EEG-Based Emotion Recognition with Quantum Neural Networks

Aheed Tahir Ali
Computer science
Fast-Nuces
Karachi, Pakistan
k214517@nu.edu.pk

Umer Naeem
Computer science
Fast-Nuces
Karachi, Pakistan
k214927@nu.edu.pk

Bilal Abdul
Computer science
Fast-Nuces
Karachi, Pakistan
k214522@nu.edu.pk

***Abstract*—This study explores the application of a Hybrid Quantum-Classical Neural Network (QNN) to emotion recognition using EEG data, inspired by recent advancements in quantum machine learning. The study contrasts the efficacy of traditional machine learning models with a QNN trained on EEG data, highlighting the potential of the quantum model in handling high-dimensional datasets and improving computational efficiency and classification accuracy.**

***Index Terms*—quantum neural networks, EEG, emotion recognition, machine learning, quantum computing**

I. Introduction

Emotion recognition from EEG data is crucial for advancements in human-computer interaction, with significant applications in medical diagnostics and therapy. Traditional approaches, primarily based on classical machine learning models like SVMs, have certain limitations, particularly in managing the high dimensionality and variability of EEG data. Recent developments in quantum computing offer new paradigms for machine learning, as evidenced by [1]'s exploration of quantum support vector machines (SVMs) for emotion recognition. Their work demonstrates the potential of quantum algorithms to enhance classification tasks through quantum parallelism and high-dimensional data handling capabilities.

II. Methodology

The project involved: (1) Data Collection: Utilizing a dataset of EEG data formatted in `.pt` files. (2) Preprocessing: Standardizing the data to ensure uniformity in analysis. (3) Quantum Neural Network Setup: Development of a Hybrid QNN, integrating classical data processing layers with quantum layers designed to exploit quantum computational advantages. (4) Training and Evaluation: The model was trained on the EEG dataset, and performance metrics were compared with traditional models to assess efficacy.

A. Enhanced Approach Using Hybrid Quantum-Classical Neural Network

Inspired by [3] , the second approach refines the hybrid model by integrating a quantum circuit directly within a PyTorch neural network framework. The quantum layer, configured with strongly entangling layers and angle embedding, processes preprocessed EEG data.

1) Data Preparation: The data undergoes normalization and PCA, reducing thousands of features to principal components.

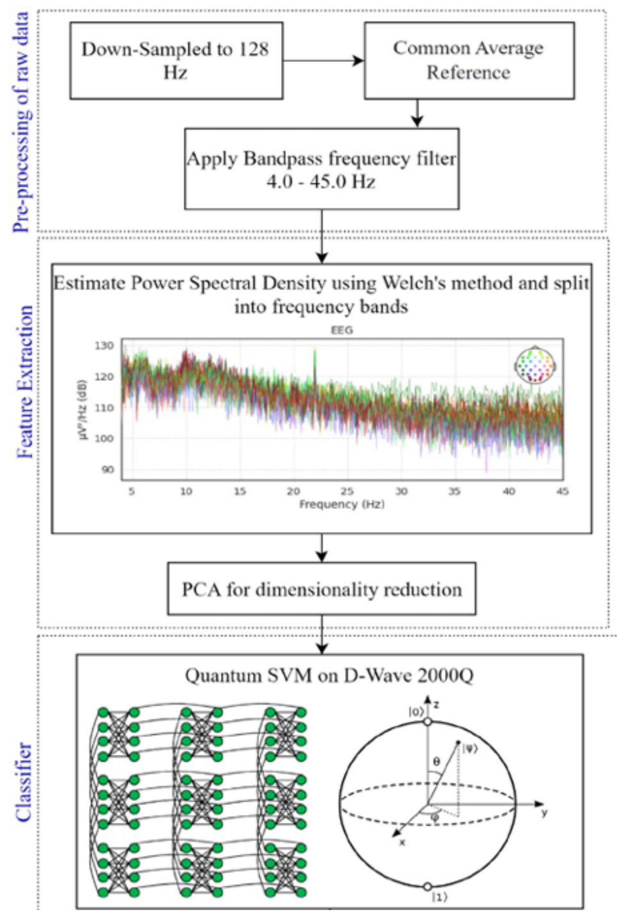

Fig. 1. Proposed method for quantum-based emotion recognition system in [1].

2) Quantum Circuit: A Hybrid QNN, integrating classical data processing layers with quantum layers.

A quantum circuit with angle embedding and strongly entangling layers is employed to process the data

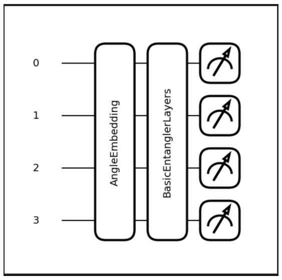

Fig. 2. Schematic of the quantum circuit used in the SEED approach.

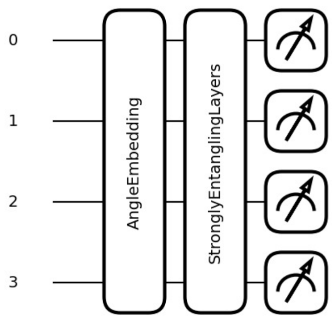

Fig. 3. Schematic of the quantum circuit used in the enhanced approach.

III. Results

The QNN model demonstrated an initial accuracy of 45.90% in emotion classification.

Fig. 4. Loss Graph of the SEED approach.

The enhanced approach significantly improved performance, achieving an accuracy of 73.6%, demonstrating the practical advantages of integrating quantum computing with traditional neural networks.

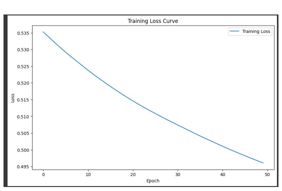

Fig. 5. Loss Graph of the enhanced approach.

This performance improvement is particularly notable compared to the 75% accuracy achieved by [1]., highlighting the effectiveness of the hybrid approach in capturing complex patterns in high-dimensional EEG data more effectively than quantum SVMs alone.

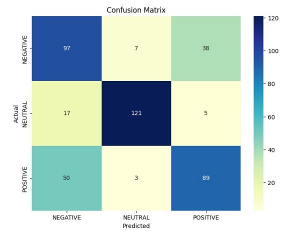

Fig. 6. Confusion Matrix of the enhanced approach.

IV. Conclusion

The study underscores the innovative capacity of quantum machine learning in revolutionizing EEG-based emotion recognition. The enhanced approach not only validated the theoretical benefits of quantum enhancements, but also showcased substantial practical improvements over classical methods.

References

1) Garg, D., Kumar Verma, G., & Kumar Singh, A. (2023). EEG-Based Emotion Recognition Using Quantum Machine Learning. SN Computer Science, 4, 480. https://doi.org/10.1007/s42979-023-01943-6
2) Zhu, Y., Liu, W., & Lu, B. L. (2022). Contrastive Learning of Subject-Invariant EEG Representations for Cross-Subject Emotion Recognition. IEEE Transactions on Affective Computing, DOI: 10.1109/TAFFC.2022.3160295. https://ieeexplore.ieee.org/document/9748967
3) Ahmed Raza Khanzada. (2022). EEG Brain Signals Emotion Classification. https://www.kaggle.com/code/arkhanzada/eeg-brain-signals-emotion-classification