QML-HEP GSoC 2022

Task V: Open Task Part

Comment on quantum computing

Besides a passion for physics, my inspiration to learn quantum computing and do research in this field began because of two factors. First was the realization of the limitations of classical hardware and approaching the end of Moore's law as the size of transistors approaches the atomic level. And although some different approaches have been proposed, they are all bounded to the physical limitation, and going beyond, we would have to enter the territory of quantum mechanics where classical operations become invalid such as a simple gate flip operation as electrons can surpass the gate barrier in a transistor, making it hard to control the outcomes.

Second was my interest in modeling and simulation where we can make predictions on an outcome of a system, which I always found fascinating. However related to the first factor, as we try to simulate smaller systems on the atomic level (which is very crucial for many applications in quantum chemistry, condensed matter, etc.), the required computational power starts to grow exponentially due to the complexity of states in superposition and limitations of classical hardware as the system we are trying to simulate operates on different laws than the hardware we have, and here comes the importance of quantum computing comes with properties like entanglement and superposition, providing a potential advantage for certain applications over classical methods.

During the NISQ era, I believe that hybrid models will play an essential role since current quantum systems are noisy and not fully fault-tolerant yet, and for some optimization tasks, classical computers provide better performance. As for machine learning applications, classical models seem to provide a much better performance, which raises the question of whether quantum models will be able to surpass classical models by providing any "quantum advantage" for realistic scales. Although that might not necessarily be the right question, I found the process of exploring and benchmarking QML models interesting and look forward to researching more in this domain. For instance in generative models, benchmarking over different hybrid approaches seems to provide different performance outcomes for various applications, like having a classical generate-quantum discriminator or vice versa against a fully quantum model for GAN architectures.

Methods of interested

I've used Qiskit and PennyLane libraries before, both provide great tools for variational algorithms and QML applications and have excellent documentation. As for Cirq and TensorFlow Quantum, I've not used them on a large-scale project before, however, I look forward to and believe that GSoC is a great opportunity for that. When it comes to generative models for HEP applications, certain calorimeter output data requires the implementation of a continuous variable architecture, where Xanadu's StrawberryFields library might also be considered useful.

Note on Task IV: I had never worked on graphical models before and It was my first time applying a GNN to a classification task. I found the approach interesting as it is discussed to provide powerful results for certain tasks and I look forward to learning more in that field.

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