Synergic generative quantum machine learning

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We present a new approach to generative quantum machine learning and describe a proof-of-principle experiment demonstrating our approach. We call our proposed approach quantum synergic generative learning because the learning process is based on the cooperation between the generators and the discriminator. The goal of the learning is for the quantum computer implementing the generative learning algorithm to learn a concept of a Bell state. After the learning process, the network is able to recognize as well as generate the entangled state. We compare our approach with the recently proposed quantum generative adversarial learning (QGAN). We present numerical proofs, obtained using quantum simulators, for single qubits as well as more qubits, and we also present experimental results obtained on a real programmable quantum computer.

The aim of QGAN which is the quantum equivalent of GAN learning, is to find a Nash equilibrium in a two player game. One player (the discriminator) generates some output, while the other player tries to determine whether the output is generated by the first player (generator) or comes from an external source. This corresponds to the min-max problem, in which the statistical distance between the outputs of generator and an external source is minimized relative to the generator strategy, while maximizing the distance between the outputs discriminator for generator and an external source relative to the discriminator strategy. It turns out that it is difficult to ensure the stability of the process in this type of optimization. In our work, we consider a conditional equilibrium state. Training such a system is based on increasing the probability of descending to the equilibrium state, which distinguishes it from learning a standard GAN, in which training is done by counting the probability of the system's exit from the equilibrium state.

We propose a new type of machine learning for quantum GANs in which a conceptually simpler problem is solved during training than in the typical QGAN approach. Our approach assumes the reversibility of the discriminator and exploits the relative entropy property and the time reversal property in unitary transformations. In the learning process, we try to minimize the cost function while making the discriminator work correctly.

References

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