Fingerprints of quantum entanglement

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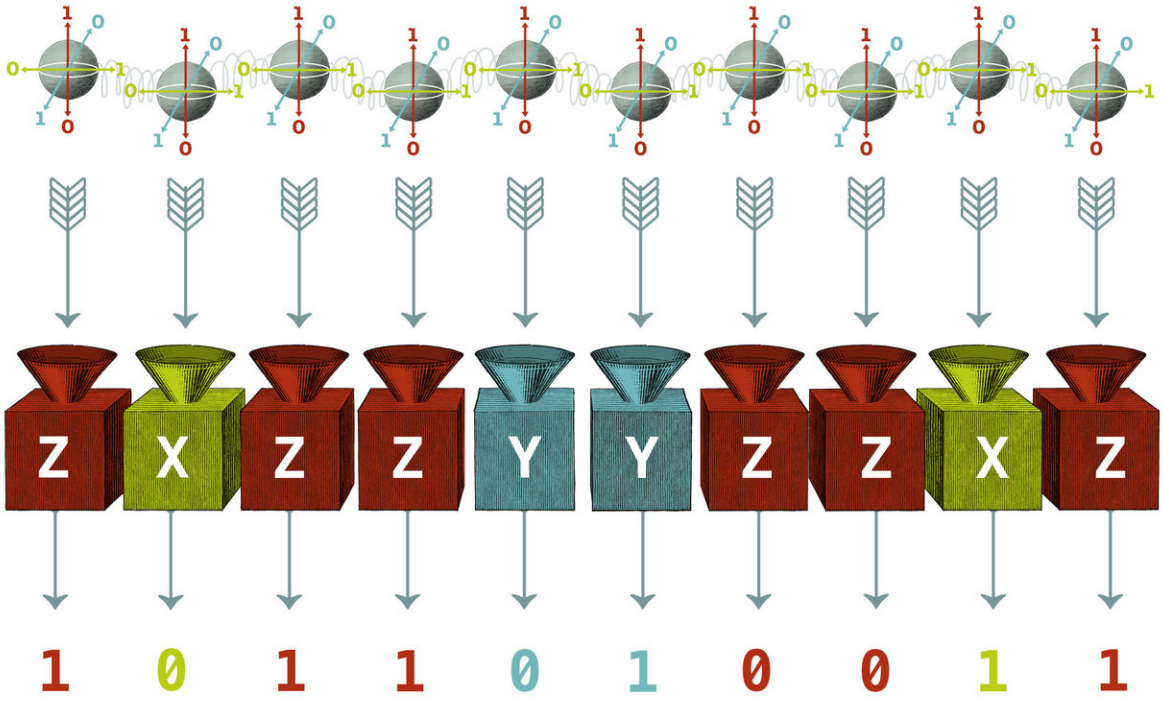

Entangled qubits are sent to measurement devices which output a sequence of zeroes and ones. This pattern heavily depends on the type of measurements performed on individual qubits. If we pick the set of measurements in a peculiar way, entanglement will leave unique fingerprints in the measurement patterns. Credit: Juan Palomino

Quantum entanglement is a key feature of quantum computing. Yet, how

can researchers verify that a quantum computer actually incorporates large-scale entanglement? Conventional methods require a large number of repeated measurements, presenting research difficulties. Aleksandra Dimić from the University of Belgrade and Borivoje Dakić from the Austrian Academy of Sciences and the University of Vienna have developed a novel method for which even a single experimental run suffices to prove the presence of entanglement. Their results are published in the online open access journal *npj Quantum Information*.

The ultimate goal of quantum information science is to develop quantum computers, fully-fledged controllable devices that make use of the quantum states of subatomic particles to store information. As with all quantum technologies, quantum computing is based on a peculiar feature of quantum mechanics known as quantum entanglement. The basic units of quantum information, qubits, need to correlate in this particular way in order for the quantum computer to achieve its full potential.

One of the main challenges is to make sure that a fully functional quantum computer is working as anticipated. In particular, scientists need to show that the large number of qubits are reliably entangled. Conventional methods require a large number of repeated measurements on the qubits for reliable verification. The more often a measurement is repeated, the more certain researchers can be about the presence of entanglement. Therefore, benchmarking entanglement in large quantum systems requires a lot of resources and time, which is practically difficult or simply impossible. Can we prove entanglement with only a low number of measurement trials?

In the current study, the researchers have developed a novel verification method requiring significantly fewer resources, and in many cases, even only a single measurement to prove large-scale entanglement with a high confidence. Aleksandra Dimić from the University of Belgrade suggests this analogy: "Consider a machine that simultaneously tosses 10 coins.

We manufactured the machine such that it should produce correlated coins. We now want to validate whether the machine produces the anticipated result. Imagine a single trial revealing all coins landing on tails. This is a clear signature of correlations, as 10 independent coins have 0.01 percent chance of landing on the same side simultaneously. From such an event, we certify the presence of correlations with more than 99.9 percent confidence. This situation is very similar to quantum correlations captured by entanglement."

Borivoje Dakić says, "In contrast to classical coins, qubits can be measured in many, many different ways. The measurement result is still a sequence of zeros and ones, but its structure heavily depends on how we choose to measure individual qubits. We realized that, if we pick these measurements in a peculiar way, entanglement will leave unique fingerprints in the measured pattern."

The method promises a dramatic reduction in time and resources needed for reliable benchmark of future quantum devices.

More information: Aleksandra Dimić et al, Single-copy entanglement detection, *npj Quantum Information* (2018). DOI: 10.1038/s41534-017-0055-x

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