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Pulses driven by artificial intelligence tame quantum systems

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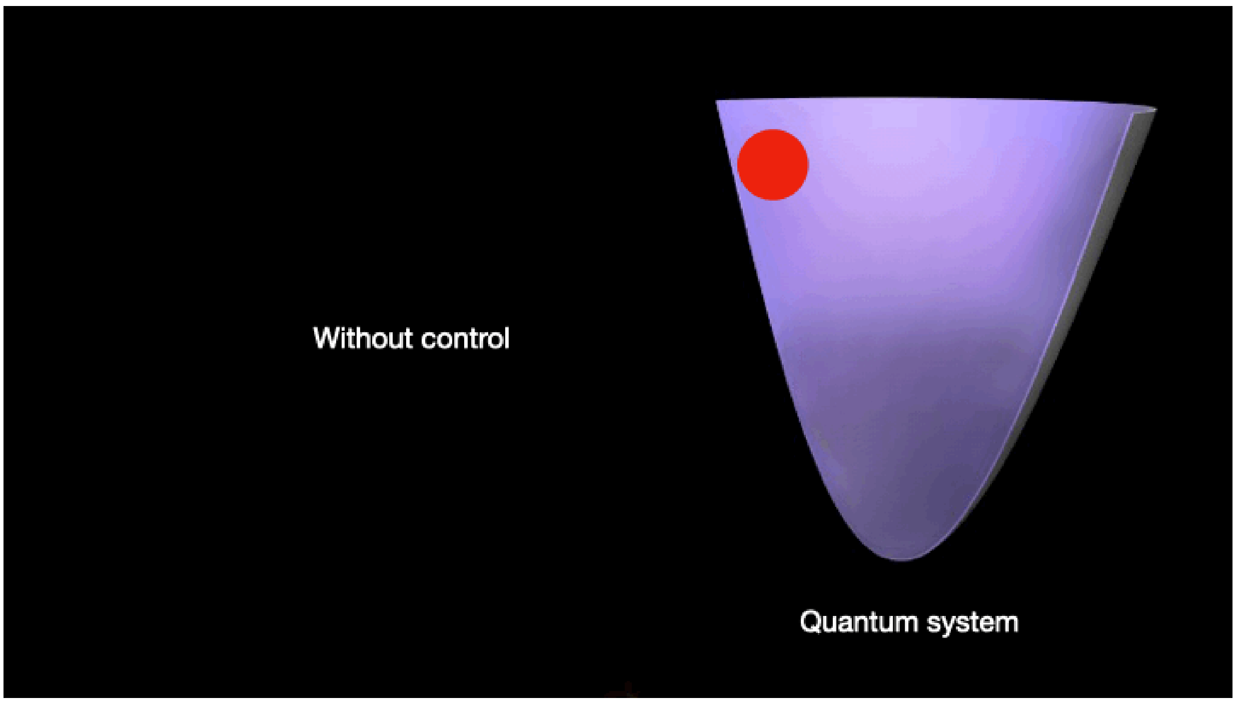

The basic idea is to achieve quantum control through the application of the AI agent (left). For instance, to cool the quantum ball (red) down to the bottom of the well in presence of environmental noises, the AI controller, which is based on reinforcement learning, would identify intelligent control pulses (middle polar graph). Credit: OIST

It's easy to control the trajectory of a basketball: Just apply mechanical force coupled with human skill. But controlling the movement of quantum systems such as atoms and electrons is much more challenging, as these minuscule scraps of matter often fall prey to perturbations that knock them off their path in unpredictable ways. Movement within the system degrades—a process called damping—and noise from environmental effects such as temperature also disturbs its trajectory.

One way to counteract the damping and the noise is to apply stabilizing pulses of light or voltage of fluctuating intensity to the quantum system. Now researchers from Okinawa Institute of Science and Technology (OIST) in Japan have shown that they can use artificial intelligence to discover these pulses in an optimized way to appropriately cool a micro-mechanical object to its quantum state and control its motion. Their research was published in November 2022 in *Physical Review Research*.

Micro-mechanical objects, which are large compared to an atom or electron, behave classically when kept at a high temperature, or even at room temperature. However, if such mechanical modes can be cooled down to their lowest energy state, which physicists call the ground state, quantum behavior could be realized in such systems. These kinds of mechanical modes then can be used as ultra-sensitive sensors for force, displacement, gravitational acceleration etc. as well as for quantum information processing and computing.

"Technologies built from quantum systems offer immense possibilities," said Dr. Bijita Sarma, the article's lead author and a Postdoctoral Scholar at OIST Quantum Machines Unit in the lab of Professor Jason Twamley."But to benefit from their promise for ultraprecise sensor design, high-speed quantum information processing, and quantum computing, we must learn to design ways to achieve fast cooling and control of these systems."

The machine learning-based method that she and her colleagues designed demonstrates how artificial controllers can be used to discover non-intuitive, intelligent pulse sequences that can cool a mechanical object from high to ultracold temperatures faster than other standard methods. These control pulses are self-discovered by the machine learning agent. The work showcases the utility of artificial machine intelligence in the development of quantum technologies.

Quantum computing has the potential to revolutionize the world by enabling high computing speeds and reformatting cryptographic techniques. That is why, many research institutes and big-tech companies such as Google and IBM are investing a lot of resources in developing such technologies. But to enable this, researchers must achieve complete control over the operation of such quantum systems at very high speed, so that the effects of noise and damping can be eliminated.

"In order to stabilize a quantum system, control pulses must be fast—and our artificial intelligence controllers have shown the promise to achieve such [a] feat," Dr. Sarma said. "Thus, our proposed method of quantum control using an AI controller could provide a breakthrough in the field of high-speed quantum computing, and it might be a first step to achieve quantum machines that are self-driving, similar to self-driving cars. We are hopeful that such methods will attract many quantum researchers for future technological developments."

More information: Bijita Sarma et al, Accelerated motional cooling with deep reinforcement learning, *Physical Review Research* (2022). DOI: 10.1103/PhysRevResearch.4.L042038

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