Scientists finally prove that a quantum computer can unconditionally outperform classical computers

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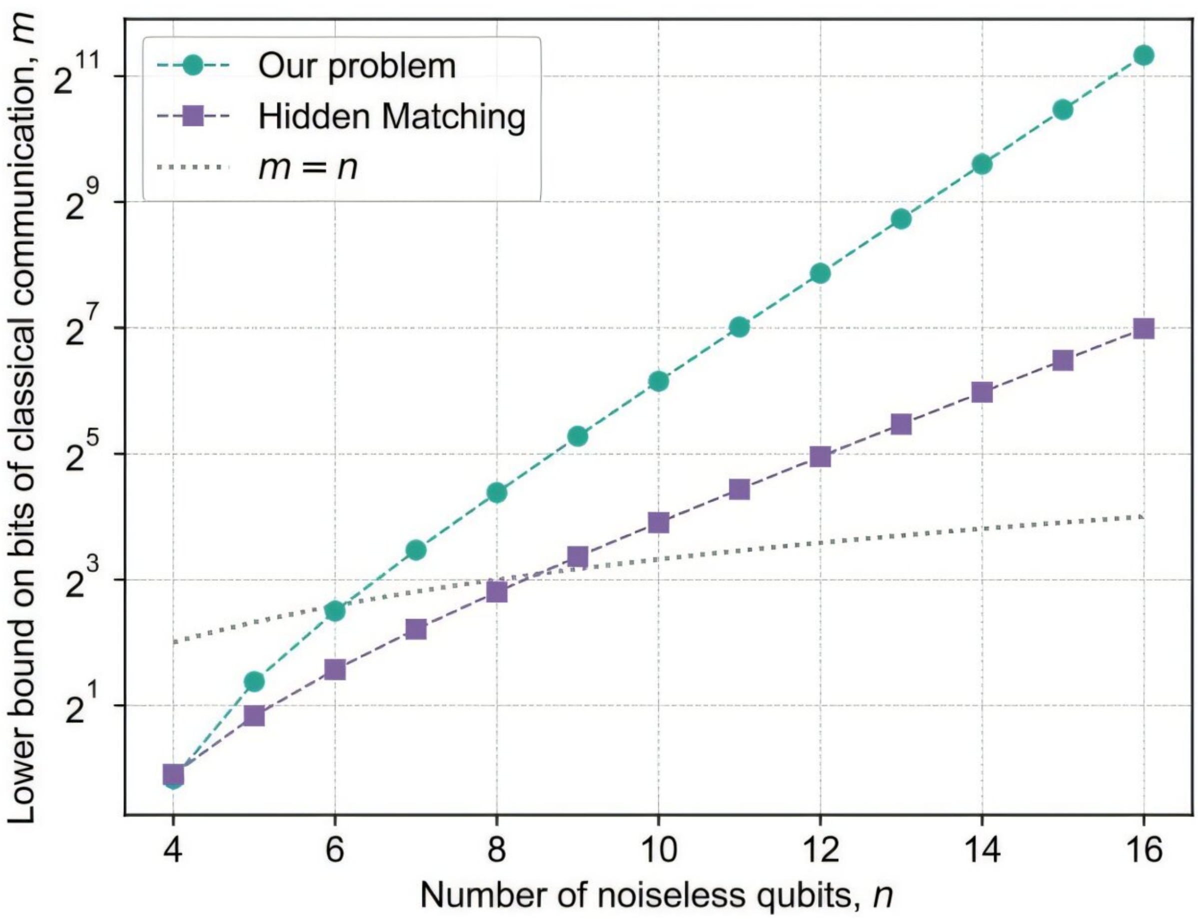

Comparison of classical one-way communication lower bounds for our problem and Hidden Matching, assuming implementation on a noiseless n-qubit quantum device. Points above the gray curve (m = n) indicate quantum advantage. Credit: *arXiv* (2025). DOI: 10.48550/arxiv.2509.07255

A quantum computer has demonstrated that it can solve a problem more efficiently than a conventional computer. This achievement comes from being able to unlock a vast memory resource that classical computing cannot match.

Instead of using classical bits that can only be 0 or 1, quantum machines use qubits, which can exist in multiple states and store exponentially more information than their traditional counterparts. However, proving that a quantum computer can access this memory advantage in the real world has been a challenge for two main reasons.

First, any successful demonstration has to be feasible on realistic quantum hardware, and second, there must be unconditional mathematical proof that no future classical algorithm could achieve the same performance.

In a study published on the *arXiv* preprint server, a U.S.-based research team led by scientists at UT Austin reports how they achieved this feat of quantum supremacy.

They constructed a complicated mathematical task designed to test this memory advantage. Their experiment was like a game between two parts of the quantum system referred to as Alice and Bob. Alice's task was to create a quantum state and send it in a message to Bob, who had to measure it to figure out what it was. The goal was to build a process so accurate that Bob could predict the state before Alice finished preparing the message.

The researchers optimized this process over 10,000 independent trials, and their analysis revealed that a classical computer would need at least 62 bits of memory to complete the task with the same success rate. The quantum device performed it using only 12 qubits.

"Our result provides the most direct evidence yet that currently existing quantum processors can generate and manipulate entangled states of sufficient complexity to access the exponentiality of Hilbert space (the vast memory resource of a quantum computer)," wrote the researchers in their paper.

"This form of quantum advantage—which we call quantum information supremacy—represents a new benchmark in quantum computing, one that does not rely on unproven conjectures."

The promise of quantum computing has always been based on unlocking its vast exponential memory and the resulting computational power. This first proof of quantum advantage moves us a step closer to being able to tap into this for real-world applications. These include cryptography, where it could enable more secure messaging, and modeling complex systems at speed, accelerating everything from drug discovery to the development of new materials.

More information: William Kretschmer et al, Demonstrating an unconditional separation between quantum and classical information resources, *arXiv* (2025). DOI: 10.48550/arxiv.2509.07255

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