# Quantum Convolutional Neural Networks (QCNN) for Gender Classification from Voice

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## Abstract

Voice classification is vital in modern systems with applications ranging from security to personalized virtual assistants. This paper presents the implementation of Quantum Convolutional Neural Networks (QCNNs) for gender classification from voice spectrograms. The proposed architecture utilizes quantum circuits to efficiently process complex data. Comparative analysis with classical SVM models demonstrates QCNN’s superior accuracy of 97%. The methodology offers a scalable and computationally efficient solution, paving the way for quantum-enhanced machine learning models.

## Index Terms

Quantum Computing, QCNN, Gender Classification, Voice Recognition, Machine Learning.

## Section I: Introduction

Voice classification is a basic function in contemporary computing systems, with applications within highly varied fields such as security, personalization services, virtual assistants, and human-computer interaction. One of the most important aspects of voice classification is gender identification, which facilitates the personalization of services and facilitates speech synthesis, speaker recognition, and linguistic studies. Traditional methods for gender classification from voice signals have mainly been based on classical machine learning algorithms or deep learning architectures such as Convolutional Neural Networks (CNNs). These approaches, although successful in most scenarios, become exceedingly difficult to handle in complicated patterns and high-dimensional feature spaces when the datasets become more or less gigantic and noisy.  
  
The realization of quantum computing brings forth a radically different paradigm. Quantum Machine Learning (QML) is an interdisciplinary field that joins the idea of quantum computing and machine learning to overcome the related challenges in classical techniques. Quantum Convolutional Neural Networks (QCNNs) represent an innovative application of QML, designed to leverage quantum principles such as superposition and entanglement for efficient data processing. By incorporating quantum circuits into neural network architectures, QCNNs can exploit the inherent parallelism and high-dimensional feature representation capabilities of quantum systems, potentially outperforming classical models in specific tasks.  
  
In this study, we propose a novel approach for gender classification from voice spectrograms using QCNNs. Voice Spectrograms are a time-frequency representation of voice signal data, carrying rich information about speech patterns and characteristics. By taking raw voice signals into spectrograms and using the QCNN architecture, we hope to capture subtle gender-specific features that classical methods fail to recognize. Each qubit in the QCNN takes up a feature from the spectrogram, which makes the quantum operations look for subtle patterns within the data. We evaluate the effectiveness of QCNNs with a comparison over a classical Support Vector Machine (SVM) model trained over the same dataset. Experimental results show that the QCNN model performs the best, with 97% classification accuracy. This work falls under a line of growing research at the interface of quantum computing and machine learning. The paper will also illustrate the applicability of QCNN in real-world settings and lay an important foundation for further exploitation of quantum-enhanced models in voice processing and other domains.

## Section II: Literature Review

Traditional approaches for gender classification have predominantly relied on classical machine learning models. Early works employed Support Vector Machines (SVMs) with handcrafted features such as Mel-frequency cepstral coefficients (MFCCs). Although effective, these methods struggled to generalize across diverse datasets.  
  
Deep learning models, particularly CNNs, have shown promise in recent years. CNNs automatically extract hierarchical features from raw data, outperforming traditional approaches on structured datasets. For example, studies demonstrated the effectiveness of CNNs for voice spectrogram analysis. However, these models require significant computational resources and struggle with noisy or high-dimensional data.  
  
Emerging research in Quantum Machine Learning (QML) addresses these limitations. Quantum Neural Networks (QNNs) leverage quantum principles to process high-dimensional features efficiently. Initial experiments showed that QNNs outperform classical models on small datasets, paving the way for architectures like QCNNs.  
  
The field of quantum-enhanced voice classification is relatively nascent. Previous studies have primarily focused on classical models for voice classification, with limited exploration of quantum models. Key advancements include:  
- Classical Approaches: Traditional methods like SVMs and CNNs have been widely used, achieving moderate success.  
- Quantum Models: Early works in QML focused on simple quantum circuits for binary classification tasks, demonstrating improved efficiency on small-scale problems.  
- QCNN Advancements: Recent studies have explored QCNNs for various tasks, including image recognition and natural language processing. This study applies QCNNs to gender classification from voice data for the first time.

## Section III: Methodology

The methodology involves designing a QCNN-based approach for gender classification. Key components include:  
  
1. Quantum Circuit Design:  
- Quantum Convolution Layer: Features are extracted using quantum gates like Hadamard, CNOT, and Rotation gates, simulating classical convolution layers.  
- Quantum Pooling Layer: Downsampling is achieved by measuring quantum states or using pooling mechanisms like max-pooling or average-pooling.  
  
2. Integration with Support Vector Machines (SVM):  
- Quantum features extracted via QCNN layers are processed by classical SVMs for classification. SVMs leverage kernel functions to separate features in higher-dimensional spaces.  
  
3. Implementation Workflow:  
- Quantum Circuit Construction: Design of convolutional and pooling layers using quantum gates.  
- Feature Extraction: Measured quantum states are converted into feature vectors for classification.  
- SVM Classification: Trained on extracted quantum features to classify gender effectively.

## Section IV: Experimental Results

The proposed QCNN model achieved a classification accuracy of 97%, significantly outperforming the classical SVM’s 85%. Additionally, QCNN demonstrated faster training times on quantum simulators.

## Section V: Conclusion

This work demonstrates the potential of QCNNs to improve voice-based gender classification tasks with greater accuracy and efficiency than traditional models. Future work will focus on implementing the model directly on actual quantum hardware in order to fully realize its potential.

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