Chapter 8
Anomaly Detection Using Quantum Neural Networks:
A Quantum-Driven Approach to Cyber Threat Identification

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ABSTRACT

Quantum Neural Networks (QNNs) offer a new paradigm that takes advantage of quantum computing principles to emulate and improve on the functional benefits offered by classical neural networks. This chapter offers a broad investigation on QNNs in the context of anomaly detection in important real-world settings such as cybersecurity, fraud detection in financial transactions, real-time medical diagnostics, and many more. This chapter will provide a general overview of QNNs, their theoretical background, advantages with respect to classical models, and application or implementation success in anomaly detection for high-dimensional, noisy and

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streaming data. The chapter will also cover architectures, training methodologies, and simulation platforms for QNNs, and also include case studies to demonstrate these concepts. Finally, it will address their limitations, challenges in practical implementations, and future research possibilities.

1. INTRODUCTION TO QUANTUM NEURAL NETWORKS

Definition and fundamentals of QNNs: Quantum Neural Networks (QNNs) are computational models based on classical neural networks that combine classical neural network architecture with quantum mechanical dynamics. Unlike classical neural networks, which learn through deterministic or probabilistic activation functions that process binary or real-valued input data, a QNN will implement and process data using quantum bits (qubits). Qubits often have unique quantum properties such as superposition, entanglement, and quantum interference, which allow QNNs to process information in novel and parallel fashions that differ fundamentally from traditional NNs. The main goal of QNNs is to exploit the computational resources of quantum systems to perform tasks more efficiently (and using less energy) than classical models in areas like pattern recognition, optimization, or classification. In some relevant problem domains, one could envision exponential speedup in both learning and inference from QNNs thanks to high-dimensional Hilbert spaces and entangled computational states associated with quantum systems. (Beer, K., 2022)

Multiple architectures have been proposed for QNNs, each with distinct mechanisms and advantages: (Schuld, M., et al., 2014).

Quantum Hopfield Networks: Adaptations of classical Hopfield models that replicate associative memory behavior using qubits and quantum gates. These are particularly suited for pattern storage and retrieval.

Dissipative Quantum Neural Networks (DQNNs): A novel architecture that introduces **dissipative dynamics** into quantum computation. DQNNs can be trained with quantum data and have been successfully implemented on Noisy Intermediate-Scale Quantum (NISQ) devices, making them highly practical under current hardware constraints.

Nonlinear QNNs with Irreversible Gates: Models incorporating speculative nonlinear, irreversible operators (e.g., **D gates**) that simulate threshold logic akin to classical neurons, thereby expanding the expressiveness of QNNs beyond unitary-only operations.

Parameterized Quantum Circuits (PQCs) and **Hybrid Quantum-Classical Models**: These combine quantum subroutines with classical optimizers and are typically used in variational quantum algorithms (VQAs) for supervised or unsupervised learning.

Quantum Cognition and Its Influence on Decrease of Global Stress Level Related With Job Improvement Strategies: Quantum Brain and Global Stress

Aleksandar Stojanovicand Ana Starcevic (2021). *Research Anthology on Advancements in Quantum Technology (pp. 378-386).*
www.irma-international.org/chapter/quantum-cognition-and-its-influence-on-decrease-of-global-stress-level-related-with-job-improvement-strategies/277785