Deep quantum learning with long short-term memory for geodetic time series prediction: Application to length of day prediction

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Abstract

Deep quantum learning is a relatively new concept in which quantum computing algorithms and/or devices are used to enhance the performance of deep learning approaches. Quantum technology originally requires quantum devices, also called quantum computers, which are specially designed computers with hardware parts built upon the concepts of quantum mechanics. Quantum devices are not widely available, but quantum algorithms are increasingly gaining more attention. These algorithms use theoretical considerations of quantum mechanics, including concepts of superposition, entanglement, and interference. Quantum algorithms have shown tremendous speedup and efficiency over traditional methods in many fundamental tasks such as prime factorization and list search. As a result of the power of quantum algorithms, they are used in deep learning approaches to increase their performance. The combined approach, which is normally called deep quantum learning, has shown competitive accuracy with respect to standard deep learning approaches. In order to take advantage of quantum algorithms for sequential data modelling, one needs to combine them with a suitable machine learning model, such as Long Short-Term Memory (LSTM) neural networks. In this study, we introduce quantum LSTM neural networks to time series prediction tasks in geodetic science. We present a special architecture consisting of three layers of LSTM, each having a quantum circuit with two qubits, and a final dense layer with a linear activation function. As an application, we focus on the ultra-short-term prediction of length of day based on geodetic and geophysical time series. We show that these networks can predict length of day better than the state-of-the-art statistical and machine learning methods, especially in the final days of the ten-day prediction window. In a test reflecting conditions of the EOP Prediction Comparison Campaign, the prediction accuracy was 0.024, 0.045, and 0.086 ms for the one-, five-, and ten-day-ahead predictions.

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