Artificial agent designs quantum experiments

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The artificial agent uses optical elements such as this beam splitter to construct new and optimized experiments. Credit: Harald Ritsch

On the way to an intelligent laboratory, physicists from Innsbruck and Vienna present an artificial agent that autonomously designs quantum experiments. In initial experiments, the system has independently (re)discovered experimental techniques that are standard in modern quantum optical laboratories. This shows how machines could play a more creative role in research in the future.

The researchers wondered to what extent machines can carry out research autonomously. They used a projective simulation model for artificial intelligence to enable a machine to learn and act creatively. This autonomous machine stores many individual fragments of experience in memory, which are networked together.

The machine builds up and adapts its memories while learning from both successful and unsuccessful attempts. The scientists from Innsbruck teamed up with the group of Anton Zeilinger, who previously demonstrated the usefulness of automated procedures in the design of quantum experiments with a search algorithm called Melvin. Some of these computer-inspired experiments have already been performed in the lab of Zeilinger. Together, the physicists determined that quantum experiments are an ideal environment to test the applicability of AI to research. Therefore, they used the projective simulation model to investigate the potential of artificial learning agents in this test bed. They have published their results in the *Proceedings of the National Academy of Sciences*.

Optimized experiments designed by an AI-agent

The artificial agent develops new experiments by virtually placing mirrors, prisms or beam splitters on a virtual lab table. If its actions lead to a meaningful result, the agent has a higher chance of finding a similar sequence of actions in the future. This is known as a reinforcement learning strategy.

"Reinforcement learning is what distinguishes our model from the previously studied automated search, which is governed by unbiased random search," says Alexey Melnikov from the Department of Theoretical Physics at the University of Innsbruck. "The artificial agent performs tens of thousands of experiments on the virtual laboratory table. When we analyzed the memory of the machine, we discovered that certain structures have developed," says Hendrik Poulsen Nautrup. Some of these structures are already known to physicists as useful tools from modern quantum optical laboratories. Others are completely new, and could, in the future, be tested in the lab.

"Reinforcement learning allows us to find, optimize and identify a huge amount of potentially interesting solutions," says Alexey Melnikov. "And sometimes it also provides answers to questions we didn't even ask."

Creative support in the laboratory

In the future, the scientists want to further improve their learning program. At this point, it is a tool that can autonomously learn to solve a given task. But in the future, a machine could possibly provide more creative assistance to scientists in basic research.

More information: Alexey A. Melnikov et al. Active learning machine learns to create new quantum experiments, *Proceedings of the*

National Academy of Sciences (2018). DOI: 10.1073/pnas.1714936115