Testing the neural network approach in the presence of topological frustration

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In recent years, neural networks are establishing themselves as a very useful research tool in the quantum physics of complex systems. As with all numerical approaches, the accuracy of the results obtained with them depends on the characteristics of the system under analysis. To give an example of this dependence, consider the DMRG, where the accuracy and speed of convergence are strongly influenced by the correlation length of the system and the type of entanglement. In the case of neural networks, due to their relative novelty, it is not yet clear what these characteristics are, nor what their relative weight is.

To shed some light on this problem, in the work that I am going to present, we have analyzed the accuracy of the solution provided by a neural network in the context of topologically frustrated one-dimensional systems, and then we have compared it with the results obtained in the absence of frustration. For some years now, topologically frustrated models have been attracting increasing attention. Indeed, despite their apparent simplicity, even in the case of analytically solvable models, topological frustration induces a very complex phenomenology which includes: the existence of incommensurate order parameters; the presence of a specific violation of the area law; the possibility of having mesoscopic chiral phases, etc. This phenomenology is the reflection of the change induced, at the ground-state level, by the presence of topological frustration which can be quantified through the use of various quantum resources such as entanglement, quantum coherence, or the so-called "magic". Therefore, by comparing the accuracies obtained by neural networks in the presence and absence of topological frustration, and comparing them with the changes in the value of different resources, we can analyze the influence that the latter has on the former.

Our results show that neither the entanglement nor the magic value is related to the accuracy of a Restricted Boltzmann Machine. These two results are quite surprising for two different reasons. As regards to entanglement, as we have already said, it is well known that its behavior affects the precision of algorithms based on the tensor network technique. In contrast, magic is a measure of complexity. Therefore, both these quantities were the main suspects in influencing the reliability of the solutions obtained with the neural networks. On the contrary, a strong correlation exists between accuracy and quantum coherence. The greater, the latter, the worse the accuracy of the state obtained from a neural network. These results open an important discussion point on systems that can be efficiently analyzed using neural networks and on possible strategies to improve their performance