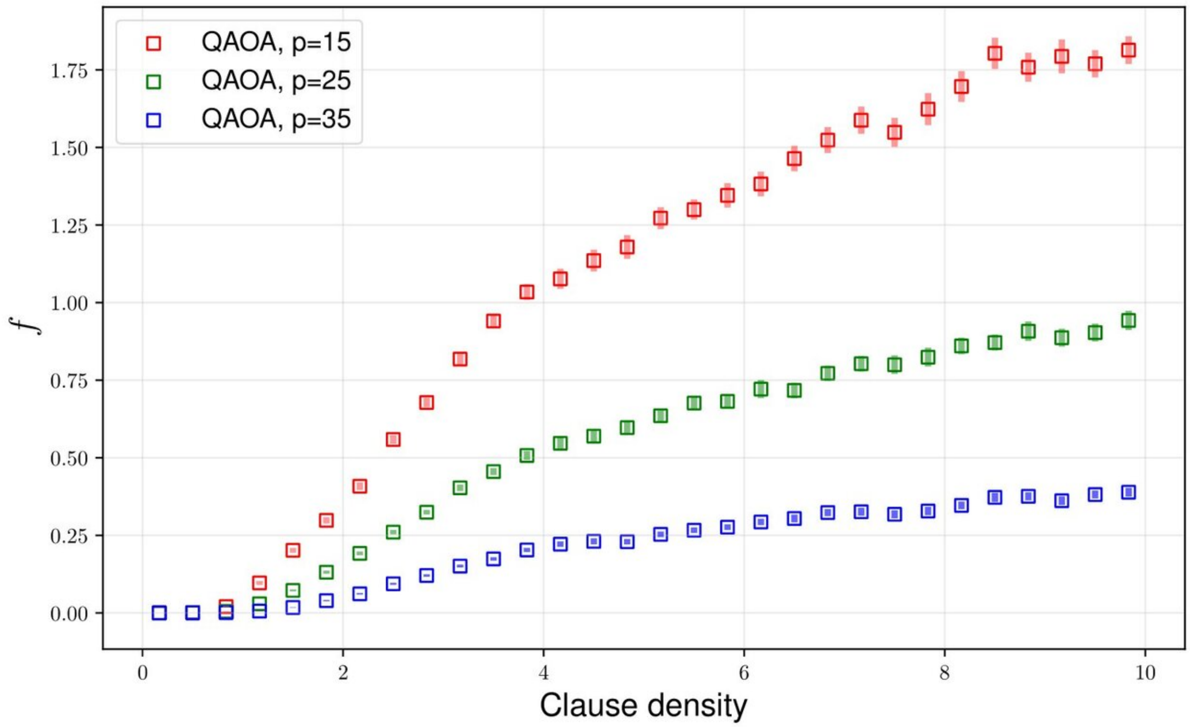


The graph represents the performance (difference between QAOA optima and exact optima) of fixed depth QAOA circuits on randomly generated MAX-SAT instances with increasing problem densities. Although higher depth versions achieve better performances, they still exhibit reachability deficits. Credit: *Physical Review Letters*

Google is racing to develop quantum-enhanced processors that use quantum mechanical effects to increase the speed at which data can be processed. In the near term, Google has devised new quantum-enhanced algorithms that operate in the presence of realistic noise. The so-called quantum approximate optimisation algorithm, or QAOA for short, is the cornerstone of a modern drive toward noise-tolerant quantum-enhanced algorithm development.

The celebrated approach taken by Google in QAOA has sparked vast commercial interest and ignited a global research community to explore novel applications. Yet, little is known about the ultimate performance limitations of Google's QAOA algorithm.

A team of scientists from Skoltech's Deep Quantum Laboratory took up this contemporary challenge. The all-Skoltech team led by Prof. Jacob Biamonte discovered and quantified what appears to be a fundamental limitation in the widely adopted approach initiated by Google.

Reporting in *Physical Review Letters*, the authors detail the discovery of so-called reachability deficits—the authors show that these deficits place a fundamental limitation on the ability of QAOA to even approximate a solution to a problem, instance.

The Skoltech team's findings report a clear limitation of the variational QAOA quantum algorithm. QAOA and other variational quantum algorithms have proven extremely difficult to analyse using known mathematical techniques due to an internal quantum-to-classical feedback process. Namely, a given quantum computation can only run for a fixed amount of time. Inside this fixed time, a fixed number of quantum operations can be executed. QAOA seeks to utilize these quantum operations iteratively by forming a sequence of increasingly optimal approximations to minimize an objective function. The study places new limits on this process.

The authors discovered that QAOA's ability to approximate optimal solutions for any fixed depth quantum circuit is fundamentally dependent on the problems "density." In the case of the problem called MAX-SAT, the so-called density can be defined as the ratio of the problems constraints to variable count. This is sometimes called clause density.

The authors discovered problematic instances of high density with optimal solutions that cannot be approximated with guaranteed success, regardless of the algorithm's run time.

**More information:** Reachability Deficits in Quantum Approximate Optimization, *Physical Review Letters* (2020). journals.aps.org/prl/abstract/ … ysRevLett.124.090504

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