Quantum Many-Body phase diagram characterization using Fidelity-based Kernels

Francesco Di Marcantonio[2,3]
Nicola Mariella[1], Enrique Rico[2], Sofia Vallecorsa[3], Sergiy Zhuk[1]

[1]*IBM Quantum, IBM Research Europe – Dublin*
[2]*Quantum Matter Group @ EHU Quantum Center, University of the Basque Country UPV/EHU*
[3]*Quantum Technology Initiative QTI @ CERN*

francesco.di.marcantonio@cern.ch

Abstract

The use of fidelities in Quantum Theory has a long history that has enhanced our understanding of quantum systems. In Quantum Many-body physics, detecting Quantum Phase Transitions (QTPs) without conventional order parameters is of particular interest, as these parameters may not work for some models. In such cases, Quantum Machine Learning (QML) comes into play, along with quantum fidelities. Our study of QPTs utilizes physics-inspired Quantum Kernels tailored to celebrated fidelities such as the Uhlmann and the Susceptibility fidelity. We leverage these Quantum Kernels for Anomaly Detection in an unsupervised setting - the anomalies being the quantum phase transition boundaries. In the Figure, we efficiently recognize the different phases of the Axial Next-Nearest-Neighbour Interaction (ANNNI) model already for spin chains of small sizes supporting the validity of our QML model.

References

[1] Richard Jozsa. Fidelity for mixed quantum states. Journal of Modern Optics, 41(12):2315–2323, 1994.
[2] John Shawe-Taylor and Nello Cristianini. Kernel Methods for Pattern Analysis. Cambridge University Press, 2004.
[3] Bernhard Schölkopf, Robert C. Williamson, Alex Smola, John Shawe-Taylor, and John Platt. Support vector machine for Novelty Detection. NeurIPS Proceedings, 12, 1999.
[4] Lei Wang, Ye-Hua Liu, Jakub Imriška, Ping Nang Ma and Matthias Troyer. Fidelity susceptibility made simple: A unified quantum Monte Carlo approach. Phys. Rev. X, 5, 2015.
[5] Maria Schuld, and Nathan Killoran. Quantum Machine Learning in Feature Hilbert Space. Phys. Rev. Lett. 122, 2019.

Figures

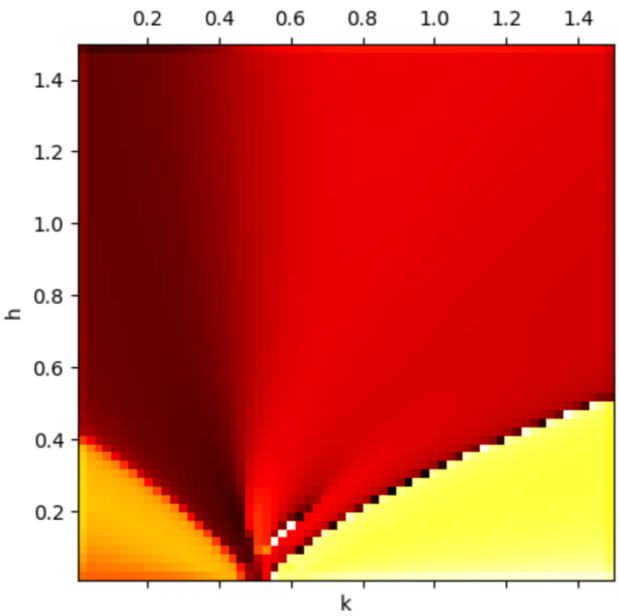

Figure 1: Phase Diagram of the ANNNI model realized using physics inspired feature mapping for our Quantum Kernel.