Contribution ID: **34** Type: **Computing**

# Quantum Autoencoders for anomaly detection to identify Gamma-Ray Bursts in the Ratemeters of the AGILE Anti-Coincidence System

*Tuesday 15 October 2024 09:35 (15 minutes)*

Quantum Machine Learning (QML) is an emerging field that integrates Machine Learning techniques with quantum computing to take advantage of the computational power of qubits. By leveraging quantum phenomena such as superposition and entanglement, QML has the potential to solve complex problems significantly faster than traditional methods, enhancing efficiency in data analysis, optimization and pattern recognition.
Astrophysics exploits ML to enhance the identification and analysis of cosmic phenomena, such as Gamma-Ray Bursts (GRBs). ML algorithms are employed to process vast amounts of data collected by space telescopes or satellites such as AGILE, enabling more accurate and rapid detection of signals associated with GRBs, while effectively distinguishing them from background noise.
The purpose of this research is to explore the use of QML for the detection of GRBs and their differentiation from background noise. This study builds upon a classical approach, where a ML model known as Convolutional Neural Network Autoencoder was employed to perform anomaly detection for the identification of GRBs in the ratemeters of the AGILE Anti-Coincidence System. The proposed QML framework aims to replicate or enhance detection accuracy and efficiency by leveraging quantum computational advantages to better distinguish between GRBs and background noise.
Therefore, we have implemented various types of hybrid quantum-classical convolutional autoencoders, which differ from their fully-classical counterparts by employing a quantum encoder that replaces classical convolutions with quantum ansatzes and quantum encoding. Different embedding techniques, such as amplitude embedding and data re-uploading, were explored using 8- and 16-qubit architectures. The models were trained in an unsupervised manner using a dataset of simulated univariate time series resembling background light curves. The reconstructed error of the autoencoder is used as anomaly score to classify the time series.
The results obtained so far indicate that the quantum approach achieves discrete outcomes, partially succeeding in reconstructing the input curves. However, its performances have not yet reached the level of precision achieved by the classical approach, which demonstrates excellent results in both curve reconstruction and anomaly detection. Finally, future work may involve developing a fully-quantum autoencoder, where the decoder is also composed of quantum circuits instead of transposed convolutions.

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**Session Classification:** Session 3