QUMETA: Quantum image classificatiOn based on Matrix-product and treE tensor architectures with Triplet Autoencoder

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Abstract: Hybrid architecture for multiclass classification combining triplet autoencoders and tensor-network-inspired quantum circuits. Latent embeddings improve class separation and reduce qubit requirements, while TN circuits with an ancilla interaction layer propagate correlations and support efficient classification.

Hybrid approaches that combine aspects of both quantum and classical computing have been developed as potential solutions to machine learning problems within the current Noisy Intermediate-Scale Quantum (NISQ) era. In this work, a new architecture is proposed that uses a triplet autoencoder and quantum circuits based on tensor networks. In the proposed architecture, a triplet autoencoder is used to encode the input data in a compact and structured form. This compact form of encoding is expected to enhance the separability of classes and reduce the dimensionality of the input data encoded in the quantum circuit.

These latent representations are then encoded as quantum states and subsequently passed through variational quantum circuits (VQCs) based on tensor networks, including a Matrix Product State (MPS) [2] with periodic boundary conditions and Tree Tensor Networks (TTNs) [2]. In particular, the MPS is extended with an additional edge between the last and first qubits, effectively forming a ring-like structure [1]. This structure is beneficial in modelling global correlations between all qubits. These quantum circuits leverage the structure of the connectivity between the qubits to efficiently propagate correlations with fewer parameters. The ring-like structure of the MPS increases the expressiveness of the circuit, enabling information flow over all qubits, and the hierarchical structure of the TTN progressively aggregates information.

To enhance the extraction of global features within the quantum state, we propose an interaction layer that moves the information contained within the computational qubits towards a group of ancilla qubits. This allows the model to concentrate the important correlations within a limited subset of qubits, which are then measured, classifying the input. By directing the attention of the measurement process towards the ancilla, we preserve the inner structure of the circuit formed within the tensor network architecture while providing a compact interface with the classical world that is suitable for the multiclass prediction task.

Overall, the proposed architecture combines structured latent representations with tensor-network-inspired quantum circuits and an ancilla-based interaction layer, enabling compact and expressive quantum models suitable for multiclass classification on near-term quantum hardware.

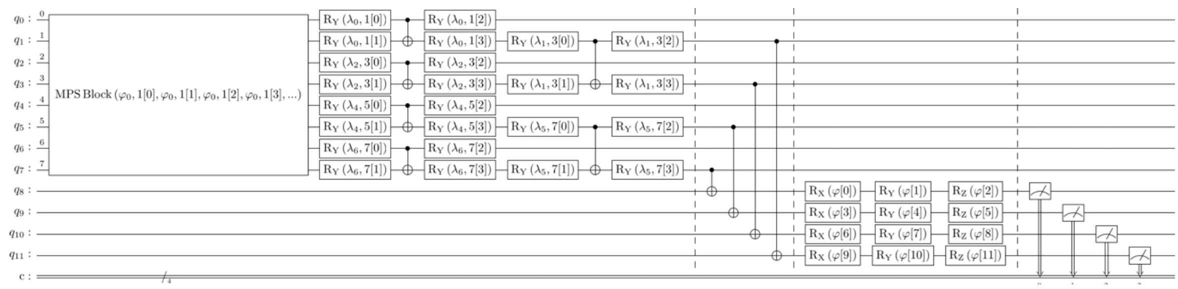

Fig. 1 Tensor-network-based quantum circuit combining MPS and TTN structures, followed by an interaction layer that transfers correlations to ancilla qubits.

References

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