Title:	Entanglement detection and gate optimization in the system of three and four NMR qubits using deep learning and machine learning
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Abstract:	It has been observed that data science techniques such as Machine Learning and Deep Learning can be used for various quantum computational tasks such as state tomography, entanglement characterization, and quantum gate optimization in NMR Quantum Computing. The recent integration of Artificial Intelligence and Quantum Computing has led to a discovery of a previously unexplored domain of science. Entanglement drives many technologies such as quantum computing, quantum cryptography, and quantum teleportation. Although exact entanglement identification for the entire Hilbert space is challenging, tools such as ”entanglement witness” can identify some but not all entangled states. Several non-linear entanglement witnesses have been developed, but they, too, can only detect entanglement in a fraction of mixed quantum states. The most robust way of detecting entanglement is via full Quantum State Tomography and density-matrix estimation; unfortunately, this method is experimentally demanding because the number of required projections grows exponentially with the dimension of Hilbert Space. For the first part of the project, we built a computational classifier that can detect and characterize entangled states in two, three and four pure NMR Qubit states using Machine Learning and Deep Learning tools. Recent papers have shown that entanglement witnesses based on artificial neural networks can significantly improve entanglement detection. However, these networks have only been trained and tested on noiseless pure state data. Noise patterns such as white noise, colored noise, and Gaussian noise can be added to the data to improve the robustness of supervised ANN-based classifiers. These results are further compared with their unsupervised counterparts. The three qubit Toffoli and Fredkin gates and the single-qubit Hadamard gate form a universal set of quantum gates and play an essential role in quantum circuits and quantum error correction. Efficient construction of these gates using an optimal set of global entangling gates and a machine learning algorithm has been used to design high-fidelity gates that do not require further decomposition into two-qubit gates. Several optimization procedures have been developed for quantum control, such as strongly modulated pulses(SMP) and GRAPE. Recently, Artificial intelligence-based Genetic Algorithms(GA) and Reinforcement Learning(RL) have also been proposed for the same.
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