Grassman Tensor-net State and Its Renormalization

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Traditional condensed matter physics is based on two theories: symmetry breaking theory for phases and phase transitions, and Fermi liquid theory for metals. Mean-field theory is a powerful method to describe symmetry breaking phases and phase transitions by assuming the ground state wavefunctions for many-body systems can be approximately described by direct product states. The Fermi liquid theory is another powerful method to study electron systems by assuming that the ground state wavefunctions for the electrons can be approximately described by Slater determinants.

From the encoding point of view, both methods only use a polynomial amount of information to approximately encode many-body ground state wavefunctions which contain an exponentially large amount of information. Moreover, another nice property of both approaches is that all the physical quantities (energy, correlation functions, etc.) can be efficiently calculated (polynomially hard). In this talk, I'll introduce a new class of states: Grassmann-number tensor-net states. These states only need polynomial amount of information to approximately encode many-body ground states. Many classes of states, such as matrix/tensor product states (M/TPS), Slater determinant states, etc., are subclasses of Grassmann-number tensor-net states.

However, calculating the physical quantities for these states can be exponentially hard in general. To solve this difficulty, we develop the Grassmann-tensor-entanglement renormalization group (GTERG) method to efficiently calculate the physical quantities. The application of this method on several interesting fermion/boson models, including gapped and gapless free fermion models, honeycomb Kitaev model and t-J model will be discussed.