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Kernel-based quantum machine learning with photons

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Abstract

Is it possible to possible to implement practical quantum machine learning? Here we answer this question by implementing first all-optical setup that implements a kernel-based supervised quantum machine learning for three standard two-dimensional classification problems. In contrast to distance-based quantum machine learning, we need only to perform projective measurements on specially designed quantum states that efficiently encode the training data set. Our experiment is a two-photon implementation of a recent proposal of Schuld and Killoran [Phys. Rev. Lett. **122** 040504 (2019)], where instead of continuous variables we implement variable spread kernels by varying the number of photons used in feature mapping circuit.

Many contemporary computational problems like drug design, traffic control, logistics, automatic driving, stock market analysis, automatic medical examination, material engineering etc. often require optimization over huge amounts of data. These very demanding problems are being solved approximately by suitable machine learning algorithms simulating a learning process in a tractable way. However, in some cases the calculations can last prohibitively long. These computations could be potentially performed more efficiently (sometimes exponentially faster) by applying quantum resources in machine learning algorithms (i.e., QML). This speedup can be partially attributed to collective processing of quantum information which is possible thanks to quantum entanglement. There are various approaches to QML that could be characterized as linear algebra solvers, sampling, quantum optimization or using quantum circuits as trainable models for inference (see, e.g., Refs. [1, 2, 3, 4]. Most of the focus both in classical machine learning and in QML is put on deep learning and neural networks. However, recently a very promising kernel-based approach to supervised quantum machine learning especially on the platform of linear optics has been proposed by [4]. It is especially interesting as it does not rely on quantum memory, but rather on combining classical and quantum computations. We theoretically demonstrate that kernel-based QML (KQML) using specialized multiphoton quantum optical circuits and our kernel that exhibits exponentially better scaling of the required number of qubits than a direct generalization of kernels described in the literature. We implement this kernel in a proof of principle experiment.

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