Detecting and Classifying Tripartite Entanglement using Neural Networks

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The integration of artificial intelligence and quantum information processing has led to new breakthroughs in solving resource-intensive problems.[1] Various artificiala neural netowork(ANN) architectures have been deployed to study different aspects of entanglement, to predict multipartite entanglement,[2] and to generate artificial entanglement witnesses for entangled states.[3] In this work, we propose an ANN model to detect genuinely multipartite entanglement (GME) in three-qubit quantum states and to classify these states into six inequivalent classes under stochastic local operations and classical communication (SLOCC). The ANN models are first trained on a simulated dataset containing randomly generated states, and are later tested and validated on real experimental three-qubit data sets generated on a nuclear magnetic resonance (NMR) quantum processor. We benchmark the ANN model via Support Vector Machines (SVMs) and K-Nearest Neighbor (KNN) algorithms and compare the results of our ANN-based entanglement classification with existing entanglement classification schemes. We demonstrate that the ANN model can perform GME detection and SLOCC classification with high accuracy, using *a priori* knowledge of only a few density matrix elements as inputs. Since the ANN model works well with a reduced input dataset, it is an attractive method for entanglement classification in real-life situations with limited experimental data sets.

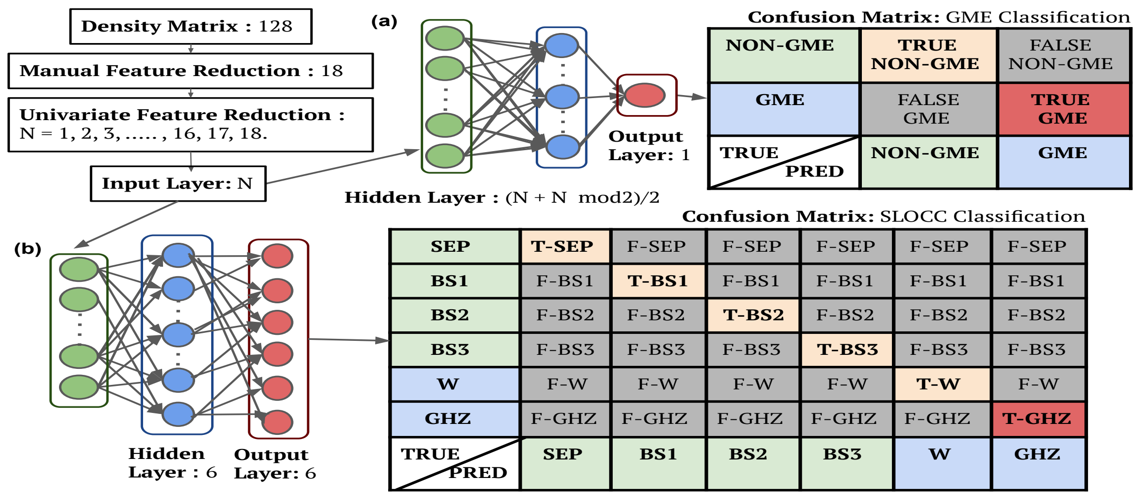

Figure 1: The ANN-based entanglement classification protocol. (a) The GME ANN model consists of N neuron input layers (L_1 in green), $\frac{N+N\text{mod}2}{2}$ neuron hidden layers (L_2 in blue) and 1 neuron output layer (L_3 in red). (b) The SLOCC ANN model consists of N neuron input layers (L_1 in green), 6 neuron hidden layers (L_2 in blue) and 6 neuron output layers (L_3 in red).

References

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[2] Y. Tian et. al, *Adv. Quantum Technol.*, 5(10):2200025, 2022.

[3] A.C. B. Greenwood et. al, *Phys. Rev. Appl.*, 19:034058, 2023.