DA6300 Project

Team members:

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Project Theme: QML research paper implementation

Project title: Quantum machine learning beyond kernel methods

Description:

This project aims to empirically validate and extend the theoretical framework presented in "Quantum Machine Learning Beyond Kernel Methods". The primary focus will be on demonstrating the practical advantages of data re-uploading and explicit quantum models over kernel methods in quantum machine learning tasks. This work provides an unifying framework by showing that the explicit and implicit QML models can both be realised as a linear model in the quantum feature space. Data re-uploading model (as a generalization of explicit model), can be mapped to an equivalent class of explicit models with restricted family of observables. Our project work will be focused on: (1) Implementing and comparing the performance of data re-uploading, explicit, and implicit quantum models on real-world datasets, emphasiszing on tasks where the explicit quantum models may outperform classical counterparts. (2) Developing an optimized circuits for data re-uploading models that can efficiently solve parity function learning tasks. We will show that there exist an exponential separation in learning between data re-uploading, linear, and kernel quantum models to solve certain learning tasks. Despite the consequences of the representer theorem (which states that implicit models can always achieve a smaller training loss over the explicit models on the same training set), this work shows that explicit model can have an exponential learning advantage in the number of data samples they use to achieve a good generalization performance. (3) Analyzing the experimental results on regression task, to verify the lower resource utility for the three models. We will show the explicit models to have an exponential learning advantage in the number of data samples they use to achieve a good generalization performance. The project will utilize quantum simulation frameworks like TensorFlow Quantum to conduct experiments and numerical simulations, aiming to provide empirical evidence for the theoretical learning separations between the model described in the paper. The ultimately gives a clarity over the ways to compare between the different quantum machine learning models and with the classical models that can achieve quantum advantage in near-term NISQ devices.

Steps to be taken/expected outcomes every two weeks:

Date	Expected Work
Feb 24	Finish the relevant literature survey required for progressing through the project. These involves learning the data re-uploading model, going through the supplementary information for the project, learning Representer theorem, learning Gate teleportation techniques and unitary feature encoding proposed in the literature, mappings from data re-uploading to explicit models, and go through the theorems.
Mar 10	Learning Tensorflow Quantum. Go through the Numerical simulation and dataset generation with labels using explicit models.
Mar 24	Going through the code and understanding it. Performance evaluation of the explicit models from the same variational family as those used to label the data and implicit models.
April 7	Establish and verify the results: (i) Learning separation and efficiency in terms of resources used and dataset size required for the explicit, implicit, and data re-uploading models in quantum tailored problem such as learning parity function. (ii) With the target function generated by the quantum explicit model, we verify the performance difference in the regression task of the explicit model compared to classical and implicit model for $n \geq 7$ (iii) flexibility of data re-uploading circuits, as well as the restricted expressivity of explicit models in using efficient and lesser resources.
April 21	As per suggestions and feedback from faculty, we will decide on the next roadmap. If time permits we will try to look into whether these models can be tailored to a machine-learning task at hand.