Tangible Reduction of Sample Complexity with Large Classical Samples and Small Quantum System

Wooyeong Song[1], Marcin Wieśniak[2,3], Nana Liu[4], Marcin Pawłowski[3], Jinhyoung Lee[1], Jaewan Kim[5] and Jeongho Bang[5,2,3]

[1] *Department of Physics, Hanyang University, Seoul, Korea.*
[2] *Institute of Theoretical Physics and Astrophysics, University of Gdańsk, Gdańsk, Poland.*
[3] *International Centre for Theory of Quantum Technologies, University of Gdańsk, Gdańsk, Poland.*
[4] *John Hopcroft Center for Computer Science, Shanghai Jiao Tong University, Shanghai, China*
[5] *School of Computer Sciences, Korea Institute for Advanced Study, Seoul, Korea*

Abstract. Quantum computation requires large classical datasets to be embedded into quantum states to exploit quantum parallelism. However, this embedding requires considerable resources. We consider a classical-quantum hybrid architecture, which allows large classical input, with a small-scale quantum system. This hybrid architecture is used to implement an oracle. It is shown that in the presence of noise in the oracle, the effects of internal noise can cancel each other out and improve the query success rate. Such an immunity of the oracle to noise directly reduces the sample complexity in the probably-approximately-correct (PAC) learning framework.

Keywords: Quantum computing, Quantum machine learning, Sample complexity, NISQ

Many quantum algorithms have shown promise for the quantum speedup. However, apart from requiring considerable computational resources needed for the main calculation, many of them involve high costs for introducing "big" classical data into quantum states, for example, by accessing QRAM. In this context, it is now highly desirable to show the possibility of achieving NISQ-based speedups without using excessively large data superposition.
One promising approach is to consider a classical-quantum hybrid architecture and identify the optimal interplay between classical and quantum strategies. Here, we devise an intriguing type of hybrid architecture, one in which [**S.1**] the large input data remain classical but a small-scale quantum system is employed and [**S.2**] quantum advantages are NISQ-compatible. The motivation and background of this study are similar to those of the recent Refs.[1, 2].
We apply our hybridization to binary classification. For this, we employ a classical-quantum hybrid oracle designed on the bases of [**S.1**] and [**S.2**] and assume that the oracle generates noisy outputs due to errors resulting from the use of erroneous quantum gates. We demonstrate our hybrid oracle can exhibit a high probability of success for queries. This advantage is attributed to the high capability of the oracle to explore a wider space of solutions, and it naturally leads to a quantum learning advantage, namely, a reduction in the sample complexity, in the Probably-Approximately-Correct (PAC) learning framework.
A more detailed account of the work can be found in Ref. [3].

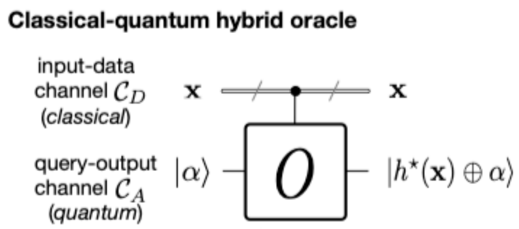

Figure 1 Schematic of our hybrid oracle. The oracle consists of two different input/output channel types, one for input classical data $\mathbf{x} = \mathrm{x}x_1x_2\cdots x_n$ $\left(x_j \in \{0,1\}\ \forall\, j = 1, \dots, n\right)$, where n can be very large , and the other for a single qubit, which produces the query-output states $|h^\star(\mathrm{x})\rangle \in \{0,1\}$.

References

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