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Quantum Machine Learning for HEP detectors simulations

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Quantum Machine Learning is one of the most promising applications on near-term quantum devices which possess the potential to solve problems faster than traditional computers. Classical Machine Learning is taking up a significant role in particle physics to speed up detector simulations. Generative Adversarial Networks (GANs) have scientifically proven to achieve a similar level of accuracy compared to the usual simulations while decreasing the computation time by orders of magnitude.
In this research we are going one step further and apply quantum computing to GAN-based detector simulations.
Given the practical limitations of current quantum hardware in terms of number of qubits, connectivity and coherence time, we performed first initial tests with a simplified GAN model running on quantum simulators. The model is a classical-quantum hybrid ansatz. It consists of a quantum generator, defined as a parameterised circuit based on single and two qubit gates, and a classical discriminator network.
Our initial qGAN prototype focuses on a one-dimensional toy-distribution, representing the energy deposited in a detector by a single particle. It uses three qubits and achieves high physics accuracy thanks to hyper-parameter optimisation. A second qGAN is developed to simulate 2D images with a 64 pixel resolution, representing the energy patterns in the detector. Different quantum ansatzes are studied. We obtained the best results using a tree tensor network architecture with six qubits.
Additionally, we discuss challenges and potential benefits of quantum computing as well as our plans for future development.

Summary

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