AlphaZero learns to rule the quantum world

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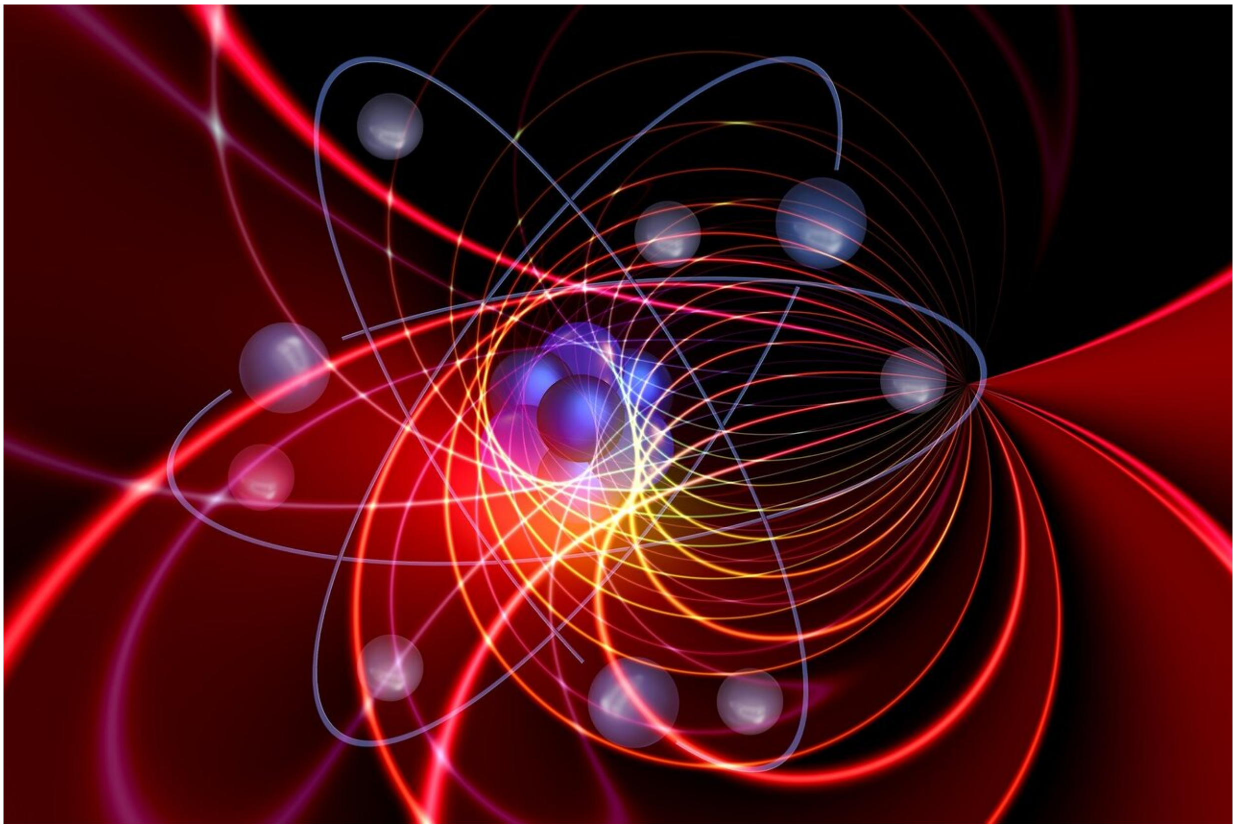

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The chess world was amazed when the computer algorithm AlphaZero learned, after just four hours on its own, to beat the best chess programs built on human expertise. Now a research group at Aarhus University in Denmark has used the very same algorithm to control a quantum computer.

All across the world, numerous research groups are attempting to build a quantum computer. Such a computer would be able to solve certain problems that cannot be solved with current classical computers, even if we combined all these computers in the world into one.

At Aarhus University, researchers share the ambition of building a quantum computer. For this reason, a research group under the direction of Professor Jacob Sherson has just used the computer algorithm AlphaZero to learn to control a quantum system.

What makes AlphaZero interesting is that it can learn on its own without any form of human expertise. In this manner, AlphaZero has beaten both humans and specialized computer programs in games such as Go, Shogi, and Chess, and it learned to do so only by playing against itself. After just four hours of playing against itself, AlphaZero managed to beat the leading chess program Stockfish. AlphaZero was so superior that Danish grand master Peter Heine Nielsen compared the program to a superior alien species that had visited the earth just to beat us in chess.

AlphaZero is good alone—but better with researchers

The research group at Aarhus University has, via computer simulations, demonstrated the broad applicability by applying AlphaZero on three different control problems that could each potentially be used in a quantum computer. Their work was recently published in *Nature Quantum Information*.

The team was very impressed with AlphaZero's ability to learn, as the lead Ph.D. student Mogens Dalgaard described: "When we analyzed the data from AlphaZero we saw that the algorithm had learned to exploit an underlying symmetry of the problem that we did not originally consider. That was an amazing experience. "

However, even though AlphaZero in itself is an impressive algorithm, the research team achieved the best results when they combined AlphaZero with a specialized quantum optimization algorithm. As Professor Jacob Sherson concludes: "This indicates that we are still in need of human skill and expertise, and that the goal of the future should be to understand and develop hybrid intelligence interfaces that optimally exploits the strengths of both".

In an attempt to speed up development in the field, the research group has made the code openly available and they were surprised about the interest. "Within a few hours I was contacted by major tech-companies with quantum laboratories and international leading universities to establish future collaboration," Jacob Sherson says, and continues "so it will probably not be long until these methods will find use in practical experiments across the world."

Background info, the quantum computer:

A quantum computer uses quantum mechanics, a branch of physics that describes the smallest building blocks of our universe. At this small scale, the rules are fundamentally different. For instance, a system can exist in more than one state at a time. When translated into computer language, this means that a quantum computer can perform multiple calculations at a time, which gives a huge speed-up over regular computers. But even though the theory of quantum computers is well-established, no one has managed to build a full-scale quantum computer yet. This requires, among other things, that we improve our ability to control these systems.

More information: Mogens Dalgaard et al, Global optimization of quantum dynamics with AlphaZero deep exploration, *npj Quantum Information* (2020). DOI: 10.1038/s41534-019-0241-0

Provided by Aarhus University

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