Entanglement Entropy and Energy Accuracy for the Small System Size: MPS, TTN, and MERA

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In the quantum spin systems, such as the Heisenberg model, the dimension of the Hilbert space increases exponentially with the number of the spins. There have been many trials for using variational functions with nite degrees of freedom to treat the exponentially increasing dimension efficiently. The density matrix renormalization group (DMRG)[1] is a successful example for the one dimensional system. However, the matrix product state (MPS), which is the variational state used for the DMRG, does not satisfy the area law on entanglement entropy (EE) for the two dimensional system. In order to calculate the two dimensional system, many methods as the extensions of the DMRG have been proposed. The multi-scale entanglement renormalization ansatz (MERA)[2] and the tree tensor network (TTN)[3] are examples of such methods. A goal is to develop a new method with high accuracy and less degrees of freedom of the variational states.

Motivated by this, we compared MPS, TTN, TTN with S^z_{total} conservation[4], MERA, and other types of tensor networks for small Heisenberg spin systems tentatively. In addition, we tried to limit the Hilbert space with the projection to $S^z_{total} = 0$ subspace and/or the projection to translational invariant subspace. We investigated EE and energy accuracy of these variants for an 8-spin system. Here we used the down-hill simplex method for optimization of the variational states. We found that, generally, the projection gives higher accuracy and enhances EE. However, the projection to $S^z_{total} = 0$ is not effective for energy accuracy of a large system. We will discuss in more detail at poster session.

References

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