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Benchmarking Quantum Convolutional Neural Networks for Signal Classification in Simulated Gamma-Ray Burst Detection

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This study evaluates the use of Quantum Convolutional Neural Networks (QCNNs) for identifying signals resembling Gamma-Ray Bursts (GRBs) within simulated astrophysical datasets in the form of light curves. The task addressed here focuses on distinguishing GRB-like signals from background noise in simulated Cherenkov Telescope Array Observatory (CTAO) data, the next-generation astrophysical observatory for very high-energy gamma-ray science. QCNNs, a quantum counterpart of classical Convolutional Neural Networks (CNNs), leverage quantum principles to process and analyze high-dimensional data efficiently. We implemented a hybrid quantum-classical machine learning technique using the Qiskit framework, with the QCNNs trained on a quantum simulator. Several QCNN architectures were tested, employing different encoding methods such as Data Reuploading and Amplitude encoding. Key findings include that QCNNs achieved accuracy comparable to classical CNNs, often surpassing 90\%, while using fewer parameters, potentially leading to more efficient models in terms of computational resources. A benchmark study further examined how hyperparameters like the number of qubits and encoding methods affected performance, with more qubits and advanced encoding methods generally enhancing accuracy but increasing complexity. QCNNs showed robust performance on time-series datasets, successfully detecting GRB signals with high precision. The research is a pioneering effort in applying QCNNs to astrophysics, offering insights into their potential and limitations. This work sets the stage for future investigations to fully realize the advantages of QCNNs in astrophysical data analysis.

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