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Imaging goes Quantum - Quantum Machine Learning for Image Generation

In this talk, Quantum Machine Learning (QML) will be introduced as a new rapidly evolving technology and explained with a successful small proto-type for image generation. This presentation serves as a dissemination of the status of the fast-developing new technology of Quantum Computing and for collecting a community inside Helmholtz Imaging interested to become familiar with it and try it out for their interdisciplinary use cases.

The central goal of our exploration of QML for Imaging is the simulation of the signals in detector parts of the Large Hadron Collider, which collides protons with protons to study and unveil the elementary particles and their fundamental interactions. An upgrade to a 10-fold intensity and luminosity imposes serious challenges for the detector simulation which cannot not be resolved with conventional computing. Generative Machine Learning (ML) approaches are very promising.
Here, the next step towards the novel technology, Quantum Computing, is taken.

Quantum Computing (QC) has the potential to revolutionize computing by operating on completely different principles from Quantum Mechanics. Expectations are high, that quantum computers can solve complex problems that cannot be addressed with classical computers. Therefore, it is good to explore, identify potential limitations and see, if it is hype or hope.

QML lies at the intersection of QC and ML, combining classical ML methods with topics of quantum algorithms and architectures.
In the current NISQ era (Noisy Intermediate-Scale Quantum computing), noise in Quantum Computers challenges the accuracy of computations and the small number of qubits (= bits of the QC) limits the size of problems to be solved. Nevertheless, ML can be robust to noise and allows to deal with limited resources of present-day quantum computers.
The Quantum Angle Generator (QAG) is a new QML model designed to produce precise images on current NISQ quantum devices. The QAG model uses variational quantum circuits as its core, and multiple circuit architectures are evaluated. The QAG model achieves excellent results that are analyzed and evaluated in detail.
The study to be presented, explores the QAG model's noise robustness through an extensive quantum noise study. The results indicate that the model when trained on a real quantum device, can learn the hardware noise behavior and produce precise outcomes. In contrast, running the noise-less trained model on real quantum hardware leads to a decrease in accuracy. Additionally, one training on real hardware showed that the model can recover even with significant calibration changes during training with up to 8% of higher noise level.
Furthermore, the QAG model seems to need less training parameters when compared to a hybrid Generative Adversarial Network GAN-mode where the QAG serves as the generator and is combined with a classical discriminator.
The ongoing efforts are heading towards an upscale of the present small proto-type of 8 pixels. In addition, for comparison the noise-robustness and the minimal number of training parameters is also investigated for a pure classical generative ML ansatz.
References:
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