Quantum Machine Learning: Quantum Kernel Methods

Sanjeev Naguleswaran[a]

[a] *QSPectral Systems, Brisbane, QLD 4171 Australia.*

Quantum algorithms based on quantum kernel methods have been investigated previously [1]. A quantum advantage is derived from the fact that it is possible to construct a family of datasets for which, only quantum processing can recognise the intrinsic labelling patterns, while for classical computers the dataset looks like noise. This is due to the algorithm leveraging inherent efficiencies in the computation of logarithms in a cyclic group. The discrete log problem.is a well-known advantage of quantum vs classical computation: where it is possible to generate all the members of the group using a single mathematical operation.

Kernel methods are a powerful and popular technique in classical Machine Learning. The use of a quantum feature space that can only be calculated efficiently on a quantum computer potentially allows for deriving a quantum advantage [1]. In this paper, we intend to first describe the application of such a kernel method to a Quantum version of the classical Support Vector Machine (SVM) algorithm to identify conditions under which, a quantum advantage is realised. A data dependent projected quantum kernel was shown to provide significant advantage over classical kernels [2].

Further, we propose to present results of investigations and ideas pertaining to extending the use of quantum kernels as a feature extraction layer in a Convolutional Neural Networks (CNN) that is a widely used architecture in deep-learning applications. In particular, we intend to discuss,

- The investigation and development of quantum kernel functions that leverage quantum-enhanced feature spaces for favourable representations of real-world data; and
- Investigation of properties and structure of real-world data that could be leveraged to provide a quantum advantage.

The outcome of this work is consistent the emerging data-centric paradigm of Machine Learning.

[1] V. Havĺıˇcek, A. D. Co´rcoles, K. Temme, A. W. Harrow, A. Kandala, J. M. Chow, and J. M. Gambetta, Supervised learning with quantum-enhanced feature spaces, *Nature.* **567**, 209 (2019).

[2] H.Y Huang, M. Broughton, M. Mohseni et al., Power of data in quantum machine learning, *Nature Communications*. **12(1)** 2631 (2021).