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# Quantum Machine Learning with Persistent Homology

By

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# Abstract

Matrix algebra, along with the symmetric and anti-symmetric nature of the wave function of multi-particle systems, has led to a new approach alongside classical physics, namely quantum mechanics. Inspired by the proposed approaches in quantum on the one hand and on the other hand trying to Build quantum computers, algorithms with goals such as optimization and solving complex problems through computers in the framework of programs Computationally developed. In this thesis, relying on the self-similarity feature of a global class called timeseries modeled Based on the fractional Brownian motion characterized by the Hurst exponent, try to use Topology data analysis derived from algebraic topology, which is resistant to noise and trends, in the field of quantum machine learning for classification of fBm time series. For this purpose, we produced 200 Fractional Brownian motion time series in ten classes of Hurst exponent as follows $H \in [0,1]$, $\Delta H = 0.1$ that we used 75 percent of them for training and the rest for testing. From each of the time series, using the persistent homology tool, we extracted seven features, which include the number of persistent pairs of Betti one, the entropy of persistent pairs of Betti zero and one, appear, disappear, and the maximum radius in Betti curve and the area under Betti curve then embed them into the quantum state by quantum domain embedding method. For constructing our quantum classification model, we use a six-layer quantum circuit composed of rotation gates (with angles as trainable model parameters) and controlled gates (providing access to entangled states) for the ten classes of our Hurst exponent classes. We set the cost function of our model, the square value of the expectation value of the Pauli-z matrix because it ranges from 0 to 1 and conveys the concept of probability. Finally, we optimize the constructed model using a classical optimizer and achieve the best accuracy of 87 percent for our models, independent of the values of the Hurst exponent.



Keywords: Quantum machine learning, Quantum optimization, Topological data analysis,

fractional Brownian motion ( fBm )