Quantum machines learn 'quantum data'

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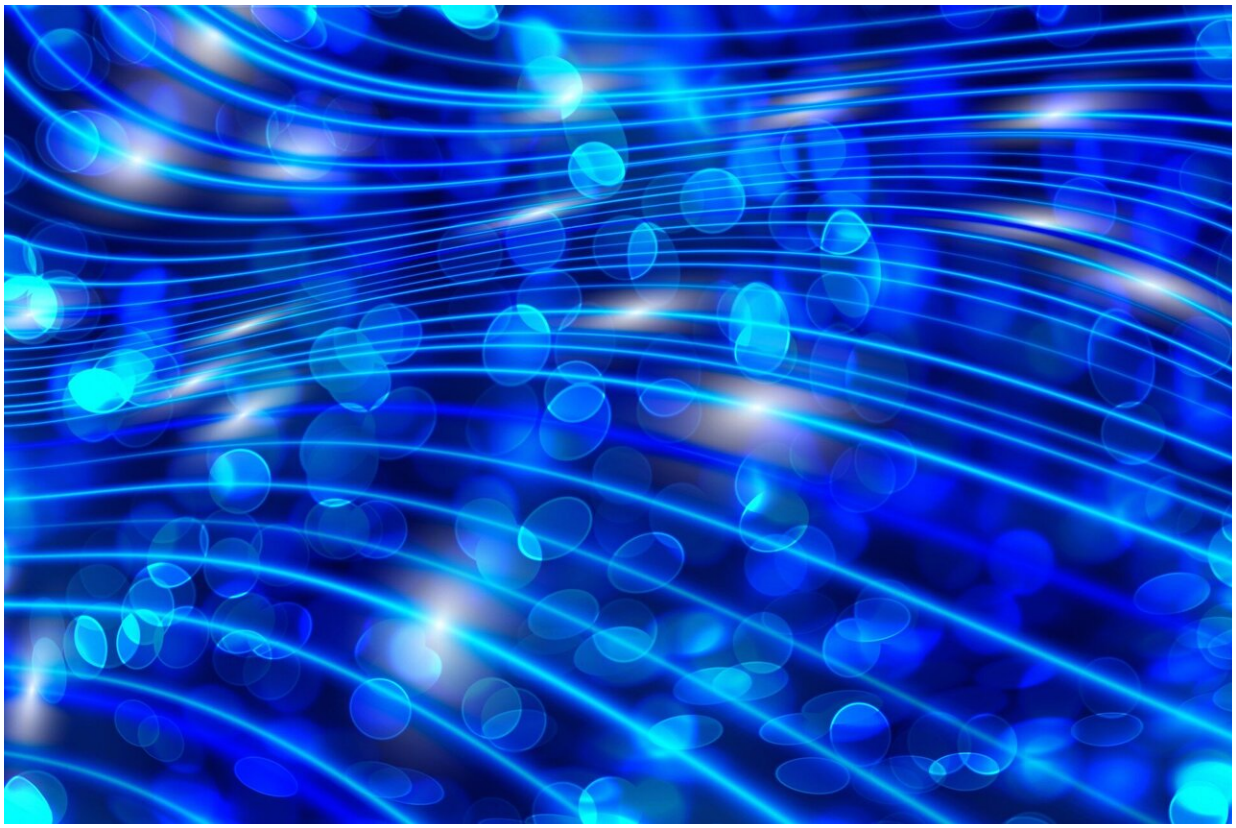

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Skoltech scientists have shown that quantum enhanced machine learning can be used on quantum (as opposed to classical) data, overcoming a significant slowdown common to these applications and opening a "fertile ground to develop computational insights into quantum systems." The paper was published in the journal *Physical Review A*.

Quantum computers utilize quantum mechanical effects to store and manipulate information. While quantum effects are often claimed to be counterintuitive, such effects will enable quantum enhanced calculations to dramatically outperform the best supercomputers. In 2019, the world saw a prototype of this demonstrated by Google as quantum computational superiority.

Quantum algorithms have been developed to enhance a range of different computational tasks; more recently this has grown to include quantum enhanced machine learning. Quantum machine learning was partly pioneered by Skoltech's resident-based Laboratory for Quantum Information Processing, led by Jacob Biamonte, a coathor of this paper. "Machine learning techniques have become powerful tools for finding patterns in data. Quantum systems produce atypical patterns that classical systems are thought not to produce efficiently, so it is not surprising that quantum computers might outperform classical computers on machine learning tasks," he says.

The standard approach to quantum enhanced machine learning has been to apply quantum algorithms to classical data. In other words, classical data (represented by bit strings of 1's and 0's) must be stored or otherwise represented by a quantum processor before quantum effects can be utilized. This is called the data-readin problem. Data-readin serves to limit the speedup that is possible using quantum enhanced machine learning algorithms.

A team of Skoltech researchers have merged quantum enhanced machine learning with quantum enhanced simulation, applying their approach to study phase transitions in many-body quantum magnetic problems. In doing so, they train quantum neural networks using only quantum states as data. In other words, the authors circumvent the data-readin problem by feeding in quantum mechanical states of matter. Such states appear to generally require an impossible amount of memory to represent using standard (non-quantum) approaches.

The lead author of the study, Skoltech doctoral student Alexey Uvarov describes the study as "a step towards understanding the power of quantum devices for machine learning." Researchers merged an assortment of techniques, which included applying some ideas from tensor networks and entanglement theory in the analysis of their approach.

The work uses a subroutine known as the variational quantum eigensolver (VQE)—an algorithm that iteratively finds an approximation to the ground state of a given quantum Hamiltonian. The output of this subroutine is a set of instructions to prepare a quantum state on a quantum computer.

Writing the state down explicitly, though, typically requires an exponential amount of memory, hence the properties of such a state are best examined by preparing it in hardware. The learning algorithm in the paper deals with the following problem: given a VQE state solving the ground state problem for a quantum spin model, find out which of the two phases of matter that state belongs to.

"While we have focused our approaches on problems from condensed matter physics, such quantum enhanced algorithms equally apply to challenges faced in materials science and drug discovery," Biamonte notes.

More information: A. V. Uvarov et al. Machine learning phase transitions with a quantum processor, *Physical Review A* (2020). DOI: 10.1103/PhysRevA.102.012415 , arxiv.org/abs/1906.10155

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