Title : Supervised and unsupervised deep Learning of topological phase transitions from entanglement aspect for one- and two-dimensional chiral p-wave superconductors

Abstract:

The one-dimensional or two-dimensional chiral p-wave superconductor proposed by Kitaev has long become a classic example for understanding topological phase transitions through various methods, such as examining the Berry phase, edge states of open chains, and, in particular, aspects from quantum entanglement of ground states. In order to understand the amount of information carried in the entanglement-related quantities, here we study   topological phase transitions of the model with emphasis of using the deep learning approach. Using both supervised or unsupervised ways, we feed different quantities, including Majorana correlation matrices (MCMs), entanglement spectra (ES) or entanglement eigenvectors (EE) originating from Block correlation matrices, into the deep neural networks for training, and investigate which one could be the most useful input format in this approach. We find that ES is information that is too compressed compared to MCM or EE. MCM and EE can provide us abundant information to recognize not only the topological phase transitions in the model but also phases of matter with different U(1) gauges, which is not reachable by using ES only. We also build a procedure for using unsupervised learning to find the phase transition points. We have used this method for other models.

[1] Deep learning of topological phase transitions from entanglement aspects, Yuan-Hong Tsai, Meng-Zhe Yu, Yu-Hao Hsu , and Ming-Chiang Chung, PRB 102, 054512 (2020)

 [2] Deep learning of topological phase transitions from the point of view of entanglement

for two-dimensional chiral p-wave superconductors, Ming-Chiang Chung , Tsung-Pao Cheng, Guang-Yu Huang, and Yuan-Hong Tsai. PRB 104, 024506 (2021)

[3] Deep learning of topological phase transitions from entanglement aspects: An unsupervised way, Yuan-Hong Tsai, Kuo-Feng Chiu, Yong-Cheng Lai, Kuan-Jung Su, Tzu-Pei Yang, Tsung-Pao Cheng, PRB, 104, 165108 (2021)