QML project

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Indice

1 Introduction **3**

2 Background **4**

References **5**

1 Introduction

In this project work I tried to replicate some of the results of the paper: "Hierarchical quantum circuit representations for neural architecture search"[1]. In this paper the authors propose a framework for for representing Quantum Convolutional Neural Networks (QCNN) architectures using techniques from Neural Architectural Search (NAS). This framework enables search space design and architecture search, the former being the most challenging point in applying NAS to QCNN. In this work we generate a family of QCNN architectures, those resembling reverse binary trees and we evaluate this family on the GTZAN music genre classification dataset showing that it is possible improve model performance without increasing complexity.

2 Background

QCNN stands out among other parametrized quantum circuits (PQC) models for its shallow circuit depth, good generalisation capabilities and absence of *barren plateaus*.

A *barren plateau* happens when the gradient of a cost function vanishes exponentially with system size, rendering the architecture untrainable for large problem sizes. For PQC, random circuits are often proposed as initial guesses for exploring the space of quantum states, due to exponential dimension of Hilbert space and the gradient estimation complexity on more than a few qubits.

It is important to note that for a wide class of PQC, the probability that the gradient along any reasonable direction is non-zero to some fixed precision is exponentially small as a function of the number of qubits[2]. For QCNN, in particular, it is guaranteed that randomly initialized QCNNs are trainable, unlike many other QNN architectures, since the variance of the gradient vanishes no faster than polynomially[3] so QCNNs do not exhibit *barren plateaus*.

Convolutional Neural Networks (CNN) are successful because they don't need manual feature design and can learn high-level features from raw data.

References

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2. McClean, J. R., Boixo, S., Smelyanskiy, V. N., Babbush, R. & Neven, H. Barren plateaus in quantum neural network training landscapes. *Nat. Commun.* **9**, 1–6 (2018).
3. Pesah, A. *et al.* Absence of Barren Plateaus in Quantum Convolutional Neural Networks. *Phys. Rev. X* **11**, 041011 (2021).