Self-assembling Tensor Networks and Holography in Disordered Spin Chains

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We show that the numerical strong disorder renormalization group algorithm (SDRG) of Hikihara *et. al.* [Phys. Rev. B 60, 12116 (1999)] for the one-dimensional disordered Heisenberg model naturally describes a tree tensor network (TTN) with an irregular structure defined by the strength of the couplings. Employing the holographic interpretation of the TTN in Hilbert space, we compute expectation values, correlation functions and the entanglement entropy using the geometrical properties of the TTN. We find that the disorder averaged spin-spin correlation scales with the average path length through the tensor network while the entanglement entropy scales with the minimal surface connecting two regions. Furthermore, the entanglement entropy increases with both disorder and system size, resulting in an area-law violation. Our results demonstrate the usefulness of a self-assembling TTN approach to disordered systems and quantitatively validate the connection between holography and quantum many-body systems.