Optimizing Quantum Neural Network Architectures for Enhanced Computational Efficiency in Edge Computing Applications

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Abstract. Quantum neural networks (QNNs) represent a pioneering convergence of quantum computing and artificial intelligence. This paper addresses the pressing challenge of optimizing QNN architectures specifically tailored for edge computing environments, where resource constraints and latency are critical. Utilizing a novel hybrid optimization algorithm that combines quantum annealing with classical gradient descent, we demonstrate significant enhancements in computational efficiency and accuracy in real-time data processing tasks. Our experimental results reveal that the proposed architecture outperforms conventional neural networks in both speed and energy consumption metrics. These findings underline the potential of QNNs in transformative edge computing applications, offering a pathway toward smarter, more efficient technological ecosystems.

Keywords: Quantum Neural Networks, Edge Computing, Optimization Algorithms, Computational Efficiency, Real-time Data Processing, Hybrid Quantum-Classical Approaches, IoT Applications

Introduction

The accelerated proliferation of Internet of Things (IoT) devices and the consequent surge in data generation have spotlighted the necessity for advanced computational paradigms that can operate efficiently at the network's periphery. Traditional computing architectures

often struggle with the constraints of limited processing power and energy capacity inherent in edge environments, leading to delays and inefficiencies in data transmission and processing. Thus, the integration of cutting-edge technologies is essential to address these challenges in a holistic manner. Quantum neural networks (QNNs), which harness the principles of quantum mechanics to perform computations, have emerged as a compelling solution to the limitations faced by classical neural networks in such settings. The relevance of this research is underscored by the projected exponential increase in edge computing applications over the next few years, especially in sectors requiring real-time analytics and decision-making, such as smart cities, autonomous vehicles, and healthcare monitoring systems. In this paper, we systematically explore the optimization of QNN architectures to enhance their practical applicability in edge computing. We begin with a comprehensive literature review, outlining the current landscape of QNN research and identifying gaps regarding their performance optimization in constrained environments. Subsequently, we present our innovative hybrid optimization algorithm that synergizes the strengths of quantum annealing and classical techniques. We validate our approach through rigorous empirical evaluations, demonstrating significant performance gains compared to established methods. The structure of this paper is as follows: we first define the essential concepts surrounding QNNs and their potential applications in edge computing, followed by the methodology employed for optimization. In the subsequent section, we detail our experimental setup and results, culminating in a discussion of the implications of our findings for future research and practical implementations. Lastly, we conclude with a reflection on the transformative potential of QNNs in advancing computational efficiency within edge computing frameworks.

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