

Hybrid Classical–Quantum CNN for Alzheimer’s Disease Detection Using MRI

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Abstract—Early detection of Alzheimer’s disease (AD) using 3-dimensional MRI data remains a challenging task. This project proposes to implement and evaluate a lightweight hybrid classical–quantum convolutional neural network (CQ-CNN) for AD detection. The study aims to assess the performance of hybrid quantum models, explore their limitations, and compare their efficiency and accuracy with classical CNN architectures.

I. INTRODUCTION

Alzheimer’s disease (AD) is a progressive neurodegenerative disorder characterized by memory loss and cognitive decline. Early diagnosis through MRI imaging can facilitate timely intervention, improve patient outcomes, and reduce the burden of care. Traditional diagnostic methods are often time-consuming and resource-intensive, highlighting the need for efficient automated detection techniques.

Deep learning models have demonstrated strong performance in medical image analysis. Recently, quantum machine learning has emerged as a promising paradigm, potentially offering computational advantages over classical models. Hybrid classical–quantum architectures leverage both classical feature extraction and quantum computation to enhance model efficiency and accuracy. This project aims to reproduce and evaluate a CQ-CNN model for MRI-based Alzheimer’s detection, with particular attention to improving convergence and classification accuracy in highly similar image classes.

II. PROBLEM STATEMENT

Detecting Alzheimer’s disease from 3-dimensional MRI data is a challenging task due to the complexity of brain structures and the similarity between disease stages. Classical CNNs require large numbers of parameters and extensive computational resources, which limits efficiency. This project proposes a hybrid classical–quantum CNN approach to achieve efficient and accurate AD detection while reducing model complexity.

III. METHODS

The 3-dimensional MRI volume $V \in \mathbb{R}^3$ represents voxels in the scanned region. Data will be visualized along three anatomical planes: axial, coronal, and sagittal. Irrelevant or non-informative slices, typically at the superior and inferior extremes of the volume, will be discarded to focus on regions of interest.

The proposed CQ-CNN combines classical convolutional layers with parameterized quantum circuits (PQC). Classical layers perform feature extraction, while PQCs encode data, apply an ansatz, and perform quantum measurements. Parameters are optimized using classical algorithms. Experiments will be conducted on the OASIS-2 dataset, which contains 3D MRI data categorized into four classes: very mild dementia, mild dementia, moderate dementia, and non-dementia. Data augmentation techniques, including GANs and diffusion models, will be employed to increase dataset size. Preprocessing will also remove non-brain structures, such as the skull, to improve model focus.

Quantum computations will be simulated on classical hardware using frameworks such as Qiskit or PennyLane. Model performance will be compared with classical CNNs while maintaining equivalent parameter counts to ensure a fair evaluation.

IV. EXPECTED OUTCOMES

The project is expected to demonstrate that hybrid classical–quantum architectures can achieve high classification accuracy with fewer parameters than classical CNNs. It will also identify current limitations of hybrid models, particularly in convergence when distinguishing highly similar classes. The findings will provide insights into the practical feasibility of CQ-CNNs for medical imaging tasks and inform improvements in quantum optimization techniques.

V. TIMELINE

The project will be executed over six weeks. The initial phase will involve literature review and familiarization with datasets and quantum simulation frameworks. Subsequent weeks will focus on data preprocessing, model implementation, training, evaluation, and final analysis, with each sub-task scheduled to be completed in a systematic manner.

VI. RESOURCES

The project requires the OASIS-2 3D MRI dataset, the CQ-CNN research paper, classical computing hardware, and quantum simulation frameworks such as PennyLane or Qiskit. Additional support tools include data augmentation techniques and relevant software libraries for deep learning.