Artificial intelligence in quantum systems, too

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Quantum biomimetics consists of reproducing in quantum systems certain properties exclusive to living organisms. Researchers at University of the Basque Country have imitated natural selection, learning and memory in a new study. The mechanisms developed could give quantum computation a boost and facilitate the learning process in machines.

Unai Alvarez-Rodriguez is a researcher in the Quantum Technologies for Information Science (QUTIS) research group attached to the UPV/EHU's Department of Physical Chemistry, and an expert in quantum information technologies. Quantum information technology uses quantum phenomena to encode computational tasks. Unlike classical computation, quantum computation "has the advantage of not being limited to producing registers in values of zero and one," he said. Qubits, the equivalent of bits in classical computation, can take values of zero, one or both at the same time, a phenomenon known as superposition, which "gives quantum systems the possibility of performing much more complex operations, establishing a computational parallel on a quantum level, and offering better results than classical computation systems," he added.

The research group to which Alvarez-Rodriguez belongs decided to focus on imitating biological processes. "We thought it would be interesting to create systems capable of emulating certain properties exclusive of living entities. In other words, we were seeking to design quantum information protocols whose dynamics were analogous to these properties." The processes they chose to imitate by means of quantum simulators were natural selection, memory and intelligence. This led them to develop the concept of quantum biomimetics.

They recreated a natural selection environment in which there were individuals, replication, mutation, interaction with other individuals and the environment, and a state equivalent to death. "We developed this final mechanism so that the individuals would have a finite lifetime," said the researcher. So by combining all these elements, the system has no single clear solution: "We approached the natural selection model as a dispute between different strategies in which each individual would be a strategy for resolving the problem, the solution would be the strategy capable of dominating the available space."

The mechanism to simulate memory, on the other hand, consists of a system governed by equations. But equations display a dependence on their previous and future states, so the way in which the system changes "does not only depend on its state right now, but on its state five minutes ago, and where it is going to be in five minutes' time," explained Alvarez-Rodriguez.

Finally, in the quantum algorithms relating to learning processes, they developed mechanisms to optimize well-defined tasks, to improve classical algorithms, and to improve the error margins and reliability of operations. "We managed to encode a function in a quantum system but not to write it directly; the system did it autonomously, we could say that it 'learned' by means of the mechanism we designed so that it would happen. That is one of the most novel advances in this research," he said.

From computational models to the real world

All these methods and protocols developed in his research have provided the means to resolve all kinds of systems. Alvarez-Rodriguez says that the memory method can be used to resolve highly complex systems: "It could be used to study quantum systems in different ambient conditions, or on different scales in a more accessible, more cost-effective way."

With respect to natural selection, "more than anything we have come up with a quantum mechanism on which self-replicating systems could be based and which could be used to automate processes on a quantum scale." And finally, as regards learning, "we have come up with a way of teaching a machine a function without having to insert the result beforehand. This is something that is going to be very useful in the years to come, and we will get to see it," he said.

All the models developed in the research were computational models. But Alvarez-Rodriguez has made it clear that one of the main ideas of his research group is that "science takes place in the real world. Everything we do has a more or less direct application. Despite having been conducted in theoretical mode, the simulations we have proposed are designed so that they can be carried out in experiments, on different types of quantum platforms, such as trapped ions, superconducting circuits and phototonic waveguides, among others. To do this, we had the collaboration of the experimental groups."

More information: Quantum Machine Learning without Measurements. arxiv.org/abs/1612.05535

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