Data re-uploaded quantum kernels for support vector machine

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Recent years have seen significant advancements in implementing supervised machine learning on quantum processors. While the ultimate goal is to surpass classical counterparts, we are currently in the implementation stage. Various approaches have been proposed for classification tasks, including quantum classifiers inspired by quantum neural networks and kernel methods that are subsequently fed into support vector machine algorithms. In this regard the data re-uploading classifier [1] utilizes a single qubit for classification. This approach enhances the model's expressiveness by incorporating multiple layers composed of encoding and processing components, thereby introducing non-linearities. On the other hand, kernel methods, thanks to the representer theorem, offer superior classification accuracy. However, selecting the optimal kernel for a specific problem remains a challenge. Therefore, training a model to determine the best kernel is of utmost importance.

Our work proposes a novel approach to identify the optimal kernel for a classification problem. We leverage the universal capabilities of the data re-uploading structure to train a single qubit quantum neural network (QNN). Subsequently, we create a quantum kernel based on the optimal data re-uploading architecture, considering both the single qubit case and the multi- qubit case with entanglement. This quantum kernel is then employed in conjunction with a support vector machine algorithm. Although this combined protocol may appear redundant, we demonstrate its superiority over the single qubit classifier. We provide analytical evidence to support this improvement and offer insights into the distribution of input data in the Hilbert space.

Furthermore, we investigate the performance of our protocol in the presence of noise. Our findings reveal a trade-off between the number of layers and the utilization of the combined protocol under different noise parameters. By studying the impact of noise, we gain a deeper understanding of the protocol's robustness and its limitations. In summary, our study presents a novel methodology to determine the best kernel for a classification problem by utilizing the data re-uploading structure. We demonstrate the efficacy of our approach through analytical proofs, highlighting its superiority over the single qubit classifier. Moreover, we examine the protocol's performance under various noise conditions, shedding light

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on the trade-offs involved.

[1] A. Pérez-Salinas, A. Cervera-Lierta, E. Gil-Fuster, and J. I. Latorre, Data re-uploading for a universal quantum classifier, Quantum 4, 226 2020.